Generic handbook for assisting in the management of contaminated food production systems in Europe following a radiological emergency

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GENERIC HANDBOOK FOR ASSISTING IN THE MANAGEMENT OF CONTAMINATED FOOD PRODUCTION SYSTEMS IN EUROPE FOLLOWING A RADIOLOGICAL EMERGENCY

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For what purpose do I want to use the Food Handbook?

Planning

Go to Section 4 "Planning in advance"

Consider customising handbook for local conditions (e.g. land use) using a stakeholder engagement process

Response

Go to Section 5 "Constructing a management strategy"

Follow the 8-step process:

1. Identify contaminated production system
2. Consult selection table of management options for the production system
3. Check applicability of management options for radionuclides released

   ELIMINATE OPTIONS

4. Check key constraints of management options

   ELIMINATE OPTIONS

5. Check effectiveness of management option

   ELIMINATE OPTIONS

6. Check for incremental doses and production of waste

   ELIMINATE OPTIONS

7. Go to Section 3 "Datasheets" for detailed information on the remaining options
8. Use selection table to select and combine options and build management strategy

Training – new user

Go to all Sections

Section 1 "Introduction"

Section 2 "Factors influencing implementation of management options"

Section 3 "Datasheets"

Section 4 "Planning in advance"

Section 5 "Constructing a management strategy"

Section 6 "Worked examples"

Consult Appendices for supporting information if required

Training – refresher

Go to Section 6 "Worked examples"

This goes through the 8-step process for two examples: an incident involving ^{131}I contamination of milk following the Windscale fire; an accident at a PWR in Belgium releasing noble gases, radioiodine and radiocaesium.

CONTENTS OF SECTION 1

1 INTRODUCTION TO THE FOOD HANDBOOK

The Handbook for Food Production Systems, or Food Handbook in short, has been developed as a result of a series of European and, in particular, UK initiatives which started in the early 1990s. It has been produced with financial support from the European Commission as part of an integrated project ‘EURANOS’. The overall aim of the project is to increase the coherence of emergency preparedness and management in Europe, following accidental or deliberate releases of radionuclides to the environment. This handbook focuses on food production systems. Two other complementary handbooks consider contamination of inhabited areas and drinking water supplies (http://www.euranos.fzk.de). A full account of the history of development of the Food Handbook is given in Appendix A. The Food Handbook should be regarded as a living document which requires updating from time to time to remain state-of-the-art.

Contaminated food production systems – what’s the problem?

Following a radiation incident, large areas of agricultural land may be affected by Government restrictions on the sale of contaminated foodstuffs. As a consequence, large volumes of produce may require disposal. Farmers need to know what they should do with any waste arisings and what steps they should take to ensure production of uncontaminated foodstuffs in the future. Livelihoods of producers could be put at risk unless actions are taken to limit the impact of the incident.

How can the Food Handbook help?

The Food Handbook provides decision makers and other stakeholders with guidance on how to manage the many facets of a radiation incident. It contains scientific and technical information on what to do during the emergency, as well as tools to assist in the selection of a recovery strategy taking into account the wide range of influencing factors. The Food Handbook is also helpful for contingency planning.

1.1 Objectives of the Food Handbook

The Food Handbook has been developed to meet several inter-related objectives:

- to provide up-to-date information on management options for reducing the consequences of contamination of the foodchain;
- to outline the many factors that influence the implementation of these options;
- to provide guidance on planning for recovery in advance of an incident;
- to illustrate how to select and combine management options and hence build a recovery strategy.

The Food Handbook also has a series of secondary aims:

- to generate awareness in emergency preparedness and management of the foodchain;

- to promote constructive dialogue between all stakeholders;
- to identify under non-crisis conditions specific problems that could arise, including the setting up of working groups to find practical solutions;
- to elaborate plans and/or frameworks for the management of contaminated food production systems at the local, national or regional level.

1.2 Audience

The handbook is specifically targeted at:

- national and local authorities
- central government departments and agencies
- experts in radiation protection
- representatives from agriculture and food production sectors
- other stakeholders who may be affected or concerned, depending on the situation.

Some examples of the types of stakeholders from Government and non-Government organisations who participated in the development of the handbook are: various food standards agencies, ministries of agriculture, health, trade and industry, environment agencies, radiological protection advisers, agriculture advisers, farming unions, food industry, retail trade, consumers, water industry, waste managers and environmentalists.

1.3 Application

The Food Handbook can be considered solely as a reference document containing well focused and generic state-of-the-art information on scientific, technical and societal aspects relevant to the management of contaminated food production systems. However, when used in isolation (i.e. not as part of a project involving a participatory process), the full potential of the Food Handbook cannot be realised. In the same way that this Handbook was developed through a process of stakeholder participation, it is intended to be applied using a similar participatory approach. Examples of the most likely applications of this Handbook are:

- in the preparation phase, under non-crisis conditions to engage stakeholders and to develop local, regional and national plans/framework/tools
- in the post-accident phases by local and national stakeholders as part of the decision-aiding process
- for training purposes
- in preparation for and during emergency exercises.

1.4 Context

The primary focus of the Food Handbook is radiological protection, i.e. reducing exposure of humans to radiation. However, experience from past contamination events, particularly the accident at the Chernobyl nuclear power plant, has shown that the consequences of widespread and long-lasting contamination are complex and multi-dimensional. Radiological protection should be considered as only one aspect of the situation, especially where agricultural production and food supply is concerned. It has been recognised that, to be efficient and sustainable, the management of consequences of radioactive contamination must take into account other dimensions of living conditions, such as economic, social, cultural and ethical issues. Therefore this Handbook also addresses aspects that go beyond those of radiological protection (see especially Section 2). The handbook is built on the premise that those living and working in the contaminated areas still wish to do so following a nuclear accident or radiological incident. This depends in part on the support provided by the authorities.

1.5 Scope

The sources of contamination considered in the Food Handbook are from a nuclear site or weapons' transport accident. However many of the management options described will also be relevant to other radiation incidents e.g. an improvised terrorist device, even though the pattern of contamination would be different. A list of the radionuclides considered in this Handbook is given in Table 1.1. The phases covered by this Handbook are the pre-deposition to post-accident phases, with emphasis on recovery in the post-accident phase. The production systems covered by this Handbook include agricultural and domestic food production, including the gathering of free foods from the wild (see Section 1.7).

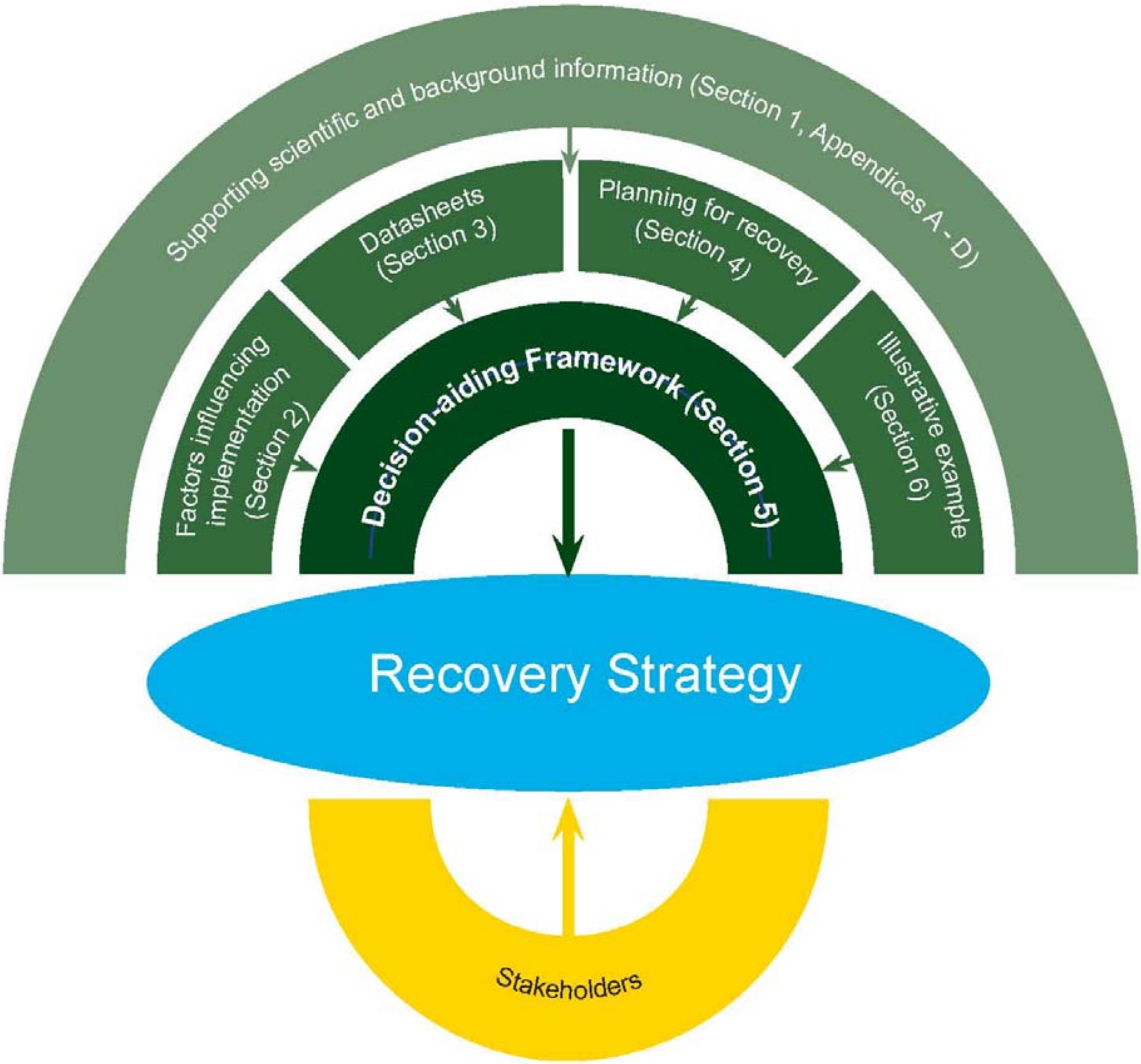
1.6 Structure of the Food Handbook

The overall structure of the Food Handbook is illustrated in the top segment of Figure 1.1. Supporting and background information is provided in the five Appendices. Section 1 sets the context, scope, audience of the Handbook, its application and how existing legislation would influence the marketing of food products in contaminated areas. Factors influencing the implementation of management options in contaminated areas are described in Section 2, whilst datasheets for individual management options are presented in Section 3. Information on the planning for recovery in advance of an incident is given in Section 4. The main decision aiding framework, including a worked example is included in Section 5 and Section 6, respectively. As noted in Section 1.3, the Food Handbook should be used as part of a participatory process involving local and national stakeholders in the development of a recovery strategy (i.e. lower segment of Figure 1.1).

Table 1.1 Radionuclides considered in the Food Handbook

Radionuclide			
Symbol	Name	Dominant radiation type	Radioactive half-life
^{60}Co	Cobalt-60	Gamma	5.27 y
^{75}Se	Selenium-75	Gamma	119.8 d
^{90}Sr	Strontium-90	Beta	29.12 y
^{95}Nb	Niobium-95	Gamma	35.15d
^{95}Zr	Zirconium-95	Gamma	63.98 d
^{99}Mo + ^{99m}Tc	Molybdenum-99 + Technetium-99m	Gamma	66 h
^{103}Ru	Ruthenium-103	Gamma	39.28 d
^{106}Ru	Ruthenium-106	Gamma	368.2 d
^{110m}Ag	Silver-110	Gamma	249.9d
^{132}Te	Tellurium-132	Gamma	78.2 h
^{131}I	Iodine-131	Gamma	8.04 d
^{134}Cs	Caesium-134	Gamma	2.062 y
^{137}Cs	Caesium-137	Gamma	30 y
^{140}Ba	Barium-140	Gamma	12.74 d
^{141}Ce	Cerium-141	Beta/gamma	32.5 d
^{144}Ce	Cerium-144	Beta/gamma	284.3 d
^{169}Yb	Ytterbium-169	Gamma	32.01 d
^{192}Ir	Iridium-192	Gamma	74.02 d
^{226}Ra	Radium-226	Alpha	1.6 10^{3} y
^{235}U	Uranium-235	Gamma/ alpha	7.04 10^{8} y
^{238}Pu	Plutonium-238	Alpha	87.74 y
^{239}Pu	Plutonium-239	Alpha	2.4 10^{4} y
^{241}Am	Americium-241	Gamma/ alpha	432.2 y
^{252}Cf	Californium-252	Gamma/ alpha	2.638 y

Figure 1.1 Structure and audience for the Food Handbook



1.7 Food production systems included in the Food Handbook

The diversity of land use, land management practices, climatic conditions and geomorphology lead to a wide range of food production systems in the European Union. Table 1.2, Table 1.3 and Table 1.4 give an overview of the types of food products for which the Food Handbook can be applied to develop a management strategy. 'Food product' is a generic term for categories of foods that can be derived from several sources. For example milk is a generic product that can be derived from cows, sheep and goats. Domestic food production includes all food that is produced by individuals in private or kitchen gardens or allotments; free foods are those that are collected from the wild.

Table 1.2 Classification of agricultural food production systems

Food product	Sources/examples
Milk and other dairy products	Dairy cow, sheep, goat
Meat	Grazing livestock: beef cattle, sheep and lamb, reindeer/deer, horse Free range: pig, poultry (chicken, turkey, geese and duck)
Eggs	Hens
Cereal	Wheat, barley, oats, oil seed rape, rye, maize
Vegetables and horticultural crops	Root crops (carrots, parsnips), tubers (potatoes), onions, legumes (peas, beans) brassicas (Brussel sprouts, cabbage, broccoli, cauliflower), salad (lettuce)
Industrial crops	Oil seeds, pulses, sugar beet, hops
Fodder plants	Silage, hay, root vegetables
Fruit	Orchard (apples, pears, plums, citrus, olives), bush (blackberry, gooseberry), canes (raspberry), herbaceous (strawberry), vines (grapes)
Honey	Commercial beehive
Fish (salt and freshwater)	Fish farm (salmon and trout), marine fish, wild salmon, freshwater fish

Table 1.3 Classification of domestic food production

Food product	Sources/examples
Meat	Domesticated livestock & fowl such as cow, sheep, goat, pig, duck, goose, turkey, guinea fowl, quail, chicken
Milk	Domesticated livestock such as cow, sheep, goat
Vegetables, herbs, edible flowers, fruit, berries	Berries such as strawberry, gooseberry Fruits such as apple, plum, cherry Vegetables such as carrots, courgettes, lettuce Edible flowers such as elderflower, nasturtium
Herbs	Mint, fennel
Nuts	Garden production of nuts such as hazelnut, chestnut, walnut, beech nut
Freshwater fish	Private lake
Honey	Private beehive
Eggs	Domesticated fowl such as duck, goose, quail, hen, peahen

Table 1.4 Classification of free foods

Food product	Sources/examples
Meat	Waterfowl, wildfowl, game fowl such as pheasant, partridge, grouse, goose, duck, snipe, woodcock Ground game such as hare, rabbit and deer Pests such as grey squirrel and pigeon
Mushrooms	Forageable mushrooms such as field mushrooms, chanterelle, puffball and oyster
Fruit, berries, herbs, edible flowers, aquatic plants	Forageable wild berries such as elderberry, blackberry and rosehips Fruits such as apple, damson and sloe Wild vegetables/herbs such as horseradish, dandelion root, nettle Edible flowers such as elderflower Forageable wild aquatic plants such as seaweed, watercress
Nuts	Forageable nuts such as hazelnut, chestnut, walnut, beech nut
Marine fish and shellfish	Fish such as cod, haddock, plaice, herring, mackerel Shellfish such as clam, scallop, oyster, cockle, mussel, winkle, crab, lobster, prawn, shrimp
Freshwater fish and shellfish	Fish such as trout, carp, eel, grayling, perch, pike, salmon Shellfish such as crayfish
Honey	Feral beehive

The prevalence of these food production systems varies between Member States (e.g. reindeer in northern Europe and goats in southern Europe). In some countries (e.g. Belgium) production is carried out intensively (e.g. livestock at high density), whilst in others (e.g. France) there are more extensive systems (e.g. lower density of livestock, less fertiliser inputs). Domestically produced food in gardens and allotments is common throughout Europe as is the gathering of ‘free’ foods from the wild.

1.8 Food production systems excluded from the Food Handbook

There are a few types of products and production systems that are currently not explicitly included in this handbook: organic farming, other farm certification schemes (e.g. free-range systems), drinking water for animals. Information on drinking water for human consumption can be found in a separate Handbook on Drinking Water Supplies.

1.9 Radiological protection criteria for food

1.9.1 Maximum permitted activity concentrations in foodstuffs

The Council of the European Communities has issued a number of Regulations concerning contamination levels in food that apply for accidents (CEC, 1989a, 1989b, 1990). These Regulations are intended to ensure uniformity of standards across the European Union (EU) and would become legally binding in the countries of the EU following an accident anywhere in the world. The Regulations specify maximum permitted activity concentrations in marketed foods, termed CFILs (Council Food Intervention Levels). The CFILs represent an EU judgement on the optimum balance between the beneficial and harmful consequences of introducing food restrictions in the

EU. In case the CFILs should prove inappropriate under the specific circumstances of a future accident, provision has been made within the Regulations for the CFILs to be revised shortly after an accident. Such a revision depends on a qualified majority agreement by the Member States.

The CFILs are listed in Table 1.5. Twenty of the CFILs are for foods (CEC, 1989a, 1989b), and three are for animal feeds (CEC, 1990). The CFILs for foods are divided into four groups of radionuclides (radiostrontium, radioiodine, alpha-emitting radionuclides, and other radionuclides with relatively long half-lives) and five food categories (baby foods, dairy foods, other major foods, minor foods and liquid foods. The CFILs for animal feeds apply to radioisotopes of caesium only, and are specified for feed intended for three categories of animal: pigs; poultry, lamb and calves and other. By using these groupings, the CFILs are kept to a manageable number, while, at the same time, important differences in the behaviour of radionuclides and people's dietary habits are taken into account.

Table 1.5 Council Food Intervention Levels (CFILs) for foods and animal feeds

	Intervention levels (Bq kg^{-1})				
Radionuclide	Baby foods	Dairy produce[d]	Minor foods	Other foods	Liquid foods
Isotopes of strontium (^{89}Sr, ^{90}Sr)	75	125	7,500	750	125
Isotopes of iodine (^{131}I)	150	500	20,000	2,000	500
Alpha-emitting isotopes of plutonium and transplutonium elements[a]	1	20	800	80	20
All other radionuclides of half-life greater than 10 days[b]	400	1,000	12,500	1,250	1,000
Animal feed intended for	Intervention levels[c] (Bq kg^{-1})				
Pigs	1,250				
Poultry, lambs and calves	2,500				
Other	5,000				

[a] This category includes ^{238}Pu and ^{241}Am

[b] This category includes ^{60}Co, ^{75}Se, ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra and ^{235}U. ^{14}C, ^{3}H and ^{40}K are not included in this group

[c] Intervention levels are for ^{134}Cs and ^{137}Cs only

[d] Milk and cream only

Within each radionuclide and food group it is the sum of the activity concentrations of all the specified radionuclides in that food which is to be compared with the CFIL. For example, if both ^{134}Cs and ^{137}Cs are present within a consignment of meat, then the activity concentrations of the individual radionuclides should be added together before comparison with the CFIL of 1,250 Bq kg^{-1}.

The CFILs are intended to be applied independently of one another; if the combined activity concentration level for one radionuclide group in a given food category is exceeded, then restrictions on food will be imposed, regardless of the concentration of other radionuclides in that food, or of the concentration of radionuclides from that group in other foods. Similarly, if the summed contributions of radionuclides within each of two groups were both more than 50% (but less than 100%) of the CFIL given for each group, then the food will not be subject to restrictions.

The relationship between CFILs and the resultant individual doses is complex and difficult to calculate generically. These doses depend on the sources and composition of an individual's diet and the variation of radionuclide concentrations within the food as a function of time. If it is assumed that 10% of each food was contaminated at the CFILs throughout the year the doses from consuming each food would range between a few hundredths of a millisievert and about half a millisievert in a year (NRPB, 1994). Except in very extreme circumstances, individuals would receive very much lower doses than these, because activity concentrations in foods vary during the year and between production locations. Since these doses were calculated for critical group intake rates, it is inappropriate to sum the doses over all the foods listed to obtain a likely total dose from ingestion.

1.10 General radiological protection principles and criteria

The International Commission on Radiological Protection (ICRP) is the primary international body for recommending radiological protection standards. After a consultation process lasting several years, in 2007 the ICRP published new recommendations for a system of radiological protection in Publication 103 (ICRP 2007). These recommendations replace the previous recommendations published in 1991 as the 1990 Recommendations (ICRP 1991a). However, it will take several years before Publication 103 becomes incorporated into national legislation.

1.10.1 Practices and Intervention

The 1990 Recommendations distinguishes two situations for which the system of radiological protection applies, 'practices' and 'interventions'.

1.10.1.1 Practices

Practices are situations that are under control and that lead to increases in the exposure of individuals such as during the operation of nuclear power stations. Emphasis is on the control of the source of exposure and this can generally be planned for before commencing the practice. ICRP's principles of protection for practices are:

- no practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. This is known as the justification of a practice
- in relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account. This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgements. This is known as the optimisation of protection
- the exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of

potential exposures. These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances.

In simpler terms, these principles may be phrased as follows: radiation can cause harm and therefore any intended use should be worthwhile (justification) and, this being the case, all reasonable steps should be taken to reduce exposures from a single source below predefined constraints (optimisation). Doses and risks to an individual from all relevant sources of radiation should be kept within pre-defined limits (dose and risk limitation).

1.10.1.2 Intervention

Interventions are situations where the sources, pathways and exposed individuals are already in place when a decision on control has to be taken such as during actions taken to reduce existing radon exposures. In such situations, protection can only be achieved by removing or modifying existing sources or pathways, or reducing the numbers of people exposed. ICRP (ICRP, 1991b) have recommended the following general principles governing the system of radiological protection for intervention:

- countermeasures should be introduced if they are expected to achieve more good than harm. This is known as the justification of intervention
- the quantitative criteria used for the introduction and withdrawal of countermeasures should be such that the protection of the public is optimised. This is known as the optimisation of intervention
- serious deterministic health effects should be avoided by introducing countermeasures to keep doses to individuals to levels below the thresholds for these effects.

In most cases, intervention cannot be applied to the source of the exposure and has to be applied in the environment and, particularly in the case of accidents, to an individual's freedom of action. Thus a programme of intervention will always have some disadvantages but should always be justified in the sense that it does more good than harm. It follows that the use of dose limits, or constraints, specified for practices as the basis for deciding on a level at which intervention is invoked might involve measures that would be out of proportion to the benefit obtained and, therefore, would conflict with the principle of justification. Thus, dose limits for practices (and, by inference, dose constraints) do not determine whether or not intervention should be undertaken. There will, of course, be some level of dose approaching that which would cause serious deterministic effects, where some form of intervention will be almost always required. Since the thresholds for deterministic effects vary to some extent between individuals and circumstances, it is helpful, for emergency planning and response purposes, to adopt robust threshold values that are lower than the known biological thresholds.

Clearly, intervention aims to avoid or avert exposure to radiation. Hence one important quantity in taking decisions on intervention is the level of dose averted by taking the remedial action (avertable dose). However, for actions undertaken during the recovery phase, it should be recognised that an equally important aim is to promote an early return to 'normal living'. Thus decision makers should consider, not only the expected consequences of implementing the strategy (e.g. the avertable dose, the costs, resources required, likely duration, level of disruption etc), but also how implementing this strategy will contribute to the re-establishment of 'normality', including, specifically, the criteria on which protective measures will be considered successful (and so can be terminated).

For situations requiring intervention, the concept of a level of dose, or directly measurable quantity, above which action should be taken, can be useful. Such criteria are termed action levels (ALs). Generic ALs may be developed before an accident (e.g. those adopted for food) or in the event of an accident, taking account of the specific circumstances.

1.10.1.3 Which system of protection for the recovery phase?

The systems of protection for both practices and intervention are relevant for the recovery phase. The system of protection for intervention would be used in the process of deciding on the form and scale of the actions taken to recover from contamination of the environment from accidental releases of radioactivity. However, the workers undertaking any of the actions would be potentially being introduced to an additional source of radiation so their exposure would be controlled under the system of protection for practices. Similarly, the handling and disposal (away from the contaminated area) of any wastes produced during the recovery actions would be controlled under the system of protection for practices.

1.10.2 Key features of the new 2007 Recommendations relating to the recovery phase

The fundamental principles of radiological protection – justification, optimisation and application of dose limits, remain the same and the dose limits are unchanged from the 1990 Recommendations. ICRP has, however, made some changes to the structure of the system of protection in order to improve clarity.

In the 2007 Recommendations ICRP has divided exposure situations into three types, which encompass the entire range of plausible exposure situations: planned exposure situations which involve the deliberate legitimate introduction and operation of sources; existing exposure situations which are situations where exposures already exist when a decision on protection has to be taken; and emergency exposure situations which require urgent action to avoid or reduce undesirable exposures. Within the framework described in the 2007 Recommendations, emergency response and its aftermath will evolve through two types of exposure situations: emergency exposure situations and existing exposure situations. ICRP uses the categorisation of exposure situations to highlight differences in the way the situations are managed: there may not be clear cut boundaries between the physical attributes of the exposures themselves. The management of the emergency exposure situations is characterised by recognition that the situation is 'abnormal' and that actions are required to protect people and to help restore the situation to 'normal'. Emergency response management is therefore concerned with initiating and managing change on a short timescale. Existing exposure situations resulting from emergencies, on the other hand, are situations where the on-going radiation risks are tolerable, even with only limited, or no, further protective actions, although the environmental contamination and potential exposures are recognised as being higher than would be accepted for planned situations. In short it is recognised that the impact of significant further environmental remediation on the people affected and on society more generally would outweigh any expected benefits. Thus a new normality can be established and which requires sustaining. The management of existing exposure situations is therefore characterised by enabling and promoting normal living in an area recognised as having higher potential exposures than other areas. This may involve continuing less disruptive protective actions, such as regular environmental monitoring, but the focus of management would be on the maintenance of normal living, not a change to normal living. The Food Handbook is likely to be applicable to both emergency exposure situations and existing exposure situations, although emergency countermeasures such as sheltering, evacuation and stable iodine prophylaxis have been deliberately excluded.

1.11 Terminology

1.11.1 Management options

Actions intended to reduce or avert radioactive contamination of food, agricultural or forestry products before they reach consumers are commonly referred to as agricultural countermeasures (IAEA, 1994). The term ‘countermeasure’, although widely encountered, was not well received by the stakeholder panels engaged in the European FARMING network (Nisbet et al., 2005). Various stakeholders, especially from the agricultural field, expressed their concern that adopting this term might prove inadequate for a number of reasons. One main objection was that, in common verbal usage, a countermeasure is often perceived as being a rather negative action, which in fact is taken to offset some preceding action. Those not acquainted with radiation protection nomenclature found that *countermeasures* for contamination could be confused with *measurements* of contamination. Others deemed the term was misleading in the sense that, a countermeasure may be perceived as an action taken to accomplish zero levels of radioactivity. They also suggested the term was mainly focused on technical aspects of the actions and did not accentuate their strategic dimension. In preparing this Handbook, these reservations were taken into account and the term “management option” has been adopted instead, to encompass interventions aimed at reducing or averting the contamination or the likelihood of contamination of food production systems.

1.11.2 Timescales for implementing management options

It will be necessary to implement management options following a nuclear or radiological accident involving an atmospheric release of radioactivity. The timescales for implementation cover the period before the release and extend over the weeks, months or even years after the event. There is no universal terminology used to describe these phases, so for the purposes of this Handbook, they are subdivided as follows:

- the *pre-deposition phase* with a time scale of hours/days, starting when a substantial risk of contamination is identified and ending when either a release occurs or the source is brought back under control. During this pre-deposition phase management options would be introduced on a precautionary basis to ensure that appropriate protection is in place. During this period, some initial estimates on the severity and consequences of the expected deposition would be possible and arrangements for managing the accident response should be activated

- the *early phase*, with a time scale of hours/days, lasting for as long as the release is in progress. This phase will require prompt implementation of management options. Relatively few measurements will be available and decisions will be based primarily on predictions of the radiological situation in the environment
- the *medium-term phase,* which extends from weeks to months after deposition. During this phase, monitoring programmes will be in place and sufficient data will be gathered over time. In the medium term, decisions to cease early-phase management actions or introduce additional ones will be based on a reasonably complete picture of activity levels and affected areas
- the *late phase*, with a time scale of several months up to more than a year. During this phase, an optimisation of strategies should be possible, aiming to reduce radiation levels in the environment, permit long-term management of agricultural production and pursue the rehabilitation of the living conditions in the affected area, including concerns about health, economic, societal, cultural, ethical issues.

It is important to note that the duration of these phases is not always clear-cut and that different phases may overlap depending on the type of the release and the evolution of contamination from a temporal and spatial perspective.

It is recognized among organisations responsible for emergency and long-term management that planning and preparing in advance of a nuclear or radiological accident is essential if the response requirements are to be satisfied. The practical goal of this *preparedness phase* is to “ensure that arrangements are in place for a timely, managed, controlled, co-ordinated and effective response at the scene, and at the local, regional, national and international level, to any nuclear or radiological emergency” (IAEA, 2002). One of the most important features of the preparations is that they should be integrated among the different stakeholders involved, establishing a common platform for actions and drawing clear lines of responsibility and authority.

1.12 References

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CONTENTS OF SECTION 2

2 FACTORS INFLUENCING IMPLEMENTATION OF MANAGEMENT OPTIONS

The 58 management options described in this Handbook encompass many types of action that can be carried out in food production systems to reduce the impact of radioactive contamination. They can be implemented at different phases of the response extending from the pre-deposition stage and continuing for the days, weeks, months and even years after the accident. The management options are designed to target particular media and contamination pathways including soil, crops, livestock and other animal products. They are not only aimed at addressing health concerns but also a wide range of other issues at stake such as the local economy, societal and ethical concerns and disposal of wastes. Table 2.1 provides a list of all the management options considered in the Food Handbook: a distinction is made between those options that may be implemented at the pre-deposition stage and those implemented in the early, medium-term and late phases following an incident. The options in the latter category are further subdivided according to the specific purposes for which they were designed. Section 3 provides a comprehensive set of datasheets for each management option which take into account most of the criteria that decision makers might wish to consider when evaluating different options.

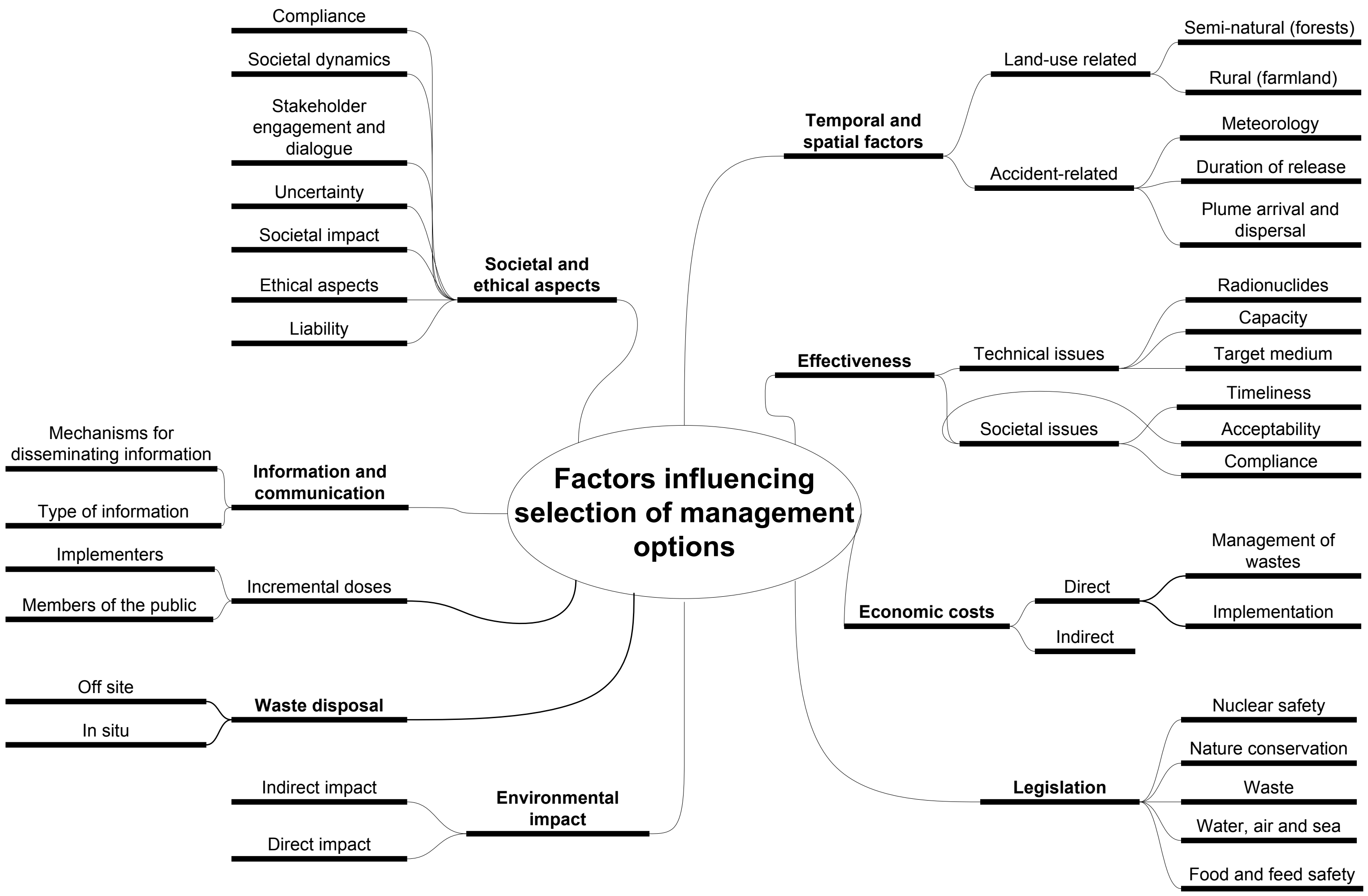
The implementation of these management options is not trivial. There are a number of complex factors that need to be taken into account when developing a good management strategy and this is further complicated by the complexity of the decision-making process itself. This chapter identifies the most important criteria although decision-makers, implementers and other stakeholders may identify additional ones. The illustration presented in Figure 2.1 gives an overview of the key criteria that might need to be considered, broken down into their main components.

Table 2.1 List of management options for food production systems

Pre-deposition phase
Closure of air intake systems to minimise the contamination of food processing plants and foodstuffs within them
Closure of irrigation systems
Covering of standing crops
Prevention of contamination of greenhouse crops
Protection of harvested crops from deposition
Short-term sheltering of dairy animals
Early to late phase
General applicability
Dilution
Feeding of animals with crops/milk in excess of intervention levels
Leaching of horticultural peat
Prevention of fire in forests, shrubland and other sensitive areas
Restriction on the entry of food into the foodchain (food ban)
Selection of alternative land use
Soils/crops/grassland
Application of lime to arable soils and grassland
Application of potassium fertilisers to arable soils and grassland
Deep ploughing
Early removal of crops
Land improvement
Processing of crops for subsequent consumption
Pruning/defoliation of fruit trees and vines
Selection of edible crop that can be processed
Shallow ploughing
Skim and burial ploughing
Topsoil removal
Livestock and animal products
Addition of AFCF to concentrate ration
Addition of calcium to concentrate ration
Administration of AFCF boli to ruminants
Administration of clay minerals to feed
Change of hunting season
Clean feeding
Decontamination techniques for milk
Distribution of saltlicks containing AFCF
Live monitoring
Manipulation of slaughter times
Processing of milk for subsequent human consumption
Salting of meat
Selective grazing regime
Slaughtering of dairy livestock

Suppression of lactation before slaughter
Societal
Compensation scheme
Dietary advice
Food labelling
Local provision of monitoring equipment
No active implementation of management options (do nothing)
Processing and/or storage prior to consumption
Raising of intervention limits
Restrictions on gathering wildfoods
Waste disposal
Biological treatment (digestion) of crops
Biological treatment (digestion) of milk
Burial of carcasses
Burning of carcasses
Composting
Disposal of contaminated milk to sea
Incineration
Landfill
Landspreading of milk and/or slurry
Ploughing in of a standing crop
Processing and storage of milk products for disposal
Rendering

Figure 2.1 Diagram showing some of the factors that might influence the selection of management options



2.1 Temporal and spatial factors

The characteristics of the radionuclides deposited into the environment from an event, as well as the type of land that is affected by the contamination and what it is used for, have a significant influence on the selection of management options. Such a selection should also take account of issues relating to time (e.g. when the incident happened, time since it happened, variation of activity concentrations of radionuclides over time, movement of radionuclides through the foodchain over time (Appendix B) and space (e.g. area affected, contamination zones based on deposited activity, and how these change over time).

Time and space related issues are discussed in the following sections in relation to the characteristics of the event and the management options. The information provided is based on Nisbet et al, 2006.

The dynamics of an event strongly depend on the kind of facility that is involved (e.g. a nuclear reactor with a cooling problem, a fire in a fuel factory, a weapons transport accident). For the purposes of the Handbook the timescales over which management options can be implemented have been divided into four phases: pre-deposition (including pre-release), early phase, medium and late phases.

Pre-deposition phase

There may be a considerable delay between the initiating event and the beginning of the release due to the presence of a containment building, (e.g. the accident at the Three Mile Island nuclear power plant in 1979). In other cases, the initiating event and the release may be almost simultaneous. Examples are the accidents that occurred at the Chernobyl nuclear power plant and Tokai-Mura.

The timing of the alert does not necessarily precede the release. In the case of very fast events, alerts are only given after the release has started. If the alert comes too late, it will not be possible to implement precautionary measures such as closing ventilation systems in greenhouses.

Generally speaking, the arrival time of the plume and, therefore, the time available to prepare actions depend strongly on the distance from the release point and the meteorological conditions (wind speed and wind direction). There may be no time available at all before the plume arrives.

Early phase

During the passage of the plume, radionuclides are deposited on different surfaces such as soil, vegetation and buildings. In general levels of contamination diminish with distance and time. However, if it rains during the release enhanced deposition levels can be found in places subject to the heaviest rainfall during the passage of the plume.

After the release has stopped there is no further deposition of radionuclides and average activity concentrations on surfaces generally diminish over time. This is due to radioactive decay and to other processes such as migration of radioactivity through the soil and transfer of radionuclides from tree leaves to soil during rainfall. The role played by the various processes depends on the vegetation, topography, meteorological conditions, soil composition, and other factors (see Appendix B).

Medium to late phases

In the medium to late phases the largest source of radionuclides is the soil. According to Alexakhin and Krouglov (2001), the main physical, chemical and biological processes that govern the behaviour of radionuclides in soil are:

- processes that define the physico-chemical state of radionuclides which are mainly responsible for determining the mobility and bioavailability, for example, sorption/desorption, fixation and assimilation by soil microbiota
- processes that regulate vertical transfer of radionuclides in soil, for example, advection, diffusion of free and exchangeable adsorbed ions, transfer by plant root systems, redistribution due to activity of soil animals (bioturbation)
- processes that lead to radionuclide transport in lateral direction, such as run off, resuspension and erosion

When selecting management options, it is helpful to consider them according to the timescale of their implementation. In the short term, prompt actions are necessary, for example, if at the time of deposition, dairy cattle are grazing outdoors, leafy green vegetables are ready for harvest and mushrooms and berries are available for gathering. However, many actions take time to organise and prepare (e.g. clean feeding, distribution of feed additives). For less urgent situations (e.g. livestock not ready for slaughter, immature crops in the field) several weeks are available in which to decide on and implement appropriate management options. Some situations may require rather drastic or irreversible actions such as change of land use, deep ploughing. In such situations, stakeholder dialogue and consultation will be essential and sufficient time must be allowed (i.e. months) for the process to be fully implemented.

Management options also need to be selected on the basis of the levels of contamination present and land use. Typically there will be areas where contamination levels are very high and priority has to be given to the direct protection of the population (e.g. by sheltering and evacuation). In these areas, protective measures for agricultural production should be considered as a low priority. In other areas not subject to emergency countermeasures, restrictions on the entry of food into the foodchain may be required. Levels of contamination in food products in these areas can be reduced by implementing a suitable set of management options. Finally, there will be other areas not contaminated at all (e.g. regions adjacent to contaminated areas) which could still be affected indirectly. In this case there would be a requirement for extra monitoring to maintain consumer confidence.

2.1.1 Management options that are applicable in the pre-deposition phase

A decision on whether to implement management options that have to be implemented prior to deposition has to be taken quickly. There is little time for discussion, and the areas involved may not be well defined. An approach often followed in that case is to define a zone for implementation based mainly upon model predictions (see Appendix C), taking into account a margin of uncertainty. The zones defined initially can be rather large and will normally be reduced in size when more precise measurement information becomes available.

2.1.2 Management options that are applicable in the early phase

After the passage of the plume, more information will be available to determine the activity deposited on soil and vegetation and the severity of the event. Monitoring will provide data to determine the extent of the contaminated areas, the radionuclide composition, zones with enhanced contamination due to rainfall or the influence of the morphology. Initial monitoring will concentrate on measurements of dose rates, activity concentrations in air and deposition on soil. These measurements will be a valuable input to model calculations to aid the selection of management options. Operational intervention levels are an important tool to delimit the zones for management strategies in this phase.

Decisions on implementing management options have to be made quickly for sensitive food products. For leafy vegetables contaminated at harvest time, the problem is immediate as there is a risk that the edible parts of the plant will be contaminated in all regions where the plume has passed. For grazing dairy livestock, the delay between deposition on to grass and contamination of milk is of the order of a day. For meat, there is less urgency to act than for milk, because the slaughter time is relatively flexible (can be delayed for days, weeks, even months).

2.1.3 Management options that are applicable in the medium term to late phase

If the composition of the deposited material consists of mainly short-lived radionuclides, or if activity concentrations of the radionuclides are low, management options may only need to be implemented in the early phase. However, if long-lived radionuclides are present, it may be necessary to consider longer-term management options. As there is more time available, it is recommended to plan for stakeholder involvement at this stage, and to base the decisions mainly upon accurate measurements both in the environment and in the products grown in the affected areas. At some point in time, it may be necessary to intervene irreversibly, for example, by making changes to land use, deep ploughing etc., to restore some form of agricultural activity in contaminated areas. These actions cannot be considered separately from a broader discussion on the rehabilitation of living conditions.

2.2 Effectiveness

The primary aim of most of the management options considered in this Handbook is to reduce the doses from the consumption of contaminated foodstuffs. In this context

effectiveness of a management option is expressed as the percentage reduction in the activity concentration in the target medium (i.e. soil, crop, or animal products) after implementing the option.

There are some management options, however, which may be considered more as supporting measures (e.g. provision of monitoring equipment and live monitoring). These can increase the effectiveness of other options as well as providing reassurance; they may not directly reduce doses

For food waste disposal options, where the objective is not dose reduction, effectiveness may be considered from a different perspective. In this case

effectiveness of disposal options for waste food products is expressed as the proportion of contaminated produce that can be removed from the foodchain by any one disposal route.

The effectiveness of management options is influenced by technical and societal criteria, some of which are very specific to one or two options. Comprehensive guidance on effectiveness is provided on individual datasheets (see Section 3). Generic non-exhaustive information on some of the more commonly encountered factors that affect effectiveness is listed below.

2.2.1 Technical factors

Technical factors tend to be those that can be easily quantified at the time of the event and do not depend on judgement or societal issues (see Section 2.2.2). They have been subdivided in Table 2.2 below into factors that are generally applicable to most management options and those that are related to soil, crop, livestock, animal product and waste product.

Table 2.2 Technical factors affecting effectiveness of management options

Factors affecting the effectiveness of most options
Availability of staff, equipment, transport, resources
Duration of treatment and application rates
Properties of the radionuclide i.e. physical and chemical form, half-life, biological half-life.
Factors affecting the effectiveness of options directed at soil
Soil type, texture, fertility and pH
Radionuclide distribution in soil profile
Rooting depths of crops
Factors affecting the effectiveness of options directed at crops
Growing stage
Leaf area index and biomass present
Texture of plant surface
Soil-to-plant transfer factor
Factors affecting the effectiveness of options directed at livestock
Stage of lactation
Nutritional status
Factors affecting the effectiveness of options directed at animal products
Type of decontamination technique
Fat content of milk
Concentration of salt solution
Factors affecting the effectiveness of waste disposal options

Moisture content
Energy value
Physical form, size and volume
Biochemical oxygen demand

2.2.2 Societal factors

Societal factors arise from people's behaviours, attitudes and perceptions. Unlike technical factors, the impact of societal factors on the effectiveness of management options is difficult to quantify and may depend on the acceptability of the option, based on judgement. Societal factors are summarised in Table 2.3 below.

Table 2.3 Societal factors affecting effectiveness of management options

Timeliness of decision-making and implementation
Acceptability and compliance with procedures (implementers)
Divergence from standard practice and willingness to adapt to new procedures
Market for end products
Expertise and training in new technology
Acceptability to consumers, environmentalists
Willingness of privately owned facilities to accept wastes
Willingness of local populations to accept wastes.

2.3 Incremental doses

An important criterion when assessing the practicability of a management option is the incremental dose received by the people implementing it. Incremental dose is defined as the additional dose that is incurred as a result of carrying out an operation that is not part of the normal practice, such as the dose a farmer receives while gathering cattle and carrying out live monitoring for reassurance purposes as this is not part of the usual farming practice.

A number of factors influence the doses people receive as a consequence of implementing management options (see Figure 2.2). The most important factors to consider are the radionuclides released into the environment and the type of medium that is contaminated (e.g. arable soil, crops, grassland, livestock or milk).

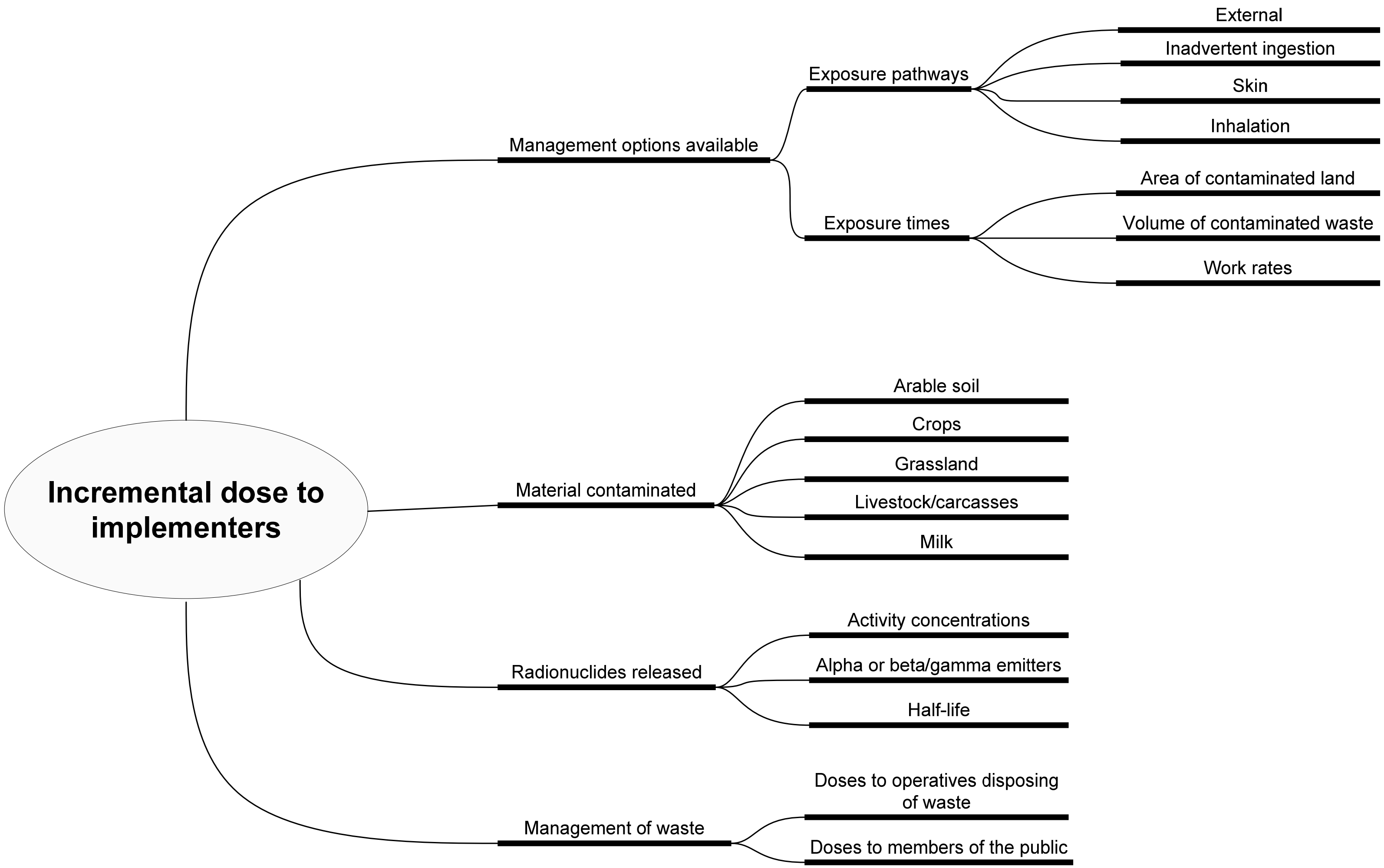
When implementing a management option the major exposure pathways to consider are external irradiation, inhalation of re-suspended material and inadvertent ingestion of contaminated material; in a few instances external irradiation of the skin is also important. The magnitude of the doses from the different pathways largely depends on the radionuclides present. For example, when ploughing arable soils contaminated with β/γ-emitting radionuclides the highest dose is generally due to external exposure to soil, whereas for some α-emitting radionuclides the highest dose is due to the inhalation of re-suspended material.

The estimation of incremental dose depends on the exposure time while implementing an option. This time depends on the area of land requiring treatment or the volume of waste requiring disposal, and the machinery and manpower available, which affect the work rate.

It is also important to note that some management options generate secondary/tertiary wastes that require disposal (e.g. topsoil removal), which may result in operatives at waste management facilities receiving incremental doses. In some cases members of the public might also receive an incremental dose depending on the final disposal site for the treated waste (e.g. application of contaminated sewage sludge to land following anaerobic digestion of waste milk).

Incremental doses and factors relevant to their assessment have been investigated by Hesketh, et al., 2006. The report provides a simple illustrative methodology for calculating incremental dose including data for the incremental doses that may be received following implementation of management options in food production systems.

Figure 2.2 Diagram illustrating some of the key factors to be considered when calculating incremental doses



2.4 Waste disposal issues

2.4.1 Generation of waste

Agricultural produce and food from domestic gardens may become contaminated as a consequence of releases of radioactivity into the environment. Depending on the transfer of radionuclides to the animal or plant products affected (see Appendix B), some or all of this produce may contain activity concentrations of radionuclides in excess of Council Food Intervention Levels (Table 1.4). According to international radiation protection standards these products cannot enter the foodchain and, therefore, restrictions must be placed on the marketing of these foodstuffs. As the food products cannot be used for the purpose for which they were grown, they can be classified as waste. Depending on the specific situation and the type of produce affected, various options exist for the management of such wastes:

- no action is taken (e.g. if the radionuclide has short half-life and/or crop is immature, or livestock not ready for slaughter)
- contamination from the food product can be removed using established techniques and the food production is re-introduced into the foodchain
- the food product is diverted to animal feeding
- the food product is disposed of as waste.

Factors affecting the suitability of these options are presented in Figure 2.3.

2.4.2 Disposal of waste

Considerable volumes of biodegradable waste can arise if restrictions are placed on the entry of contaminated foodstuffs into the foodchain. Waste may also arise as a by-product of some of the other management options designed to reduce the subsequent transfer of radionuclides through the foodchain.

The types of produce that might require disposal include:

- crops and by-products from processing
- grass products (fresh grass, silage, hay)
- milk and by-products from processing
- whole animal carcasses and meat
- soil.

Twelve options have been identified for the disposal of these wastes. Comprehensive guidance on these options is given in the individual datasheets (see Section 3). They have been classified according to whether the waste would be typically treated in situ or transported to an off-site treatment or disposal facility (see Table 2.4). Seven important criteria need to be considered in the selection of the most appropriate disposal options:

- characteristics of the waste
- legislation concerning disposal routes for the waste
- capacity of disposal facilities
- agricultural impact following disposal
- environmental impact following disposal

- radiological impact during and after disposal
- societal/ethical issues.

Each of these criteria is influenced by site-specific information, which has been summarised in more detail in Figure 2.4.

Table 2.4 Management options giving rise to waste

Management option	Waste produced
Clean feeding	Cut grass, slurry
Decontamination techniques for milk	Resins
Early removal of crops	Crops
Processing of crops for subsequent consumption	Wastewater during processing, crop by-products
Processing of milk for subsequent human consumption	Milk products (e.g. butter, cheese), milk by-products (e.g. whey), waste water
Pruning/defoliation of fruit trees and vines	Cut branches, leaves
Restriction on the entry of food into the foodchain (food ban)	Crops, milk and meat
Salting of meat	Wastewater during processing
Selection of edible crop that can be processed	Wastewater during processing, crop by-products
Slaughtering of dairy livestock	Animal carcasses
Topsoil removal	Soil

Table 2.5 Classification of waste disposal options

In situ	Target medium
Composting[a]	Crops, cut grass
Landspreading of milk and/or slurry[a]	Milk
Ploughing in of a standing crop	Crops, pasture
Off-site	**Target medium**
Biological treatment (digestion) of crops	Crops
Biological treatment (digestion) of milk	Milk
Burial of carcasses	Animal carcasses
Burning of carcasses	Animal carcasses
Disposal of contaminated milk to sea	Milk
Incineration	Crops, grass and grass products, meat, animal carcasses, dried milk, by-products from processing
Landfill	Soil, crops, grass and grass products, meat, solid by-products from processing
Processing and storage of milk products for disposal	Milk
Rendering	Animal carcasses

[a] Can also be carried out off-site

Figure 2.3 Diagram illustrating factors influencing management of waste food

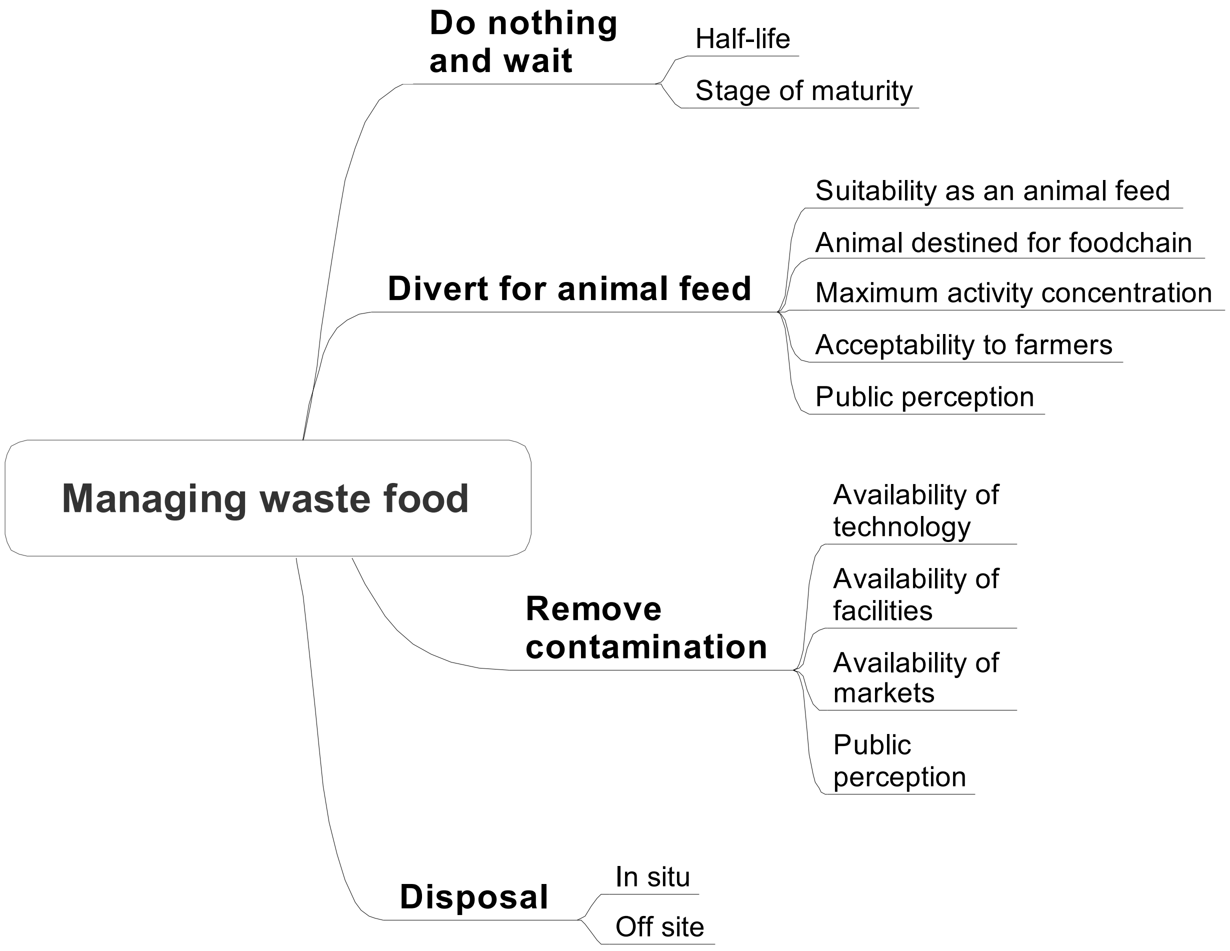
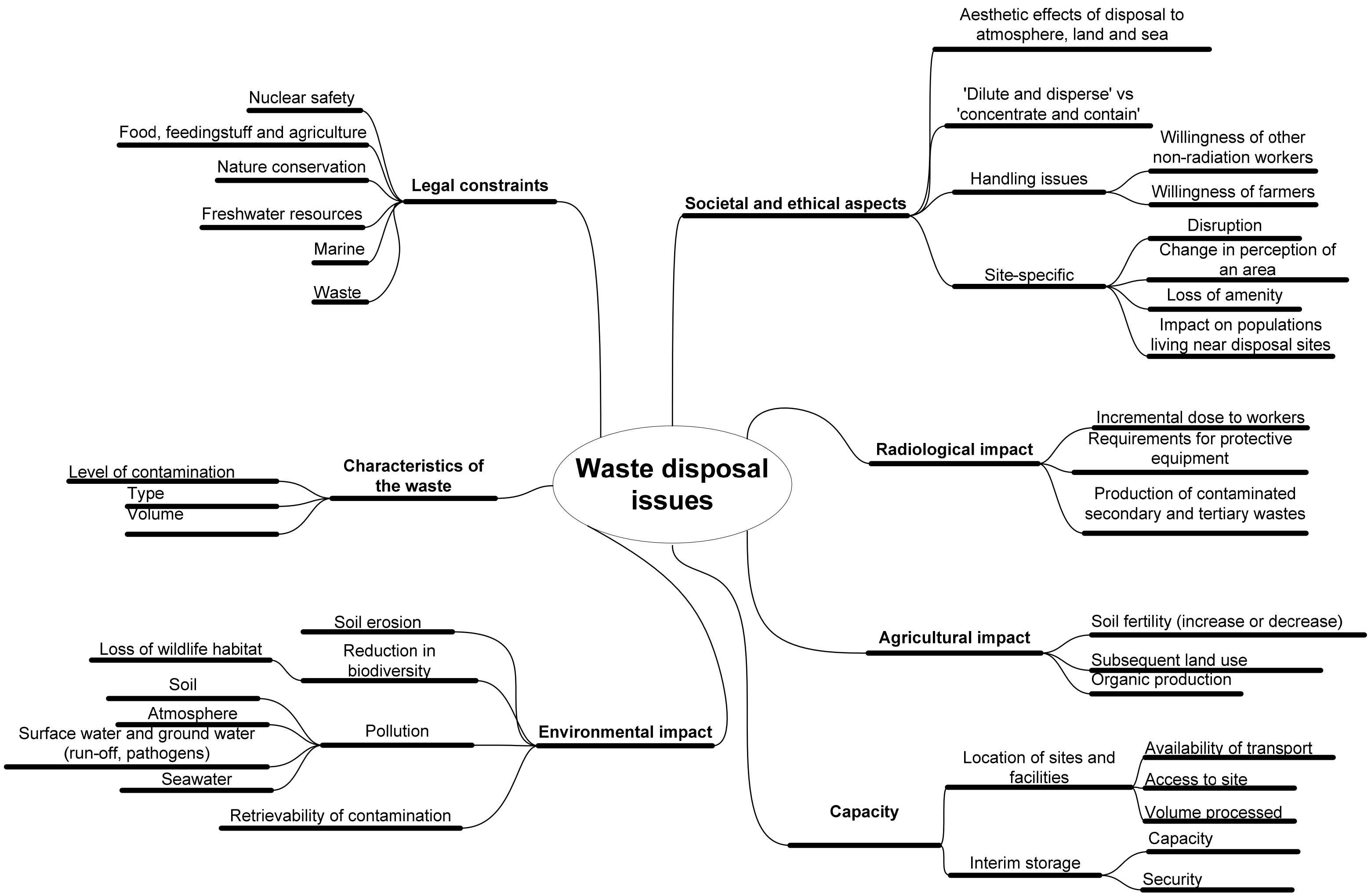


Figure 2.4 Diagram illustrating some of the main waste disposal issues to be considered when constructing a strategy of management options



2.5 Societal and ethical factors

The consequences of a radiological event raise not only technical, health-related and radiological problems, but also societal and ethical issues. Radiological contamination on a large scale has an impact on living conditions at an individual and community level (i.e. on health, economy, agriculture and environment) and can affect relationships within families, with neighbours and with the surrounding countryside. The event can also affect the relationships between those living inside and outside the contaminated area, especially if the area or population living there become stigmatised in some way. The information provided in this section is based on Nisbet et al, 2006.

2.5.1 Management of the contamination

Societal and ethical factors are also relevant to the management of the contaminated areas, for example, when deciding which management option should be carried out it is important to understand the implication of any actions on the population, to take into account individual and community concerns and to recognise the need to involve local stakeholders in the identification of problems and their solution.

Societal and ethical aspects must also form part of the decision-making process. Decision-makers should define the strategy not only according to technical criteria, but also to cultural and ethical points of view. For example, two potential strategies for managing milk considered unfit for the foodchain consist of spreading the contaminated milk back on land or transporting it to storage facilities for subsequent decontamination and disposal. The former is a relatively straightforward and inexpensive option already used for other types of contaminant but it could be perceived as diluting and dispersing radionuclides in the environment. The latter option is complex, expensive and has limited capacity but serves to concentrate and contain the contaminant.

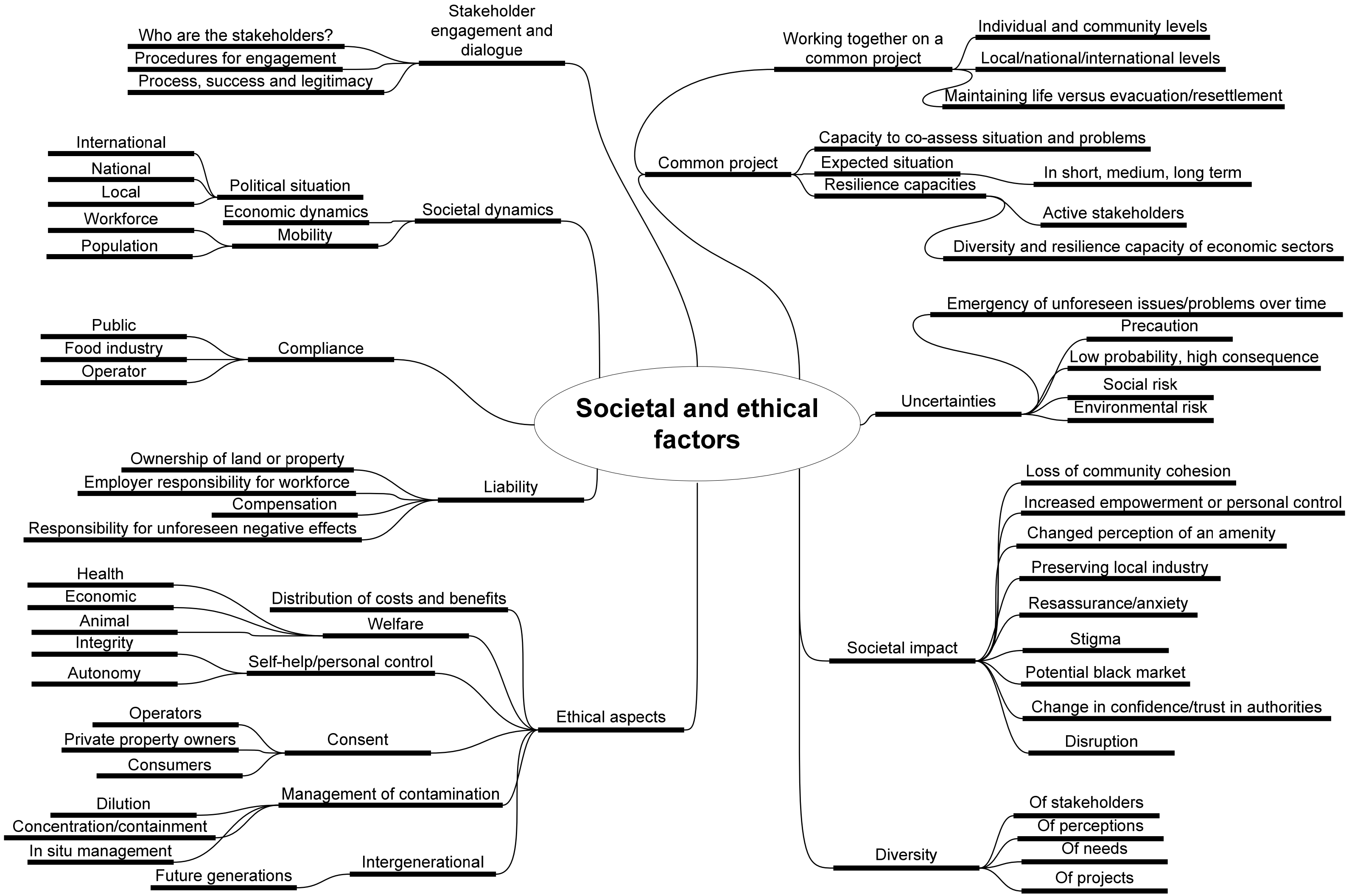
2.5.1.1 An overview of criteria affecting societal and ethical aspects

Figure 2.5 resents an overview of some of the main societal and ethical factors associated with a radiological event and its management. This diagram is not meant to be exhaustive or prescriptive, but rather to illustrate the multidimensional and complex nature of the issues at stake. Many criteria are interrelated (e.g. compliance may depend on the perceived disruption) and may produce knock-on effects (e.g. inequitable distribution of costs and benefits can produce stigma).

In practice, the choice of management option will almost always involve a balance or trade-off between health, economic and social consequences, as well as trade-offs between the interests of different stakeholders and communities of stakeholders. Such complexity means that it is difficult, if not impossible, to predict the way in which these factors may impact on the situation. A process involving discussion of all the issues at stake with the people affected form a necessary part of any management strategy.

In this respect a variety of tools and procedures can be used to help initiate a discussion of societal and ethical aspects. Such processes need to be open, transparent and inclusive, and directed towards both citizens and technical experts (see Section 2.9).

Figure 2.5 Diagram illustrating some of the main societal and ethical factors to be considered when constructing a strategy of management options



2.6 Environmental impact

Agricultural and domestic food production is closely linked with the environment. In the context of this Handbook the term "environment" refers to natural environments that surround all living beings (i.e. air, soil, water, as well as natural habitats and ecosystems such as forests, moorlands). Each environment has a diversity of uses for different stakeholders (i.e. those involved in farming, recreation and leisure, study, ecologists). In the event of radioactive contamination, these environments and the relationships people develop with them are affected, in a complex way. The implementation of management options often requires changes in agricultural practices and management, such as tillage, fertilisation, animal husbandry, which can affect the environment. All of these impacts are highly dependent on the characteristics of the environment in which the management options are applied (e.g. sensitivity to contamination, soil properties, topography, climate, historical and current management practices) and to the historical and current management of these environment. For example they could cause changes in the quality of water, air and soil or in the conservation or amenity values of the area. It is important therefore to give serious consideration to environmental issues at the time when a management strategy is being developed in the contaminated areas, as these have an impact on the acceptability of the overall management. Further information on the secondary effects of implementing management options can be found in the report by Salt and Rafferty (2001).

2.6.1 Direct and indirect environmental impacts of management options

Management options that have a direct impact have been grouped according to the target medium to which they are directed, specific options are given in parentheses (Table 2.6). Management options also have indirect impacts on the environment which have societal consequences (Table 2.7).

Table 2.6 Direct environmental impact of management options

Options directed at mechanical and chemical treatment of the soil
Changes in nutrient status and thus plant and animal diversity, with possible changes in landscape, especially for grasslands (potassium and lime applications, land improvement)
Change in mineralization of organic matter (potassium and lime applications, ploughing, land improvement)
Changes in bioavailability and mobility of nutrients and pollutants may lead on to effects on water quality (potassium and lime applications, ploughing, land improvement)
Soil fertility destroyed (topsoil removal, deep ploughing)
Long-term changes in soil structure (topsoil removal, deep ploughing, and for undisturbed land all forms of ploughing)
Soil erosion (topsoil removal, ploughing operations, early removal of crops)
Changes in landscape
Options directed at crops
Soil erosion (early removal of crops)
Changes in bioavailability and mobility of nutrients and pollutants may lead on to effects on water quality (ploughing in of a standing crop, in situ composting of crops)
Loss of wildlife habitat (ploughing in of a standing crop)
Options directed at livestock
Housing of livestock in summer could lead to high levels of ammonia in buildings (clean feeding)
Inappropriate disposal of slurry or contaminated milk from housed livestock (clean feeding, landspreading of milk) could lead to pollution of water courses and re-distribution of radionuclides
Changes in grazing pressure could cause changes to landscape and increases in biodiversity (manipulation of slaughtering time, selective grazing)
Options directed at changing land use
Change in ecosystem and biodiversity (select alternative land use, e.g. to non-food products)

Table 2.7 Indirect environmental impact of management options having societal consequences

Impact on the conservation of species
Changes in the status of natural habitats and communities
Symbolic changes where environments that are usually seen as “natural” and “clean”, could be seen as “dirty” and “dangerous” places
Changes in the utility of the environment where leisure pursuits can no longer be followed (e.g. gathering of wild foods, hunting)
Feeling of loss of a healthy environment which according to the gravity of the contamination, could also apply in relation to passing down a polluted or changed landscape to future generations
Changes in the accessibility of environments for agriculture and other economic activities
Restrictions in freedom to carry out traditional activities and ways of living with nature

2.7 Economic cost

Predicting the economic cost of implementing management options is a time consuming and difficult process. There will be direct costs such as those incurred through loss of production, implementation of management options (Table 2.8), handling of wastes (Table 2.9), as well as indirect costs such as those incurred through impact on the environment and loss of market share (Table 2.10). The magnitude of these direct and indirect costs will depend on many factors such as the date of the event, since an event occurring in the late spring has larger consequences for food production systems than one occurring in the late autumn; the period of time over which a management option is implemented; the scale of the event as costs are proportional to the area of land affected; land use, given that direct economic costs in areas of intensive agricultural production are likely to be much larger than when only marginal agricultural activity is present; and finally the availability of equipment and consumables. A discussion of the general categories of loss that can occur can be found in the COCO-2 report (Higgins et al, 2008), which also provides details of how such losses may be combined.

Table 2.8 Direct economic cost of implementing management option

Labour: salaries for the workforce involved (may need to be supplemented for work being undertaken), protection cost such as dosimetry or medical follow-up, overhead costs to organise the work, requirement for additional staff to be brought in
Consumables: specific products (e.g. ammonium ferric hexacyanoferrate (AFCF) or other additives)
Specific equipment: some management options (e.g. live monitoring of livestock) require dedicated equipment that may have to be hired or purchased (investment cost) and subsequently maintained and possibly decontaminated
Communication: information for the general public (guidance on behaviour, information for transparency and reassurance, etc.), and for special groups such as the people implementing the options
Support from abroad (e.g. civil protection, police, military, overseas consultants', etc.), leading to extra costs for travelling and subsistence, fees or salaries, etc
Transportation
Verification of laboratory analyses or screening techniques

Table 2.9 Direct economic costs of handling waste products

Labour
Special consumables for interim storage and processing of by-products after the intervention
Dedicated equipment: special containers etc
The design of a short-, medium- or long-term storage facility
Decontamination of the equipment and clean-up
Transportation: distances to suitable disposal/treatment facilities may be significant
Research and small scale testing of waste management options
Biodegradability of food products may impose special requirements on their storage

Table 2.10 Indirect costs

There will be indirect loss down the supply chain when production is stopped, as particular supplies and services will no longer be required
The implementation of management options to restore or conserve both the agricultural potential of an area and also the broader environment may cause changes in soil structure (e.g. in the case of deep ploughing) or acidity, and pollution of surface water (not only radiological, but also biological or chemical)
The loss of market share. Even if the food products originating from the affected area comply with the CFILs, customers, and consequently, the retail industry may refuse to buy the products even when the situation has returned to normality from a radiological point of view. Products from other regions will be imported to the market of the affected area, and this loss of market share in the affected area may last for a much longer time than the radiological crisis
Regional impact. Consumers may refuse to buy products from a much larger area than that directly affected (e.g. county, province, even national levels)
Side effects of management options such as reduction in fertility of soils and yields in the first few years after intervention
Restrictions on subsequent land use. Land may be used for non-food production requiring investment of resources in alternative seed stocks, expertise, new markets (e.g. processing industry) and marketing
Impact on social and economic fabric, such as tourism but also on the whole economy of the region (if, for example the management option chosen is the alternative land use one)

2.8 European legislation

It is likely that in the case of long term contamination, European, national and local legislation will be modified, according to the scale of the event. Laws affecting agricultural production are most likely to change because of the importance of market forces and food safety.

Regulations from the Council of the European Communities specify intervention levels for radioactive contamination in marketed foods and animal feeds (Council Food Intervention Levels, CFILs). These CFILs will be legally binding in the European Union in the event of a future event, although provision has been made for Member States to agree revisions to the CFILs shortly after the event. CFILs lead to the placing of restrictions on the entry of contaminated food into the foodchain. The imposition of these food restrictions has to be followed by an action either to reduce activity concentrations below the relevant intervention level and/or to select a suitable waste management strategy. These actions are themselves subject to other forms of European and national legislation to protect, for example, animal welfare, the environment, wildlife, etc. This legislation will impact on whether particular management options can be implemented. The datasheets presented in Section 3 contain information on relevant European legislation for each management option. A non-exhaustive summary of key legislation applicable to the management of food production systems is presented in Table 2.11.

Table 2.11 Non-exhaustive summary of key legislation applicable to the management of food production systems

EC legislation	Management options affected by legislation
Nuclear safety	
Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation. Official Journal No L 159, 29/06/1996 P. 0001–0018	All management options
Council Directive 89/618/Euratom of 27 November 1989 on informing the general public about health protection measures to be applied and steps to be taken in the event of a radiological emergency Council Decision 87/600/Euratom of 14 December 1987 on Community arrangements for the early exchange of information in the event of a radiological emergency Convention on Early Notification of a Nuclear Accident (Notification Convention	Most waste disposal options
Food, animal feed and agriculture	
Directive 2002/32/EC of the European Parliament and of the Council on undesirable substances in animal feed. Official Journal No L 140/10, 30/05/2002 P. 0001–0005 Regulation (EC) No 183/2005 of the European Parliament and of the Council of 12 January 2005 laying down the requirements for feed hygiene. Official Journal No L 35/1, 08/02/2005 P. 0001–0012 Commission Regulation (EC) No 2013/2001 of 12 October 2001 concerning the provisional authorisation of a new additive use and the permanent authorisation of an additive in feedingstuffs. Official Journal No L 272 , 13/10/2001 P. 0024–0028 Corrigendum to Regulation (EC) No 882/2004 of the European parliament and of the Council of 29 April 2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules. Official Journal No L 191/1, 28/05/2004 P. 0001–0038 Council Regulation (Euratom) No 3954/87 of 22 December 1987 laying down maximum permitted levels of radioactive contamination of foodstuffs and of feedingstuffs following a nuclear accident or any other case of radiological emergency. Official Journal No L 371, 30/12/1987 P. 0011–0013 Council Regulation (Euratom) No 2218/89 of 18 July 1989 amending Regulation 87/3954/EURATOM laying down maximum permitted levels of radioactive contamination of foodstuffs and of feedingstuffs following a nuclear accident or any other case of radiological emergency. Official Journal No L 211, 22/07/1989 P. 0001–0003 Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption. Official Journal No L 273, 10/10/2002 P. 0001–0018	Short term sheltering of dairy animals Clean feeding Clean feeding for domestic livestock Addition of AFCF to concentrate ration Addition of calcium to concentrate ration Administration of AFCF boli to ruminants Administration of clay minerals to feed Distribution of saltlicks containing AFCF Feeding of animals with crops/milk in excess of intervention levels Restriction on the entry of food into the foodchain Live monitoring Manipulation of slaughter time Slaughtering of dairy livestock Suppression of lactation before slaughter Raising of intervention levels
Nature conservation and terrestrial living resources	

Table 2.11 Non-exhaustive summary of key legislation applicable to the management of food production systems

EC legislation	Management options affected by legislation
Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention) Convention on Biological Diversity (CBD) Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) Convention on the conservation of European wildlife and natural habitats Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds	Select alternative land use Application of lime to arable soils and grassland Application of potassium fertilisers to arable soils and grassland Deep ploughing Skim and burial ploughing Land improvement Topsoil removal Selective grazing regime Clean feeding Clean feeding for domestic livestock Pruning/defoliation of fruit trees Restrictions during hunting and fishing seasons Restrictions on gathering wild foods Disposal of contaminated milk to sea
Freshwater resources	
Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources Council Directive 91/271/EEC (Urban Waster Water Directive) of 21 May 1991 concerning urban waste water treatment Council Directive 80/68/EEC (Groundwater Directive) of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances	Select alternative landuse Application of lime to arable soils and grasslamd Application of potassium fertilisers to arable soils and grassland Biological treatment of milk Burial of carcasses Composting Disposal of contaminated milk to sea Landfill Landspreading of milk Leaching of horticultural peat

Table 2.11 Non-exhaustive summary of key legislation applicable to the management of food production systems

EC legislation	Management options affected by legislation
	Ploughing in of a standing crop
	Processing and storage of milk products for disposal
Marine	
Convention for the Protection of the Marine Environment of the North East Atlantic (Oslo and Paris Convention [OSPAR])	Disposal of contaminated milk to sea
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972)	
Waste	
Council Directive 96/61/EC (Integrated Pollution Prevention and Control Directive) of 24 September 1996 concerning integrated pollution prevention and control	Biological treatment of milk
Council Directive 86/278/EEC (Sewage Sludge Directive) of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture	Burial of carcasses
Council Directive 75/442/EEC (EC Framework Directive on Waste) of 15 July 1975 as amended by Council Directive 91/EEC and adapted by Council Directive 96/350/EC	Composting
Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972	Disposal of contaminated milk to sea
Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste	Incineration
The Euratom Treaty Article 37 (1957) on the provision of general data on the disposal of radioactive waste	Landfill
Council Directive 2000/76/EC (Waste Incineration Directive) of 4 December 2000 on the incineration of waste	Landspreading of milk
Council Directive 90/667/EEC (Animal Waste Directive) of 27 November 1990 laying down the veterinary rules for the disposal and processing of animal waste	Processing and storage of milk products for disposal
Council Directive 91/689/EEC of 12 December 1991 on hazardous waste	Processing of milk for subsequent human consumption
	Rendering

2.9 Information and communication issues

In situations involving radioactive contamination of the environment, information and communication issues are likely to be very important, whatever the scale of the release. The provision of information and how that information is communicated will have a significant influence on how the authorities tackle the situation, on the response of society to the event and on the overall success of the management strategy. It is particularly important for situations involving foodchain contamination, as whole agricultural sectors can be severely affected by an inappropriate response.

The following sections taken from Nisbet et al, 2006, describe some of the communication and information issues that authorities and other stakeholders should consider when developing their management strategy and mechanisms which can be used to disseminate this information. They are not meant to be an exhaustive analysis of the topic.

2.9.1 Levels of dissemination and communication

2.9.1.1 National and local level

Most countries have an emergency information policy, together with guidelines for who bears responsibility for providing information, including procedures to ensure that relevant authorities communicate with each other before the release of press statements. Over time, many other stakeholders from public and private bodies at the national and local level will contribute to information collection, dissemination and communication.

2.9.1.2 Trans-national level

If the event is expected to have trans-boundary consequences, then countries are obliged to provide information under the *Council Decision on Community arrangements for the early exchange of information in the event of a radiological emergency* (87/600/Euratom, 4 December 1987, http://ec.europa.eu/index_en.htm) and the *Convention on Early Notification of a Nuclear Accident* (Notification Convention, http://www.iaea.org/).

2.9.1.3 European level

Even if the event does not have trans-boundary consequences, other member states will probably have information and communication requirements. European bodies will facilitate communication within the European Union and with countries outside Europe. Moreover, the requirement to provide information is also covered by European legislation, including *Council Directive on Informing the General Public about Health Protection Measures to be applied and steps to be taken in the event of a Radiological Emergency* (89/618/Euratom, 27 November 1989, http://ec.europa.eu/index_en.htm).

2.9.2 Types of information to be communicated over time

Information is required about the event itself and subsequently about the management strategy for dealing with its consequences.

2.9.2.1 Dissemination and communication of general information about the event

Information and communication is necessary from the pre-deposition phase onwards. The pre-deposition and early phases are characterised by a lack of information about the event, so there will be much reliance on predictions about the scale and impact of the contamination and the expected consequences. Information will be required about what is being done to deal with and mitigate the situation, and advice on what citizens themselves can do. The authorities will be the main communicators of information in the early phase.

As the situation evolves, the sources of information (specialised institutions, associations, intermediate communicators such as teachers and health workers) and the routes for dissemination will grow rapidly (e.g. media, Internet, leaflets). This could lead to a multitude of contradictory information. The authorities will need to cope with this situation and be in a position to provide information on the types of management options that have been applied, those that have been excluded, the reasons for these choices, and the likely timescale for further actions.

2.9.2.2 Dissemination and communication of information about management options

In the early phase after an event, management options for food production systems will be directed at the placing of restrictions on the movement and sale of contaminated or potentially contaminated foodstuffs, and the provision of dietary advice. A well-focused communication strategy and dialogue is required with affected populations and other stakeholders, especially those involved in agriculture and food production. There is a need to provide information on what the management options are, why they have been chosen, how they work, how they can be applied and by whom, any side-effects due to environmental or radiological impact as well as societal, ethical and economic consequences.

As the situation evolves over time, there may be dissent among affected populations regarding differences in the distribution of costs and benefits in the community from implementing the various management options. It is essential that every opportunity for dialogue and debate about appropriate management strategies is taken to pre-empt these situations as much as possible.

2.9.3 Mechanisms for communication and dissemination

2.9.3.1 Objectives

One of the main challenges for the communication and dissemination of information is the maintenance of the public's trust in the competence of the authorities and other organisations to deal with the situation. Trust is fragile, easy to lose and notoriously difficult to develop or regain once lost. Because knowledge will be limited in the early phase of an accident or release, information should properly reflect such uncertainties, and any advice should err on the side of caution. In most cases, people also need information and advice on what they can do personally to reduce exposure, particularly with respect to their children. As far as agricultural issues are concerned, maintaining public confidence in the safety of food products is paramount. Experience of other kinds of crisis affecting the foodchain, such as bovine spongiform encephalitis (BSE), shows that without a properly developed and targeted communication strategy, a crisis could lead to a long-term collapse of part of the agricultural sector.

2.9.3.2 Developing a communication framework

Feedback following the Chernobyl accident has highlighted the importance of developing a framework for information and communication strategies under non-crisis conditions. This should be set up in the planning phase and be dynamic to fit with the evolution of the situation and problems through time and space. There are a few key points to consider:

- the development of a communication framework should ideally include stakeholder involvement due to the complexity of the issues, the wide range of people likely to be affected and uncertainties about characteristics of potential future accidents or incidents
- the type of information disseminated should be tailored to meet the needs of a variety of people (i.e. those inside and outside the affected area, those involved in implementing actions, those affected by the actions)
- the form of communication should be adapted to different levels of understanding, to reflect the circumstances under which people live and to address the specific issues at stake and problems being faced
- the framework for information and communication should be considered in parallel with the development of management strategies
- at all stages of the response, authorities should not understate the constant need for information, and the need to consult different stakeholders, including experts and lay people, to learn about the needs and expectations of communities, what they know and what they do not know, what the uncertainties are and other issues.

2.10 References

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CONTENTS OF SECTION 3

3 DATASHEETS OF MANAGEMENT OPTIONS

3.1 The datasheet template

This handbook considers 58 management options that may be implemented in food production systems in the event of a nuclear accident or incident; 12 of these focus specifically on waste disposal. There is a large amount of information on each of these management options, which needs to be considered before a decision can be made on the most appropriate option(s) to select. A datasheet template was designed to systematically record information in a standardised format, taking into account most of the criteria that decision-makers might wish to consider when evaluating different options. The template includes a short description of the option, its key attributes, constraints, effectiveness, feasibility, the waste generated, the types of incremental doses incurred, costs, side effects, and a summary of practical experience of implementing the option. Table 3.1 presents the template with a brief summary of the information that appears under each heading.

Table 3.1 Datasheet template*

Name of management option	
Objective	Primary aim of the option (e.g. reduction of external or internal dose).
Other benefits	Secondary aims of the action (if any). For instance, the primary objective may be reduction of internal dose, whereas an additional benefit may be a limited reduction in external dose.
Management option description	Short description of how to carry out the management option.
Target	Type of object, on/to which the option is to be applied (e.g. soil, crop, animal).
Targeted radionuclides	Radionuclide(s) that the option is aimed at. Radionuclides considered within the EURANOS project have been attributed to one of three categories: **Known applicability**: *Radionuclides for which there is evidence that the option will be effective*. **Probable applicability**: *Radionuclides for which there is no direct evidence the option will be effective but for which it could be expected to be so.* **Not applicable:** *Radionuclides for which there is evidence that the option will not be effective. Reasons for this are given.*
Scale of application	An indication of whether the option can be applied on a small or large scale.
Contamination pathway	The step in the contamination pathway at which the option acts (e.g. soil to plant, plant to animal) if appropriate.
Exposure pathway pre-intervention	The pathway(s) through which people may be exposed as a result of the contamination, prior to implementation of the option (e.g. inhalation, ingestion, external exposure).
Time of application	Time relative to the accident/incident when the option is applied. Can be pre-deposition (i.e. measures which can be implemented when a potential contamination risk has been identified but before passage of the contaminated air-mass), early phase (days), medium-term phase (weeks-months), or late phase (months-years). An indication of the frequency of application is given where appropriate (e.g. annually etc.).
Constraints	**Provides information on the various types of restrictions that have to be considered before applying the management option.**
Legal constraints	Laws referring to, for example, regulation of foodstuffs, nature protection, animal welfare and cultural heritage protection.
Social constraints	Social constraints include the acceptability of the option to the affected population or to workers responsible for implementing it.
Environmental constraints	Constraints of a physical nature in the environment, such as snow, frost, soil type, slope and structure of land.
Effectiveness	**Provides information on the effectiveness of the management option and factors affecting effectiveness.**
Management option effectiveness	Effectiveness is the reduction in activity concentration in the target (e.g. crop or animal product or surface in the environment).
Factors influencing effectiveness of procedure	Technical (e.g. climate, soil fertility, fat content of milk) and social factors (e.g. is the method fully understood by workers, are there markets for alternative produce) that may, under different circumstances, influence the effectiveness of the method.
Feasibility	**Provides information on all of the equipment and facilities required to carry out the management option.**
Required specific equipment	Primary equipment for carrying out the option.
Required ancillary equipment	Secondary equipment that may be required to implement the option (e.g. monitoring equipment, tankers).
Required utilities and infrastructure	Utilities (e.g. water and power supplies) and infrastructure (e.g. building and manufacturing plants) which may be required to implement the option.
Required consumables	Consumables which may be required to implement the option (e.g. fertiliser, and sorbents).

Required skills	Skills which may be required to implement the option, necessitating the training of operators.
Required safety precautions	Safety precautions which may be necessary before the operative can implement the option.
Other limitations	Feasibility limitations that are not covered under other headings (e.g. capacity).
Waste	**Some management options create waste, the management of which must be carefully considered at the time the option is selected.**
Amount and type	Nature and volume of waste (e.g. number of livestock carcasses, volume of milk, amount of soil). Also, indication of whether waste is contaminated and, if so, to what level compared with the original material. STRATEGY produced datasheets for a number of waste options, which were updated as part of NRPB (now HPA-RPD) report W58 (Nisbet et al., 2004) – these are referred to here with hyperlink(s) to appropriate waste datasheet(s).
Possible transport, treatment and storage routes	Type of vehicle required to transport waste. Requirement to treat waste *in situ* or at an off site facility. Options for storage if no direct disposal option.
Factors influencing waste issues	Factors that may influence the way that wastes are dealt with (e.g. public acceptability and legal feasibility of the waste treatment /storage route).
Doses	**Provides information on how the management option leads to changes in the distribution of dose to individuals and populations.**
Incremental dose	Incremental doses that may be received by individuals in connection with the implementation of the option (e.g. operators, members of the public). This dose is influenced by procedures (if any) adopted to protect operators. The inclusion of a pathway in the datasheets means that it needs to be considered; it may not be important in particular circumstances.
Intervention Costs	**Provides information on the direct costs that may be incurred from implementing the management option.**
Equipment	Cost of the primary equipment.
Consumables	Cost of the consumables.
Operator time	Time required to carry out the option per unit of the target that is treated.
Factors influencing costs	Size and accessibility of target to be treated. Seasonality. Availability of equipment and consumables within the contaminated area. Requirement for additional manpower. Wage level in the area.
Compensation costs	Cost of lost production, loss of use.
Waste cost	Cost of managing any wastes arising, including final disposal. Refer and link to waste datasheet(s) as appropriate.
Assumptions	Any other assumptions which might significantly influence the intervention costs.
Communication needs	Identification of possible communication needs, mechanisms and recipients.
Side-effect evaluation	**Provides information on side-effects incurred following implementation of the management option.**
Ethical considerations	Possible positive and/or negative ethical aspects (e.g. promotion of self-help, requirement for informed consent of workers, distribution of costs and benefits).
Environmental impact	Impact that an option may have on the environment (e.g. with respect to biodiversity or wildlife reserves, pollution).
Agricultural impact	Impact that an option may have on the future suitability of land for agricultural use (e.g. after reductions in soil fertility).
Social impact	Impact that an option may have on behaviour and on society's trust in institutions.
Other side effects	Some options may have other side effects (e.g. maintain farm income, help communities affected by overproduction by encouraging diversification, promotion of self-help, distribution of costs and benefits).

FARMING Network stakeholder opinion	Summarises opinion, where available, from the FARMING Network stakeholder panels in France, the UK, Finland and Greece.
Practical experience	State-of-the-art experience in carrying out the management option. Some options have only been tested on a limited scale, whilst others are standard agricultural practices.
Key references	References to key publications leading to other sources of information.
Comments	Any further comments not covered by the above.
* adapted from Nisbet et al., 2004; location of hyperlinks to more detailed documentation are highlighted by underlined text.	

3.2 The datasheets

The datasheets are both comprehensive and concise and intended to be generally applicable across Europe. The format and content of the datasheets are based largely on similar documents developed initially in the STRATEGY project (Nisbet et al., 2004), and more recently within the EURANOS project itself (Beresford et al., 2006; Nisbet et al., 2006). Some additional minor changes have been made to the datasheets presented here to improve consistency and compatibility with the handbook: for example, links within the datasheets have been refined.

3.2.1 References

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Table 3.2 Index of all management options, with hyperlinks to datasheets

Table 3.2 Index of all management options, with hyperlinks to datasheets

Back to list of options

1 Closure of air intake systems to minimise the contamination of food processing plants and foodstuffs within them

Objective	To reduce: (1) contamination of foodstuffs from unfiltered air used in processing, and (2) contamination of food processing facilities. In the following text these objectives are referred to as (1) and (2) where comments are specific.
Other benefits	Maintain the credibility of safe food production systems to consumers (1,2). Reduce inhalation of contaminated indoor air in industrial buildings and external dose to workers in contaminated industrial plants after the passage of a radioactive plume (2).
Management option description	In food industries relatively large volumes of air are used for drying, roasting and pneumatic transport of food products. Outdoor air may be used directly or after purification with filters (e.g. EU filter categories 3 to 10). Due to large air volumes, sufficient filtering is not always possible. Contamination of foodstuffs can be prevented by halting those processes at risk before and during the passage of the plume (1). For protection of facilities in general, intake rates of air into buildings can be reduced to a minimum or stopped (2). The measures are precautionary, and only useful if implemented before the passage of the radioactive plume. Normal operation should be able to be resumed soon after the passage of the plume. Time available for stopping industrial processes and closing air intake systems varies according to the conditions of atmospheric transport of the radioactive material and the distance from the source of release. The duration of closure would depend upon the duration of the release and local contamination of air.
Target	1. Industrial food processes: milling, roasting, drying, dairy or meat plants, bakery and catering industries etc. Predominantly targeted at food processes involving powdered foodstuffs. 2. All facilities of food processing industry.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Potentially large scale.
Contamination pathway	From air to foodstuffs.
Exposure pathway pre intervention	Ingestion (1) Ingestion of contaminated foodstuffs (external and inhalation) (2)
Time of application	Pre-deposition phase.
Constraints	
Legal constraints	Requirement to consider radiation protection if there is a risk of operators being exposed to contaminated air-masses (i.e. if time were short). Instructions for shutdown of a process or ventilation system must be followed.
Social constraints	Resistance of operators to carry out procedure. Resistance of supporting industries; e.g. willingness to enter the affected area to collect products.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	1. For batch processes that are completed and stopped before passage of the plume the effectiveness should be *circa* 100% assuming that

	processing is not restarted until air concentrations are reduced to close to background levels. 2. Prevention of contamination of industrial plants through closure of air intakes will result in substantial reductions. However, this will not result in air tight buildings, so effectiveness cannot be expected to be 100%.
Factors influencing effectiveness of procedure	Incomplete or erroneous timing of the measures may substantially reduce their effectiveness. Sufficient time is needed to stop any existing processing prior to passage of the plume (1). The ability/possibility to make plants air-tight will vary (2). Minimal time needed if processes can be shutdown via a central control panel. Closing air intakes of an industrial plant can be more complicated. Availability of suitably trained personnel. Depending on the time and labour required, operators may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with public sheltering advice or evacuation. Although the effectiveness of this measure is independent of weather conditions, airborne radionuclide activity concentrations will be lower under conditions of wet deposition. Contamination risk varies with the particle size distribution of a foodstuff and the volume of air used per unit quantity of foodstuff.
Feasibility	
Required specific equipment	None.
Required ancillary equipment	None
Required utilities and infrastructure	Access to air intake systems in industrial buildings and facilities.
Required consumables	None for the actual implementation of the measure. After passage of the plume the air filters will need to be changed and disposed of (see EURANOS Urban datasheet Filter removal from industrial areas).
Required skills	Capabilities will exist on site. Competent persons would need to be available and may have to be called on to implement the management option out of hours.
Required safety precautions	There may be a risk that operators may be exposed to contaminated air mass (an effective system of communication must be in place). Otherwise none for implementation of the actual measure. To maintain an uncontaminated status, staff will need instruction and surveillance may be needed (2).
Other limitations	Delayed implementation may result if the measure is not sufficiently well known to the key persons in advance. Only competent staff members with the right to stop a process in an actual threat situation will be able to implement the measure (unless otherwise stated in emergency handbook prepared for a particular site). Requirement for well informed pre-warning may make this measure more applicable to sites far away from the source. A decision on implementation will have to consider the (potentially unknown) technical consequences of a sudden shutdown of some industrial processes.
Waste	
Amount and type	No waste will be generated from the measure (1). Filters in air ventilation systems will require disposal (2).
Possible transport, treatment and storage routes	n/a
Factors influencing waste issues	n/a

Doses	
Incremental dose	No additional doses to operators from the actual measure, although there may be additional doses associated with waste issues associated with disposal of contaminated air filters.
Intervention Costs	
Equipment	None.
Consumables	Air filters have to be changed.
Operator time	Additional staff/ extra work/ overtime may be required.
Factors influencing costs	Potential for spoilage of food products if processes are shutdown.
Compensation costs	Industry may need compensation if: • production is lost as a consequence of unnecessary shutdown • plant subsequently fails because of shutdown • large quantities of food are contaminated in the event that the information provided regarding the timing of the management option was incorrect
Waste cost	Disposal of ventilation system air filters.
Assumptions	None.
Communication needs	As the measure would have to be implemented prior to the arrival of contaminated air mass – rapid and comprehensive instructions to plant operators would be required. Depending upon time of day information on risks would need to be communicated to workers prior to their leaving home. Clear and readily available instructions should be provided in the processing plants' existing emergency handbook. Information must be updated regularly to ensure operators are not exposed to contaminated air mass. Cost of communicating the management option and its objectives to operators and the industry; multiple channels may be necessary (e.g. advisory centre, leaflets, internet). Provision of information to consumers on the rationale of the management option and evidence of its effectiveness would be important. Responsibilities regarding compensation may need to be defined.
Side-effect evaluation	
Ethical considerations	As this measure is precautionary authorities are unlikely to loose public trust even if with hindsight measures are proved to have been unnecessary. Self-help if carried out by facility owners. Redistribution of dose from consumers to operators/owners. Informed consent, a there is a risk that operators may be exposed to contaminated air mass.
Environmental impact	None.
Agricultural impact	None.
Social impact	As the measure is preventative, with little risk to consumers, it is likely to help maintain public confidence in the safety of food products and promote trust in authorities.
Other side effects	If properly communicated and implemented by competent operators, no negative side-effects are expected from shutting the processing facility although non radiological food risks will need to be considered (1). A review of different types of food processing plants could reveal potential risks from complete closure of air-intake systems (2) at specialised technical facilities.

FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	An assessment of the potential contamination risks to milled products from contaminated air was carried out during a training session for cereal based industry in 1996. The case initiated a research project (see key references). No experience of implementation in accidental situations has been found. Food contamination from processed air containing harmful microbes or heavy metals has been considered by the food industry.
Key references	Valmari T, Rantavaara A and Hänninen R (2004). Transfer of radionuclides from outdoor air to foodstuffs under industrial processing during passage of radioactive plume. STUK-A 209, Helsinki: Radiation and Nuclear Safety Authority. 50pp. + appendix 1p. (in Finnish with English summary).
Comments	In discussions during emergency training of the food industry the management option has mostly been evaluated as useful (Finland). As for all pre-contamination management options the time between notification and deposition is critical and this may limit the feasibility of this option. Management option may also be relevant for food storage facilities – non radiological food safety issues may preclude use under some food storage systems.
Document History	**STRATEGY originator:** n/a **STRATEGY contributors:** n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originator:** STUK (Rantavaara, A). **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; CEH (Beresford NA, Barnett CL and Howard BJ) and HPA-RPD (Nisbet AF) provided general comments. **EURANOS peer reviewer(s):** Vandecasteele C (Federal Agency for Nuclear Control, Belgium); Mustonen I and Latvio E (Finnish Food and Drink Industries Federation).

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2 Closure of irrigation systems	
Objective	To reduce contamination of soil, and surface and ground waters, following dry deposit and interception by standing crops.
Other benefits	
Management option description	Foliar interception is sometimes greater if deposition is dry than wet. Arial irrigation would solubilise radionuclides deposited on plant surfaces which may increase foliar absorption and also remove intercepted radionuclides to the ground. Closing aerial irrigation systems prior to the passage of the contaminated air mass would avoid further contamination of water networks and land. This measure is precautionary, and only useful if implemented before the passage of the radioactive plume. To be effective it must be combined with implementation of early harvesting of contaminated standing crops.
Target	Irrigated standing crops. (Agricultural irrigation is a significant user of water in Europe, accounting for around 30% of total water use in the north, and 60% in the south).
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Large.
Contamination pathway	Plant to soil (and later soil to plant); foliar absorption (and subsequent transfer to edible parts).
Exposure pathway pre intervention	Ingestion of contaminated food.
Time of application	Pre-deposition.
Constraints	
Legal constraints	Regulations on water management. Protection of workers.
Social constraints	Depending on the time and labour required, farmers may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with advice on subsequent public sheltering or evacuation.
Environmental constraints	Only effective if it does not rain before implementation of associated early harvesting management options.
Effectiveness	
Management option effectiveness	Difficult to quantify - only impacts on intercepted deposit. Effectiveness therefore dependent upon the degree of interception.
Factors influencing effectiveness of procedure	Sufficient time between notification and deposition. Time between deposition and implementation of associated management option early harvesting of contaminated standing crop. Irrigation system must have regulation mechanism. Compliance/resistance of farmers/agricultural workers to carry out procedure.
Feasibility	
Required specific equipment	None.
Required ancillary equipment	None.
Required utilities and infrastructure	Method of stopping irrigation system.
Required consumables	None.
Required skills	Required skills likely to be present in farming community.
Required safety precautions	Especially if being conducted in the near field, operators have to vacate area prior to deposition/passage of contaminated air mass (effective system of communication must be in place).

Other limitations	Requirement for well informed pre-warning may make this measure more applicable to sites far away from the source.
Waste	
Amount and type	None directly from this management option but contaminated wastes would be generated as a consequence of implementation of the associated management option 16 Early removal of crops.
Possible transport, treatment and storage routes	n/a
Factors influencing waste issues	n/a
Doses	
Incremental dose	No additional dose during the operation if people shelter before arrival of contamination.
Intervention Costs	
Equipment	None.
Consumables	None.
Operator time	That associated with closing irrigation systems.
Factors influencing costs	
Compensation costs	For crops with a low yield or of insufficient quality for sale (especially if water supply stopped to crops which are subsequently found to have been in areas receiving comparatively low levels of deposition).
Waste cost	See datasheet for associated management option – 16 Early removal of crops.
Assumptions	None.
Communication needs	Provision of information to farmers and agricultural workers on correct application of the procedure in advance. Information must be provided quickly and updated regularly to ensure operators are not exposed to contaminated air mass.
Side-effect evaluation	
Ethical considerations	As this measure is precautionary authorities are unlikely to loose public trust even if with hindsight measures are proved to have been unnecessary. Self-help if carried out by farmers. There is a risk that operators may be exposed to contaminated air mass.
Environmental impact	None.
Agricultural impact	Crops to which irrigation water was stopped as a precautionary measure in areas subsequently determined to have received low deposition may be low yielding or of poor quality.
Social impact	Prevention of water contamination likely to be of a positive impact, helping to maintain public confidence.
Other side effects	The prolonged dryness of the ground may increase resuspension of radionuclides.
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	In France this practice is routinely applied in agriculture to limit water consumption in dry summers.
Key references	Willrodt C (1993). Agrotechnical countermeasures to be applied before and during deposition of radioactive fallout. *Science of Total Environment*, 137, 21-29.

Comments	Closing of irrigation systems is intended to be a pre-deposition management option to reduce contamination of the ground and water in the case of a dry deposit. There will be a requirement for the implementation of further rehabilitation actions and 16 Early removal of crops. The main objective is not to limit contamination level of fruit (leaf – fruit transfer) but of soil. Consequently, the fruits cropped the year of the accident may be in excess of the Council for Food Intervention Limits. The management option may increase re-suspension and future leaching of radionuclides. As for all pre deposition management options the time between notification and deposition is critical and this may limit the feasibility of this option.
Document History	**STRATEGY originator:** n/a **STRATEGY contributors:** n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originators:** (IRSN) Reales, N. and Gallay, F. **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; CEH (Beresford NA, Barnett CL and Howard BJ), HPA-RPD (Nisbet AF) and UoI (Papachristodoulou C and Ioannides K) provided general comments. **EURANOS peer reviewer:** Carini F (Universita Cattolica del Sacro Cuore).

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3 Covering of standing crops

Objective	To prevent contamination of above ground plant parts.
Other benefits	Reduces the amount of potential contaminated waste. Prevents the contamination of soil.
Management option description	Covering plants with plastic sheets or waterproof tarpaulin for a limited period of time until deposition has ceased (for a maximum of a few days). Management option most effective for dry deposition; in the case of dry deposition horticultural fleece could be used. The management option is precautionary, and only useful if implemented before the passage of the radioactive plume. Largely applicable for self–help but could be used for larger areas (e.g. to protect high value crops).
Target	Predominately kitchen garden vegetables, soft fruit and high value crops close to harvest.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Large scale if being used as self help measure; small scale if being used for commercially produced crops.
Contamination pathway pre intervention	Direct deposition (later soil to plant).
Exposure pathway	Ingestion of contaminated crops.
Time of application	Pre-deposition phase.
Constraints	
Legal constraints	Requirement to consider radiation protection if there is a risk of personnel being exposed to contaminated air-masses (i.e. if time were short) and also those workers subsequently removing contaminated protective covering.
Social constraints	Personnel may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with public sheltering advice or evacuation. Resistance of supporting industries; e.g. willingness to enter the affected area to collect crops. Resistance of consumers/food industry to accept produce – provision for monitoring of foodstuffs may be required. Resistance of farmers etc. regarding the selection process for areas where the management option is applied.
Environmental constraints	If machinery required for application, slope and access may be a constraint for some crops (e.g. terraced grape vines). Would be difficult to implement in high winds.
Effectiveness	
Management option effectiveness	Up to 100%.
Factors influencing effectiveness of procedure	Incomplete or erroneous timing of the management option may substantially reduce its effectiveness. Appropriate selection of priority areas and crops. Compliance of personnel to carry out procedure. Availability of covering materials. Horticultural fleece may provide an alternative to plastic, waterproof tarpaulins. Whilst it is not waterproof it will protect crops from dry deposition and reduce particulate fractions of wet deposition. Its advantages include being a breathable fabric and bespoke machinery may be available to apply it to comparatively large areas.

Factors influencing effectiveness of procedure (continued)	If target area is comparatively large and an un-mechanised application is used, then manpower resources may be limiting. If the covering requires jointing or is damaged its effectiveness will be greater for dry deposition than wet. Low growing crops easier to cover than taller crops/fruit trees. The management option may have to be implemented out of hours. If puddles of contaminated water run off the protective sheet as it is removed and onto crop or soil then effectiveness will be reduced.
Feasibility	
Required specific equipment	Plastic sheeting/waterproof tarpaulin and/or horticultural fleece. Methods of securing covering material (e.g. pegs, ropes, rocks).
Required ancillary equipment	Machinery if applicable.
Required utilities and infrastructure	None
Required consumables	None
Required skills	Skill likely to be present within community – including those required to apply mechanically.
Required safety precautions	Ensure personnel are removed from field prior to deposition/passage of contaminated air mass, (effective system of communication must be in place).
Other limitations	Requirement for well informed pre-warning may make this measure more applicable to sites far away from the source.
Waste	
Amount and type	Covering material dependant upon area treated.
Possible transport, treatment and storage routes	53 Incineration or 54 Landfill. Existing organised routes of disposal of agricultural plastic wastes, (e.g. silage bale wrapping) will be inappropriate if it is usually recycled. If suggested as self help measure collection of covering materials by local authorities should be considered.
Factors influencing waste issues	Radionuclide composition of deposit (e.g. if predominately short lived isotopes no long term waste issues). Crop covering is unlikely to be biodegradable. Landfill operators are reluctant to accept large quantities of plastic waste as it works its way to the surface and causes drainage problems. There are limits on radioactive wastes that can be disposed of to landfill.
Doses	
Incremental dose	Incremental doses to personnel applying coverings should be minimal as long as the procedures are completed before the arrival of the contaminated air mass. Dose to personnel handling contaminated coverings.
Intervention Costs	
Equipment	Cost of covering and securing materials.
Consumables	None.
Operator time	Not known but likely to be highly variable.
Factors influencing costs	Size of each area treated relative to size of available covering materials, crop type and nature of covering material.
Compensation costs	Possible if crop is damaged.
Waste cost	Transport and disposal of covering materials. Crops may require disposal if damaged.
Assumptions	None.

Communication needs	Cost of communicating the management option and its objectives to those likely to be affected (e.g. gardeners and commercial producers); multiple channels may be necessary (e.g. media broadcasts, advisory centre, leaflets, internet). Advice on handling waste. Provision of information to consumers on the rationale of the management option and evidence of its effectiveness would be important. Information must be provided quickly and updated regularly to ensure operators are not exposed to contaminated air mass and that management option is not applied post deposition. This is largely a self-help, and therefore optional, management option. In the post deposition phase differing advise would need to be given to gardeners who had implemented the measure (e.g. how and when to remove covering, disposal routes etc.) and to those who had not (e.g. potential need to wash or dispose of their produce). This could lead to considerable confusion.
Side effect evaluation	
Ethical considerations	As this measure is precautionary authorities are unlikely to loose public trust even if with hindsight measures are proved to have been unnecessary. Self-help if carried out by owners. Risk that operators may be exposed to contaminated air mass. The short time available may preclude extensive stakeholder consultation, thus making it difficult to satisfy conditions of informed consent from owners and operators.
Environmental impact	Issues associated with disposal of waste plastics. Environmental impact of covering ground with plastic for short periods is minimal.
Agricultural impact	If covering is required for a prolonged period then crop spoilage due to increased humidity/temperature may occur (especially under warm weather conditions).
Social impact	May impact on *public confidence* i.e.: • Loss of confidence that farm produce and derivative products from affected areas is 'safe' (resulting in loss of employment in local 'cottage' industries or growth of a black market). • Increased public confidence that the problem of contamination is being effectively managed. • As the measure is preventative, with little risk to consumers, it is likely to help maintain public confidence in the safety of food products and promote trust in authorities.
Other side effects	As a consequence of reducing deposition to ground, crops grown in subsequent years will be less contaminated.
FARMING Network stakeholder opinion	Not considered by FARMING Network
Practical experience	Widespread usage of cloches/polytunnels in production of (predominantly) soft fruit and salad crops but debatable how useful this would be in emergency. Agricultural machinery is available to cover large areas of productive land with fleece – but it is unlikely to be available in the time period required and would need adaptation to dispense different materials.
Key references	
Comments	As for all pre contamination management options the time between notification and deposition is critical and this may limit the feasibility of this option. Potential for run-off from covering materials to result in comparatively high activity concentrations in soil at edge.
Document History	**STRATEGY originator:** n/a

	STRATEGY contributors: n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originator:** CEH (Beresford NA, Barnett CL and Howard BJ) in collaboration with the Belgian FARMING network stakeholder group. **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; HPA-RPD (Nisbet AF) provided general comments. **EURANOS peer reviewer:** Vandecasteele C (Federal Agency for Nuclear Control, Belgium).

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4 Prevention of contamination of greenhouse crops	
Objective	To stop contaminated air or water getting into greenhouse and/or polytunnels thus preventing or minimising the contamination of crops and growing media within them.
Other benefits	Reduces the amount of potential contaminated waste.
Management option description	Switch off ventilation systems during passage of plume and close all windows, doors and vents. The management option is precautionary, and only useful if implemented before the passage of the radioactive plume. Normal operation should be able to be resumed soon after the passage of the plume.
Target	Greenhouse and/or polytunnel crops.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Potentially large scale.
Contamination pathway	Direct deposition (later soil to plant).
Exposure pathway pre intervention	Ingestion of contaminated crops.
Time of application	Pre-deposition phase.
Constraints	
Legal constraints	Requirement to consider radiation protection if there is a risk of personnel being exposed to contaminated air-masses.
Social constraints	Resistance of farmers/operators to carry out procedure.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Potentially 100% depending upon radionuclide. Radionuclides in gaseous form (e.g. a fraction of radioiodine would still be found inside after implementation of the management option).
Factors influencing effectiveness of procedure	Incomplete or erroneous timing of the measures may substantially reduce their effectiveness. Depending on the time before arrival of the plume, operators may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with public sheltering advice or evacuation. Compliance of farmers/operators to carry out procedure. Personnel may have to implement the management option out of hours. Type and condition of greenhouse and/or polytunnel. Availability of alternative water supplies if rainwater normally collected although this method of irrigation is unlikely to be used by large scale producers or in southern climates due to the limited volumes of water likely to be collected. If it was to be collected again after deposition the roof would have to be cleaned or suitable period elapsed between deposition and collection in the case of short lived radionuclides.
Feasibility	
Required specific equipment	None
Required ancillary equipment	None
Required utilities and infrastructure	Alternative water supply if rainfall normally used.
Required consumables	None
Required skills	Skills are present within horticultural community.
Required safety precautions	Ensure operators are removed prior to deposition/passage of

	contaminated air mass (effective system of communication must be in place).
Other limitations	Requirement for well informed pre-warning may make this measure more applicable to sites far away from the source.
Waste	
Amount and type	None. However, rainwater collected during deposition should not subsequently be used to irrigate greenhouse crops.
Possible transport, treatment and storage routes	n/a
Factors influencing waste issues	n/a
Doses	
Incremental dose	Incremental doses to operators should be minimal as long as the procedures are completed before the arrival of the contaminated air mass.
Intervention Costs	
Equipment	None
Consumables	None
Operator time	Minimal
Factors influencing costs	n/a
Compensation costs	Potential costs if crops spoilt as consequence of measure.
Waste cost	Potentially transport and disposal of rainwater. Crops may require disposal if damaged – but contamination level should be minimal.
Assumptions	None.
Communication needs	Cost of communicating the management option and its objectives to those likely to be affected (e.g. gardeners and commercial producers); multiple channels may be necessary (e.g. media broadcasts, advisory centre, leaflets, internet). Information must be provided quickly and updated regularly to ensure operators are not exposed to contaminated air mass and that management option is not applied post deposition. The short time available may preclude extensive consultation, thus making it difficult to satisfy conditions of informed consent from operators. Provision of information to consumers on the rationale of the management option and evidence of its effectiveness would be important. Whilst the management option is likely to help maintain consumer confidence, it may be necessary for monitoring of foodstuffs to ensure acceptability of produce.
Side-effect evaluation	
Ethical considerations	As this measure is precautionary authorities are unlikely to loose public trust even if with hindsight measures are proved to have been unnecessary. Self-help if carried out by owners. Redistribution of dose from consumers to operators/owners. Informed consent, a there is a risk that operators may be exposed to contaminated air mass.
Environmental impact	None
Agricultural impact	Potential spoilage of crop due to lack of ventilation.
Social impact	Should help maintain public confidence regarding the quality of food products and trust in authorities, however food originating from the contaminated area could be rejected by consumers and this may generate mistrust and a loss in value of produce. This could lead to disruption in farming practice and inequitable distribution of benefits and harms.

	May result in growth of a 'black market'.
Other side effects	Avoids contamination of growing medium.
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	
Key references	
Comments	As for all pre contamination management options the time between notification and deposition is critical and this may limit the feasibility of this option.
Document History	**STRATEGY originator:** n/a **STRATEGY Contributors:** n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originator:** CEH (Beresford NA, Barnett CL and Howard BJ) in collaboration with the Belgian FARMING network stakeholder group. **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; HPA-RPD (Nisbet AF) and STUK (A Rantavaara) provided general comments. **EURANOS peer reviewer(s):** Vandecasteele C (Federal Agency for Nuclear Control, Belgium).

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5 Protection of harvested crops from deposition	
Objective	To prevent the contamination of crops which have been harvested prior to deposition and those stored outside awaiting processing (e.g. sugar beet).
Other benefits	Public confidence in food products.
Management option description	Covering of hay, silage (stored in clamps) and fodder crops (e.g. beets) stored on farms with plastic sheets or waterproof tarpaulin. The management option is precautionary, and only useful if implemented before the passage of the radioactive plume. Normal operation should be able to be resumed soon after the passage of the plume.
Target	Predominantly animal forage and fodder crops although also applicable to other harvested crops where appropriate.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Potentially large scale but depends on the time available between notification and arrival of the plume and availability of resources/materials.
Contamination pathway	Direct deposition.
Exposure pathway pre intervention	Ingestion of contaminated animal products, (possibly crops).
Time of application	Pre-deposition phase.
Constraints	
Legal constraints	Requirement to consider radiation protection if there is a risk of farmers being exposed to contaminated air-masses and subsequently when removing contaminated covering.
Social constraints	Compliance/resistance of farmers/operators to carry out procedure. Compliance of supporting industries, for example entering the affected area to collect crops.
Environmental constraints	Would be difficult to implement in high winds. Some crops may spoil if covered for prolonged periods in hot weather.
Effectiveness	
Management option effectiveness	Up to 100%.
Factors influencing effectiveness of procedure	Incomplete or erroneous timing of the management option may substantially reduce its effectiveness. Farmers may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with advice for public sheltering or evacuation. Availability of covering materials. Farmers may have to implement the management option out of hours. Degree to which covering diverges from usual practice. If contaminated water runs off protective sheet onto crop upon removal then effectiveness will be reduced.
Feasibility	
Required specific equipment	None
Required ancillary equipment	None
Required utilities and infrastructure	None
Required consumables	Plastic sheeting/waterproof tarpaulin and method of securing (e.g. pegs, ropes, rocks etc.).

Required skills	Skills are present in agricultural community.
Required safety precautions	Ensure operators are removed from field prior to deposition/passage of contaminated air mass (effective system of communication must be in place).
Other limitations	Requirement for well informed pre-warning may make this measure more applicable to sites far away from the source.
Waste	
Amount and type	Contaminated covering materials.
Possible transport, treatment and storage routes	53 Incineration or 54 Landfill. Existing organised routes of disposal of agricultural plastic wastes, such as silage bale wrapping, will be inappropriate where recycling is the aim of the existing schemes.
Factors influencing waste issues	Radionuclide composition of deposit Covering material is unlikely to be biodegradable. Removal of covering would have to be done in a way such that remobilisation of deposition was avoided. Landfill operators are reluctant to accept large quantities of plastic waste as it works its way to the surface and causes drainage problems. There are limits on radioactive wastes that can be disposed of to landfill.
Doses	
Incremental dose	Additional doses to people applying coverings should be minimal as long as the procedures are completed before the arrival of the contaminated air mass. Dose to persons handling contaminated coverings.
Intervention Costs	
Equipment	Covering and securing materials.
Consumables	n/a
Operator time	Not known but likely to be reasonably limited.
Factors influencing costs	Amount and nature of crop to be covered. Existing storage method for crop (e.g. fodder likely to be under cover with one or more open walls).
Compensation costs	Potential if crops damaged by prolonged coverage.
Waste cost	Transport and disposal of covering materials. Crops may require disposal if damaged.
Assumptions	n/a
Communication needs	Cost of communicating the management option and its objectives to farmers; multiple channels may be necessary (e.g. media broadcasts, advisory centre, leaflets, internet). Information must be provided quickly and updated regularly to ensure farmers are not exposed to contaminated air mass and that management option is not applied post deposition. The short time available may preclude extensive consultation, thus making it difficult to satisfy conditions of informed consent from operators. Advice on handling waste. Provision of information to consumers on the rationale of the management option and evidence of its effectiveness would be important. Whilst the management option is likely to help maintain consumer confidence, it may be necessary for monitoring of foodstuffs to ensure acceptability of produce.
Side-effect evaluation	
Ethical considerations	As this measure is precautionary authorities are unlikely to loose public

	trust even if with hindsight measures are proved to have been unnecessary. Self-help if carried out by farmers. Redistribution of dose from consumers to operators/owners. Informed consent, a there is a risk that operators may be exposed to contaminated air mass.
Environmental impact	Issues associated with disposal of waste plastics.
Agricultural impact	Risk of spoilage of some crops if covered for prolonged periods. If forage or fodder to be sold from the farm market value may be reduced.
Social impact	Should help maintain public confidence regarding the quality of food products and trust in authorities, however food originating from the contaminated area could be rejected by consumers and this may generate mistrust and a loss in value of produce. This could lead to disruption in farming practice and inequitable distribution of benefits and harms. May result in growth of a ‘black market’.
Other side effects	Provides uncontaminated feed source for animals being housed as emergency measure.
FARMING Network stakeholder opinion	Not considered by FARMING Network
Practical experience	Farmers will have experience of covering crops after harvest (e.g. silage clamps) or to protect from weather.
Key references	
Comments	As for all pre contamination management options the time between notification and deposition is critical and this may limit the feasibility of this option. Could consider removing the top layer of crop when removing the covering material to potentially reduce the activity concentration of the remaining crop (confirm if required by monitoring).
Document History	**STRATEGY originator:** n/a **STRATEGY contributors:** n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originator:** CEH (Beresford NA, Barnett CL and Howard BJ) in collaboration with the Belgian FARMING network stakeholder group. **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; HPA-RPD (Nisbet AF) provided general comments. **EURANOS peer reviewer:** Vandecasteele C (Federal Agency for Nuclear Control, Belgium).

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6 Short-term sheltering of dairy animals

Objective	To avoid or limit contamination of food products derived from grazing animals (by reducing the ingestion of contaminated feed during and soon after the passage of the radioactive cloud).
Other benefits	Minimise the volume of contaminated milk requiring disposal. Will reduce exposure of farm animals especially to short-lived radionuclides. Public confidence in food products.
Management option description	Short-term housing of grazing dairy animals prior to deposition and feeding with stored feedstuffs. The long-term clean feeding/housing of livestock is dealt with in a separate datasheet (29 Clean feeding). It is possible that this management option may coincide with the evacuation of the human population. If so farmers (or suitable emergency workers) will need to return at regular intervals to tend stock (until the evacuated population are allowed to return or, if evacuation is likely to be for a prolonged period, a decision is made to remove or slaughter the animals (see 37 Slaughtering of dairy livestock). For extreme emergency situations requiring the immediate evacuation of the public, this management option will not be possible.
Target	Grazing dairy animals.
Targeted radionuclides	**Known applicability:** All (especially radioiodine) **Probable applicability:** - **Not applicable:** -
Scale of application	Potentially large scale depending on farming practices.
Contamination pathway	Direct deposition and ingestion by animals, (inhalation of airborne radionuclides will still occur although this may be reduced).
Exposure pathway pre intervention	Ingestion of contaminated dairy products.
Time of application	Pre-deposition phase (not long-term)
Constraints	
Legal constraints	Requirement to consider radiation protection if there is a risk of farmers being exposed to contaminated air-masses. Animal welfare regulations. Regulations on the management of agricultural discharges; e.g. the management option will result in the production of manure and/or slurry on which there may be legal restrictions with regard to when it can be spread to land.
Social constraints	Resistance of farmers/operators to carry out procedure. Compliance of supporting industries, for example entering the affected area to collect milk or deliver feed. Acceptability of produce to food industry/consumers – need for monitoring data on foodstuffs.
Environmental constraints	Housing of livestock produces large volumes of manure and/or slurry. This must be stored and disposed of to land at times so as not to cause pollution (e.g. from nitrates). Storage capacity on farm for manure and/or slurry.
Effectiveness	
Management option effectiveness	Up to 100% dependant upon radionuclide composition, housing type, and water and feed supplies.

Factors influencing effectiveness of procedure	Incomplete or erroneous timing of the management option may substantially reduce its effectiveness. Compliance of farmers/operators to carry out procedure. They may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with advice for public sheltering or evacuation. Distance between pastures and shelters. Farmers may have to implement the management option out of hours. Degree to which management option diverges from usual practice. Type of housing will determine exposure to airborne radionuclides (e.g. some housing, especially that in southern European countries, is likely to be of a more open construction and therefore inhalation of radionuclides will still occur, potentially more important for radioiodine. Availability of forage – combined implementation with protection of harvested crops may aid in this (see EURANOS datasheet, 5 Protection of harvested crops from deposition). Unlikely to be sufficient local housing and conserved foodstuffs in systems using summer grazing regimes remote from farmsteads (may limit practicability of this measure in extensive Mediterranean systems). Water sources may be contaminated – especially relevant to farms with local water supplies.
Feasibility	
Required specific equipment	n/a
Required ancillary equipment	Equipment to remove manure/slurry – may not be required in emergency phase.
Required utilities and infrastructure	Suitable housing with water supply, and power if required. Storage capacity for extra manure/slurry.
Required consumables	Stored feed must be available. Bedding (straw etc.) if used.
Required skills	Farmers would possess the necessary skills as housing animals is general practice.
Required safety precautions	Especially if being conducted in the near field ensure operators are removed from field prior to deposition/passage of contaminated air mass (effective system of communication must be in place). If carried out with evacuation of population, health physics advice/monitoring and protective clothing may be required when farmers return to tend stock.
Other limitations	Roads must not be blocked by moving animals when people need to be evacuated. Roughage is generally exhausted at the end of winter (concentrates will normally still be available).
Waste	
Amount and type	No contaminated waste expected although manure and/or slurry will need to be disposed of when emergency situation has passed. This may be slightly contaminated through the inhalation route. However, the activity concentration is likely to be minimal due to the rapid decay of the short lived radionuclides.
Possible transport, treatment and storage routes	Use of normal slurry/manure disposal routes is unlikely to be a problem given short term nature of management option.
Factors influencing waste issues	n/a
Doses	
Incremental dose	No additional dose during the operation if farmers/operators return to shelter before arrival of contamination.

	Additional dose if this management option is combined with population evacuation for those who will have to come back regularly to milk and feed animals.
Intervention costs	
Equipment	n/a
Consumables	Stored feed. Bedding (straw etc.) if used.
Operator time	Extra work for farmer looking after housed animals and subsequently disposing of manure and/or slurry
Factors influencing costs	Time for which animal sheltering is required. Availability of feed locally. In near field situations, especially where population may have been evacuated, health monitoring of animals may be required even if only for reassurance purposes.
Compensation costs	Farmer for replacement feed (and bedding) and for additional work/labour.
Waste cost	n/a
Assumptions	n/a
Communication needs	Information must be provided quickly and updated regularly to ensure farmers are not exposed to the contaminated air mass and that management option is not applied post deposition. Provision of information on the rationale of the management option and evidence of its effectiveness, to consumers would be crucial. This includes the need to communicate to public why the animals are being sheltered (to protect the foodchain) as it may cause concern that there may not be simultaneous advice given for human populations (especially children) to shelter. May be a requirement to monitor animal health for reassurance purposes. Cost of communicating the management option and its objectives to farmers, other operators and the food industry (e.g. milk collectors); multiple channels may be necessary (e.g. media broadcasts, advisory centre, leaflets, internet). The short time available may preclude extensive consultation, thus making it difficult to satisfy conditions of informed consent from operators. Whilst the management option is likely to help maintain consumer confidence in foodstuffs, it may be necessary for monitoring to ensure acceptability. Advice to farmers on handling waste (manure and/or slurry).
Side effect evaluation	
Ethical considerations	As this measure is precautionary authorities are unlikely to loose public trust even if with hindsight measures are proved to have been unnecessary. Self-help if carried out by farmers. Redistribution of dose from consumers to operators/owners. Informed consent, a there is a risk that operators may be exposed to contaminated air mass. Ethical issues will depend on whether the management option is introduced as mandatory, or as advice to farmers (whilst the considerations will be the same the weight of the various aspects will change).
Environmental impact	None
Agricultural impact	Normally changes from grazing to conserved feeds would be progressive. In an emergency situation diet would have to be changed rapidly this will to lead to reduced productivity and negative health effects.

	Animal welfare issues associated with housing animals in emergency facilities (i.e. may not be as well prepared as when normally housed) and if housed in summer when ventilation/temperature may be a problem.
Social impact	May impact on *public confidence* i.e.: - Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are 'safe' (may result in loss of employment in local 'cottage' industries or growth of a black market). - increase confidence that the problem of contamination is being effectively managed. Disruption/adjustment of farming and related industrial activities, and people's image/perception of 'countryside'. Stigma associated with the area affected.
Other side effects	None.
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	Potential efficiency demonstrated in those countries where animals were still housed at time of Chernobyl accident (e.g. Norway, Finland).
Key references	IAEA (1994). Guidelines for agricultural countermeasures following an accidental release of radionuclides. Technical Reports series No. 363. (section 15.2), Vienna, IAEA.
Comments	Sheltering is intended to be a short-term management option to reduce ingestion during deposition and whilst external contamination and short-lived radionuclides dominate. There may be a requirement for continued provision of uncontaminated feed in which case the clean feeding datasheet should be consulted. This management option targets dairy animals to reduce the volumes of contaminated milk (and subsequently waste milk requiring treatment). Contaminated meat is not such a short-term issue – clean feeding and/or changing slaughter time are likely to be more appropriate. Management option could be combined with a harvesting of grass in the pre-deposition phase to increase feed stocks. However, it is unlikely that there would be sufficient time to harvest grass prior to deposition using normal practices (e.g. large bale silage making generally requires 2 days). There may also be restrictions on available labour to harvest grass given animal housing would need to be prepared and livestock gathered at the same time. As for all pre contamination management options the time between notification and deposition is critical and this may limit the feasibility of this option.
Document History	**STRATEGY originator:** n/a **STRATEGY contributors:** n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originator:** CEH (Beresford NA, Barnett CL and Howard BJ) in collaboration with the Belgian FARMING network stakeholder group. **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; HPA-RPD (Nisbet AF) provided general comments. **EURANOS peer reviewer:** Vandecasteele C (Federal Agency for Nuclear Control, Belgium).

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7 Dilution	
Objective	To provide foodstuffs with activity concentrations less than the intervention level.
Other benefits	Reduces amount of food requiring disposal.
Management option description	Contaminated produce may be mixed with uncontaminated produce in the appropriate proportions until the overall activity concentration in the bulk foodstuff is less than the intervention level.
Target	Grain and milk.
Targeted radionuclides	*For milk* **Known applicability:** All **Probable applicability:** - **Not applicable:** - *For grain* **Known applicability:** ^{60}Co, ^{75}Se, ^{89}Sr, ^{90}Sr, ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf **Probable applicability:** - **Not applicable: -** Short half-lives of $^{99Mo/99m}$Tc, ^{127}Sb, ^{131}I, ^{132}Te, ^{140}Ba, ^{140}La likely to mean this management option is not applicable.
Scale of application	Small to medium.
Contamination pathway	n/a
Exposure pathway pre intervention	Ingestion of contaminated grain or milk by individuals (collective dose is unaffected).
Time of application	Early to medium term.
Constraints	
Legal constraints	The sale of grain and milk intended for human consumption is subject to Council Food Intervention Levels (CFILs). Contaminated foodstuff is not normally allowed to be added to an acceptable batch to allow it to be distributed. The principle is derived from current EU-legislation on foodstuffs (see key references). Dilution is not accepted in international trade (confirmed by Finnish Custom Laboratory in 2004). However, an initiative for revision of intervention values for radionuclide concentrations in foodstuffs can be made to European Council by the Commission or by Member States through the Commission. Probable requirement for labelling products that have undergone dilution.
Social constraints	Potential for dispute regarding selection of produce for dilution. Resistance of operators/industry to: • transport contaminated produce • allow contaminated milk/grain into dairies/mills • accept diluted products for sale when alternatives can be sourced. Media interest is likely to be high. “Dilute and disperse” has a negative reputation in environmental ethics.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Can be highly effective in reducing volumes of milk requiring disposal. However, there would be no averted collective dose.

Factors influencing effectiveness of procedure	Relative activity concentrations in contaminated and uncontaminated produce. Relative quantities of contaminated and uncontaminated produce. Extent to which supplies of either contaminated or uncontaminated produce are homogeneous. Resistance to the management option by all stakeholders.
Feasibility	
Required specific equipment	None.
Required ancillary equipment	To allow optimal reduction in activity concentration of the final product sufficient numbers of containers may be required to allow the low and highly contaminated products to be stored separately until dilution took place.
Required utilities and infrastructure	Dairy or mill.
Required consumables	Uncontaminated produce.
Required skills	The operators at the dairy and/or mill would have the necessary skills to carry out the dilution. Monitoring would be carried out by trained personnel.
Required safety precautions	Consider respiratory protection for operators at mill, if not standard practice.
Other limitations	Availability of produce that is either clean or contains concentrations of radionuclides below the chosen intervention levels.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Driver:** • external exposure while transporting contaminated grain and milk to dairy/mill **Operative at dairy/mill:** • external exposure to contaminated milk at milk processing plant, • external exposure to contaminated grain at flourmill.
Intervention Costs	
Equipment	Extra containers/storage vats if required.
Consumables	Uncontaminated milk and grain from outside the affected area.
Operator time	Staff time to calculate dilution ratio etc. Operators at dairy or mill if additional labour is required.
Factors influencing costs	None.
Compensation costs	To dairy or mill: • for accepting contaminated produce, • for possible decontamination of equipment.
Waste cost	None.
Assumptions	Monitoring programme to ensure diluted products are less than CFILs.

Communication needs	Media interest is likely to be high. "Dilute and Disperse" has a negative reputation in environmental ethics. Cost of communicating both the management option and its objectives and rational to farmers, and the public through multiple channels (e.g. media, advisory centre, leaflets, internet), preferably as part of emergency management planning; requirement for updating as situation develops. Possible advertising campaign highlighting environmental concerns/animal welfare issues if this management option is rejected in favour of disposal or slaughtering options. Debate and dialogue is required on ethical premises. The principle of informed consent suggests that such foodstuffs should have their origins labelled. Dilution as a measure to get 'acceptable' foodstuffs for distribution would be a negative start of managing the contamination of food supply chain and cause additional mistrust towards later, possibly defensible measures. Also, retailers and consumers would not have the confidence that plants could be put back to normal operation after treatment has taken place, without the risk of contaminating milk and milk/grain products.
Side-effect evaluation	
Ethical considerations	If prices are lowered in response to reduced demand, there is an inequitable distribution of the residual contamination to poorer populations, and the possibility of their incurring a higher dose than that received by typical members of the population. Loss of profit to producers if the treated food is not accepted by consumers. The practice could be perceived as actively causing contamination of previously non-contaminated foodstuffs. Liability and responsibility for negative side-effect consequences will have to be addressed.
Environmental impact	None.
Agricultural impact	None.
Social impact	Potential for generating widespread mistrust of food production systems. Possible rejection of the final product, decrease in market price. Foodstuffs with activity concentrations that have been brought below the relevant CFIL by dilution are unlikely to be acceptable to the retail trade. Dilution as a measure for managing the contaminated foodstuffs might make the farming society unresponsive and lower its self-confidence. Thereby implementation of dilution may prevent both early and long-term implementation of acceptable management options that would reduce contamination in the foodchain.
Other side effects	None.
FARMING Network stakeholder comments	Unanimously agreed that the dilution of contaminated produce with clean material was felt to undermine consumer confidence and should not be adopted under any circumstances.
Practical experience	Dilution was used in Valdres, Norway where Chernobyl deposition was around 100 kBq/m^2. Some milk tankers collecting milk from this area were redirected to other dairies further away. In return, tankers from clean areas were sent to Valdres to dilute local supplies and so avoid the bulk milk exceeding the intervention limit. The redirection of milk tankers was a locally based decision that was not widely publicised.
Key references	Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295. Regulation (EC) No 178/2002 of the European Parliament and of the

	Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety, *Off. J. Eur. Commun.*, 1.2.2002 L 31/1.
Comments	This management option would have limited applicability in that it would be most likely to be adopted when clean supplies were limited. However, under such circumstances the amount of milk available as a diluent would also be limited.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY Contributors:** Mercer JA and Hesketh N (HPA-RPD); Liland A, Thørring H and Bergan T (NRPA); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Radiological Protection and Research Management Division, Food Standards Agency, UK. **EURANOS originator:** n/a **EURANOS Revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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8 Feeding of animals with crops / milk in excess of intervention levels

Objective	To minimise volumes of contaminated crops (including fruits) and milk requiring disposal.
Other benefits	Offsets the loss in cash value of the contaminated crop/milk by making use of it as animal feed. Can reduce requirements for animal feed on the farm.
Management option description	In general, only a fraction of the activity present in a feed is transferred to the meat or milk of an animal consuming that feed. Foodstuffs with activity concentrations known to exceed the CFIL could therefore be fed to animals while still subsequently producing meat or milk acceptable for human consumption. The activity concentration in the potential feeds should be measured and a prediction of the likely activity concentration in animal derived foodstuffs made and compared to appropriate Council Food Intervention limits (CFILs) before this management option is implemented (to avoid the production of milk/meat/eggs in excess of CFILs). Cereals make an important contribution to the typical daily ration of pigs, poultry and ruminants intended for both milk and meat production. Cereals grown for human consumption could therefore be fed to animals. Immature cereal crops (grain plus haulm) with the grain at the 'milk' stage, have a higher feeding value for ruminants than that from a mature crops (grain plus straw). Immature cereal crops can be fed directly or ensiled. In Mediterranean areas especially, by-products from the fruit industry can make an important addition to animals feed. Citrus pulp (peel and rag) is palatable, rich in nutrients and easily mixed with other feed ingredients. To increase its usefulness, it can be preserved by drying. Olive by-products (leaves and olive cake in all forms) are considered as crude lingo-cellulose feeds, comparable to cereal straw or poor quality hay, and can be used in animal diets when supplemented by a good quality protein source. Rice hulls and straw, treated with a mixture of urea and molasses to make up for their low energy, mineral and protein content, can be included as a roughage source in rations being fed to livestock. Furthermore, contaminated land could be specifically used to grow other crops for the purpose of animal feeding. Crops as well as milk could also be used for feeding to animals that are not likely to enter the human foodchain in the near future e.g. replacement heifers, dry cows, suckler beef cows, breeding ewes and young replacement females, breeding gilts and pregnant sows, adult fibre goats and males kept for breeding purposes (bulls, rams, boars and billy goats). There is also the potential of feeding these materials to leisure and working horses and to animals used in fur production.
Target	Crops and milk.
Targeted radionuclides	**Known applicability:** All if being fed to non-productive animals **Probable applicability:** - If being fed to animals producing milk or eggs, or meat animals soon to be slaughtered: ^{95}Nb, ^{95}Zr, ^{89}Sr, ^{90}Sr, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{127}Sb, ^{131}I, ^{140}Ba, ^{140}La, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf **Not applicable:** ^{60}Co, ^{99}Mo/^{99m}Tc, ^{110m}Ag, ^{134,137}Cs, ^{132}Te, ^{192}Ir if being fed to productive animals because of comparatively high transfer from diet to animal derived food products.
Scale of application	Small scale. Restricted to mixed farming systems where crops or milk produced on the farm can be fed to livestock on the same farm. The transportation of contaminated crops to other farms is likely to be unacceptable although in the case of using contaminated fruits as animal feedstuffs this would be necessary.

Contamination pathway	n/a
Exposure pathway pre intervention	Ingestion of contaminated milk and crops.
Time of application	Early to medium term. However, crop harvest should be delayed to allow for decay of short lived radionuclides and weathering of surface deposit. Most suitable at times of year when livestock are housed.
Constraints	
Legal constraints	For ^{137}Cs and ^{134}Cs marketed animal feedstuffs are subject to Maximum Permitted Levels (MPLs) set by the EC (CEC, 1990). These are: 1250 Bq kg^{-1} for pig feed; 2500 Bq kg^{-1} for poultry, lamb and calf feeds; 5000 Bq kg^{-1} for feed for all other animals. Possible requirement for labelling products directly or indirectly affected by application of the management option.
Social constraints	Acceptability of, and compliance with, management option by consumers and producers i.e. • Acceptability of new feedstuff with respect to animal welfare issues (e.g. diet less palatable, lower in fibre/energy levels etc.). • Acceptability to food industry/consumers of residual levels of contamination in animal products after applying this management option. • Transportation of contaminated feeds to areas not affected by fallout is unlikely to be acceptable. • Willingness of processing industries to manufacture animal feedstuffs (especially fruits in Mediterranean areas).
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Most effective if fed to animals not producing milk or not destined for the foodchain, in which case effectiveness is 100%.
Factors influencing effectiveness of procedure	Activity concentration of radionuclide in crop/milk (see Nisbet *et al.*, 1998) and biological half-life of each radionuclide compared to the time between feeding and slaughter or lactation. Number of animals on the farm compared to the amount of crop production. Availability of pigs/veal (or non-food producing animals) for consumption of milk. The production of citrus pulp or olive cake would have to be carried out in special facilities and transported to livestock farms. Assumptions within the derivation of MPLs for radiocaesium levels in animal feedstuffs do not guarantee production of animal derived foodstuffs below CFILs. Acceptability to farmers, food industry and consumers of feeding contaminated produce to animals destined for foodchain. Acceptability of, and compliance with, management option. Acceptability of selection process for areas where management option is applied.
Feasibility	
Required specific equipment	Equipment/processing plants to convert crop into suitable form to be used as animal feed. Stock proof fencing if cereal or vegetable crops are grazed in the field in summer.
Required ancillary equipment	None.
Required utilities and infrastructure	Storage facilities may be required for contaminated crops prior to feeding. Water, power supply and ventilation if animals are housed.
Required consumables	Additional concentrates or supplements may be required to nutritionally

	balance the diets.
Required skills	Farmers would possess necessary skills but would need guidance on feeding alternative diets.
Required safety precautions	None.
Other limitations	Liquid milk can only be incorporated into the diets of pigs and veal, although with modern ration mixing equipment it may be possible to mix milk with a dry cereal to produce a high quality concentrate feed for other animals. Crops will deteriorate in storage unless processed. Some crops can only be included in small amounts to maintain nutritional balance and palatability of diets. Other crops such as onions, garlic and herbs cannot be used as they will taint milk and meat. Changes in dietary composition are often introduced gradually over a 1-2 week period to minimise welfare issues.
Waste	
Amount and type	Contaminated excreta.
Possible transport, treatment and storage routes	Spread on surrounding farmland.
Factors influencing waste issues	
Doses	
Incremental dose	**Farmer while feeding animals:** • external exposure from feedstuffs while feeding animals • inadvertent ingestion of feedstuffs while feeding animals • hand skin exposure to feedstuffs while feeding animals **Farmer while ensiling:** • external exposure, inadvertent ingestion and inhalation while ensiling harvested crops. **Operatives at processing plant:** • whilst processing products into suitable animal foodstuffs
Intervention Costs	
Equipment	Equipment for producing animal feed. Fencing.
Consumables	Additional concentrates/supplements.
Operator time	Extra work by farmer (or processing plant operatives) e.g. processing crop to suitable form for feeding to livestock; implementation of the alternative feeding regime; erecting fencing.
Factors influencing costs	Availability of alternative housing. Need to modify housing. Requirement for concentrate supplements to make nutritionally balanced diets. Manpower. Social concerns.
Compensation costs	**Farmer:** • loss of value of crop grown originally for human consumption • additional work, especially if crops need processing before feeding to animals • loss of income from not adhering to conservation schemes. **Processing plants:** • fruits used as feedstuffs may have lower market value than normal • loss to producers if the treated product is not accepted by consumers.

Waste cost	None.
Assumptions	That there is a market for products from animals fed contaminated crops/milk.
Communication needs	High likelihood of negative media coverage. Potential need to facilitate widespread debate regarding ethics and practice of this management option, including dialogue for selecting areas where management option is applied. Possible cost of labelling milk and meat products from regions where the management option is applied.
Side-effect evaluation	
Ethical considerations	Increased dose from animal products that would otherwise be less contaminated highlights animal welfare issues. Informed consent.
Environmental impact	None.
Agricultural impact	Reduced grazing on fields.
Social impact	May impact on *public confidence* i.e.: • Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are 'safe' (may result in loss of employment in local 'cottage' industries or growth of a black market). • Increased confidence that contamination is being effectively managed. • Foodstuffs may not be acceptable to the retail trade when "clean" foodstuffs can be obtained from other sources. • Disruption/adjustment of farming and related industrial activities i.e. reduced supply of crops and milk to the food industry and therefore potential for market shortages.
Other side effects	Reduction in cost of buying in animal feed.
FARMING Network stakeholder opinion	The diversion of contaminated crops grown for human consumption to animals was viewed as unacceptable, even when the radionuclide content of the resulting milk and meat would be less than the intervention level set by the EC. The feeding of contaminated crops (and meat) to animals not destined for the foodchain was considered to be acceptable under specific circumstances only (i.e. it was acceptable for fur producing animals but not pets).
Practical experience	Many farmers have experience of formulating balanced animal rations from a wide range of feedstuffs.
Key references	Brown J, Wilkins BT and Nisbet AF (2002). Management options for food production systems affected by a nuclear accident: Diversion of crops grown for human consumption to animal feed. NRPB-W18. Nisbet AF, Woodman RFM, Brown J, Smith JG and Wilkins BT (1998). Derivation of working levels for animal feedstuffs for use in the event of a future nuclear accident. NRPB-R299. CEC. Council Regulation (Euratom) No. 770/90 laying down maximum permitted levels of radioactive contamination of feedingstuffs following a nuclear accident or any other case of radiological emergency. *Off. J. Eur. Commun.*, L83/78 (1990).
Comments	With modern silage-making methods it is possible to ensile any vegetable crop, including not only cereals, but also brassicas, legumes and root crops (whole or tops). Such silage can be stored for a number of years; this would allow long-term planning of livestock feeding practices. It would also allow shorter-lived radionuclides time to decay to less hazardous levels.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Hunt J (ULANC), Oughton DH (UMB).

	STRATEGY peer reviewer(s): Mayes B (Macaulay Land Use Research Institute, UK). **EURANOS originator:** n/a **EURANOS Revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Arapis G (Agricultural university of Athens).

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9 Leaching of horticultural peat	
Objective	Removal of (soluble) radionuclides from horticultural peat prior to its use as growing medium for greenhouse crops thereby reducing radionuclide concentration in subsequent crops.
Other benefits	Maintenance of production of greenhouse crops. Maintenance of peat industry. Reduce external irradiation of greenhouse workers.
Management option description	The management option should be applied to 'prepared' peat (i.e. sieved peat, with a residual moisture content of 45-65% by weight and prior to fertilisation). Some of the (soluble) radionuclides (notably radiocaesium) are removed by the following procedure. • The 'prepared' peat is first brought to saturation capacity. This is achieved with *circa* 4 litres of water per 1kg of prepared peat. • This is then 'flushed' with *circa* 4 litres water per 1kg of prepared peat – a further 'flushing' may improve the efficiency (see management option effectiveness). The management option should not be conducted after fertilisation as the effluent would then unnecessarily contain potassium, phosphate and nitrate.
Target	Horticultural peat intended for use in greenhouse crop production.
Targeted radionuclides	**Known applicability:** $^{134,137}Cs$ **Probable applicability:** - **Not applicable:** -
Scale of application	Small-large. Most likely to be applied by commercial growers or large scale horticultural peat producers.
Contamination pathway	Soil to plant.
Exposure pathway pre intervention	Ingestion of contaminated crops; external exposure of growers.
Time of application	Long-term.
Constraints	
Legal constraints	No legal constraints for leaching. However, the sale of crops intended for human consumption is subject to Council Food Intervention Limits (CFILs). Requirement for basic radiation protection training of and/or advice to operators. Requirement to protect local environment from effluents.
Social constraints	Resistance of commercial growers to use the treated peat, particularly if it is used in previously uncontaminated areas and resistance of food consumers to accept crops grown in treated peat. In both situations acceptability is likely to be related to the availability of alternative sources of clean peat.
Environmental constraints	Temperature must be above freezing. Preferably conducted in summer to assist in drying peat.
Effectiveness	
Management option effectiveness	The management option is only effective if applied to 'prepared' peat (see management option description). A reduction in radiocaesium activity concentration of about 50% can be expected if *circa* 4 l of water is used per 1 kg of 'prepared' peat. Repeating the procedure with an additional 4 l of water is expected to give a combined reduction of 80%.

Management option effectiveness (continued)	The intensity of leaching can be manipulated depending upon the level of contamination of peat.
Factors influencing effectiveness of procedure	The volume of peat to be treated should not be so large as to inhibit leaching of the entire mass. Leaching of newly harvested peat after liming may increase efficiency of radiocaesium removal. In modern horticultural production the volume of growing medium for specific plant species is optimised thereby limiting the total amount of radiocaesium in the growing bed. Also, slight watering in excess is normal practice during the growing period of greenhouse crops, this will result in further decontamination of the growing medium and hence reduce the activity concentration found in the crops. Compliance to the management option by peat industry workers/ market gardeners and the acceptability of the waste disposal options (water run-off and sorbents) by all stakeholders. Acceptability of the management option by the public/consumers, particularly if the decontamination process takes place at a site other than that of peat extraction.
Feasibility	
Required specific equipment	A suitable source of water. Hose-pipes (or similar).
Required ancillary equipment	Monitoring equipment/laboratories to determine the activity concentration of the peat prior to leaching (to optimise amount of water required and thus reduce the volume of effluent).
Required utilities and infrastructure	Systems for the collection and disposal of effluents (e.g. availability of drain pipes to the sewage network). Note: The required infrastructure is unlikely to be available at peat extraction sites as they are often situate in remote areas. If this is the case the effluent could be channelled directly into containers for subsequent disposal.
Required consumables	Water - quantities required will depend upon the volume and contamination level of peat and should be optimised so as to produce the smallest volume of effluent. Sorbents (biological and/or mineral) for absorption of small quantities of effluent that may leak from the collection system. Containers for storing effluent (if required). Materials to protect the land at the leaching site against unnecessary contamination.
Required skills	Professional gardening skills will be sufficient if the peat industry/market gardeners receive well documented instructions and objectives. Technicians for sampling of peat from stacks. Services/staff to perform radioactivity measurements. Experts on the treatment of effluents from farming practices are likely to be able to offer advice on handling effluents.
Required safety precautions	Radiation safety of persons implementing the management option.
Other limitations	The peat industry is generally lacking the technology for conducting this management option. The overall scale of the operation should be carefully considered (i.e. is the leaching site big enough to cope with the throughput of peat and associated effluent).
Waste	
Amount and type	Effluent from leaching and materials contaminated by effluent.
Amount and type (continued)	Complete watering of a 'dry' batch of peat will release roughly the same amount of water required to bring the peat to field moisture capacity (*circa* 4 litres per kg of dried peat). The effluent contains radionuclides,

	notably radiocaesium, and some soluble minerals e.g. iron.
Possible transport, treatment and storage routes	If no direct drainage to sewage system an alternative method of disposal would be required (e.g. transport in containers to sewage treatment plant or to a sea discharge pipe. Absorbent materials used for collection of small effluent leaks could be disposed to 54 Landfill.
Factors influencing waste issues	Discharge of leaching effluent to sea - if unfertilised peat has been leached there would be no environmental problems but the practice may provoke public resistance as would disposal to municipal sewage system. The volume and activity concentration of effluents need careful monitoring to protect land at leaching site.
Doses	
Incremental dose	**Operators:** during leaching process. **Drivers:** if tankers used to transport effluent.
Intervention Costs	
Equipment	Watering devices for leaching. Holding tanks with sufficient capacity at leaching site for effluent.
Consumables	Water. Materials for preparation of the leaching site and effluent holding tank. Possibly Labels.
Operator time	Depending on the dryness/volume/surface area of stacks/beds of peat, one leaching operation can take several hours. That associated with the transport of waste. That associated with additional transport of peat from producers/users lacking appropriate equipment for leaching.
Factors influencing costs	Use of existing watering and effluent collection systems would simplify and reduce the costs associated with the management option. If this was not possible then to reduce costs all details of the operation (i.e. preparation of the treatment area, construction of effluent collection system and conduct the management option) need to be planned in advance, prior to the usual planting time. The additional cost from increased through-flow for increased decontamination of peat is usually low. Transport of wet peat should be avoided due to increased costs. The time required for re-drying peat after leaching. If the management option was carried out at the growers premises modifications to the usual delivery of bagged peat would be required. Centralised implementation would facilitate controlled disposal of effluents and maintain peat production.
Compensation costs	Peat supplier or grower (depending upon responsibility for implementation of management option): for increased production costs, including effluent disposal.
Waste cost	To minimise costs efficient collection of leachate should be planned in co-operation with agricultural effluent experts. Costs for managing wastes, including final disposal, depend upon feasibility of the collection of effluents from the treatment site, sorbents used, and transport costs.
Assumptions	

Communication needs	The peat industry and vegetable growers need advice and information on all stages and aspects. Requirement for dialogue with users to ensure acceptability of selection process for areas where the management option is performed and product used. The impact of the management option (i.e. residual contamination of land at the leaching site) should be made clear to the landowner together with information on the future agricultural uses of the land. The public needs to be informed of the actions taken to ensure the safety of crops. It should be stressed that watering of peat is a natural method of decontamination. Normal communication channels can be used, and only a large scale intervention may cause substantial additional costs for communication to stakeholders. Possible requirement for labelling products directly or indirectly affected by application of the management option.
Side-effect evaluation	
Ethical considerations	Self-help if carried out by the growers themselves. Free informed consent of workers (to risks of radiation exposure). If residual levels of radionuclides in peat, informed consent regarding consumption of foodstuffs (residual contamination levels will be further reduced by normal watering during the period of growth). Consideration of re-distribution of dose if commercial peat containing residual levels were transported to non-contaminated areas. Re-distribution of dose from consumers to decontamination and waste operators.
Environmental impact	Restoration of the leaching site may be required. Environmental consequences of waste generation should be considered, however, if leaching is carried out close to site of peat collection/extraction, there would be benefits of *in situ* treatment.
Agricultural impact	Efficient collection of effluent will minimise any long-term contamination. Residual contamination at the leaching site may restrict subsequent agricultural uses.
Social impact	Help maintain peat production industry, particularly if community based. If there was likely to be a shortage of peat available for horticultural use, the management option would help maintain the production of greenhouse crops. Change in public perception or use of an amenity. Possible disruption to the peat industry and related activities and potential loss of profit to producers if crops grown in the treated product are not accepted by the food industry/consumers. May impact on public confidence i.e. loss of confidence that farm produce is 'safe', or increase confidence that the problem of contamination is being effectively managed.
Other side effects	
FARMING Network stakeholder opinion	Not considered by FARMING Network.

Practical experience	The measure was used in 1986-87 by some commercial growers in the area of Finland affected by the Chernobyl accident. The method was tested and implemented in close co-operation of food control authorities, vegetable producers and the peat industry. The management option was implemented to achieve activity concentrations in crops below a national intervention limit with batches of peat being analysed to determine their radiocaesium contamination level in advance of leaching. The harvest of tomatoes and cucumbers had lower radiocaesium activity concentrations than those anticipated because of additional 'decontamination' due to normal watering. Consumers' confidence was maintained through regular press releases on current contamination of various domestic foodstuffs, and particularly of new harvests.
Key references	The test results of the method will be published in the time scale of the EURANOS programme.
Comments	Other approaches to addressing the issue of contaminated peat should be considered. These include importing less contaminated peat or using an alternative growing medium. These could be used as alternatives to 'contaminated' peat or mixed with peat from affected areas to dilute activity concentrations to acceptable levels. All activity concentrations in peat should be given as dry matter, to be unambiguous. Whilst the measure has only been applied for radiocaesium it will possibly be effective for other radionuclides which have a weak binding to peat.
Document History	**STRATEGY originator:** n/a **STRATEGY contributors:** n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originator:** STUK (Rantavaara, A). **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; CEH (Beresford NA, Barnett CL and Howard BJ) and HPA-RPD (Nisbet AF) provided general comments. **EURANOS peer reviewer(s):** Vuorinen A (Plant Production Inspection Centre, Agricultural Chemistry Department, P.O.Box 83, FIN-01301 Vantaa, FINLAND).

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10 Prevention of fire in forests, shrubland and other sensitive areas

Objective	To prevent fires, and their subsequent spread so that there is less risk of radionuclide resuspension and subsequent transfer to areas used for agricultural production.
Other benefits	Dose reduction by restricting the use of contaminated semi-natural or forest areas. Internal dose reduction due to reduced collection of wild foods. Reduce the need for making fire breaks **after contamination** that would cause radiation exposure to workers.
Management option description	Forest fires may be an important source of radionuclide resuspension; for example, 40-70% of the Cs stored in vegetation could be released in the atmosphere during a fire. The risk is particularly pronounced in Mediterranean areas, especially during summer. 1. In the early period following a radiological accident **closing forests and semi-natural areas to the public and banning any practices likely to cause fires** (e.g. agricultural burning, campfires etc.) would greatly reduce the risk of fire starting due to human negligence. This ban would need to be actively policed and enforced. 2. After a few days, or weeks further actions may be required to prevent initiation and spread of fire. Some areas may be more at risk than others. **The most sensitive areas should be treated as a priority** (e.g. railways, roads, electric lines, rubbish dumps): • install/ maintain concrete barriers, safety fences or netting • widening of the road hard shoulders • improving inspection, surveillance networks • fuel management/clearing of dry vegetation from shrubland, semi-natural areas and beside sensitive sites (see comments). 3. **Increase readiness for fire fighting in affected areas:** • Ensure rapid availability of fire fighting equipment and suitably trained personnel in the sensitive areas (in highly contaminated areas preference would be to use aircraft capable of deploying water over large areas). In the following text, these actions are referred to as (1), (2) and (3) where comments are specific.
Target	Radioactively contaminated forests (especially Mediterranean), located beside agricultural land, shrubland and other fire sensitive areas (e.g. road/railway verges).
Targeted radionuclides	**Known applicability:** All (predominantly long-lived radionuclides). **Probable applicability:** - **Not applicable:** -
Scale of application	Large scale.
Contamination pathway	Re-suspension and subsequent re-deposition.
Exposure pathway pre intervention	Predominantly external (1) but some internal (1-3).
Time of application	Early (banning) to long-term.
Constraints	
Legal constraints	Relevant legislation at national European levels concerning the management of fire risk in semi-natural and forest areas. (see key references). Non-compliance with any environmental protection schemes. Waste treatment and disposal - normal practices (e.g. biofuel) may not be acceptable.
Legal constraints (continued)	National guidelines would apply regarding dose limits which would

	include a requirement for basic radiation protection training of operators so they avoid unnecessary exposure to radiation.
Social constraints	Public resistance to long term closure of forest or restrictions upon leisure practices (1). Operators' resistance to manage contaminated areas. They may be reluctant to perform tasks in the event of radioactive contamination because of the possibility of relatively high exposure levels (2 and 3).
Environmental constraints	Areas requiring specific management because of their sensitivity fire risk may be difficult to gain access to (2).
Effectiveness	
Management option effectiveness	Less than 100% as: • impossible to guarantee total closure of contaminated areas • impossible to avoid deliberate arson • accidental fires starting (e.g. lightening).
Factors influencing effectiveness of procedure	Information, acceptability and willingness of affected population to follow fire prevention guidance (e.g. cigarette butts, barbecues). Adequate policing is likely to improve effectiveness (1). Extent of the contaminated area, number of access points, human and technical resources for monitoring and long term maintenance of contaminated areas (1-3). Appropriate selection of priority areas. Degree to which the management option diverges from common practice. Availability of water. Acceptability of disposal/treatment procedures/Compliance and availability of operators to carry out procedure.
Feasibility	
Required specific equipment	Tracked machinery, tractors, chainsaws for clearing and suitable trucks for taking waste vegetation to disposal site, all are likely to be available as used in normal forest management (2). Fire fighting equipment (fire fighting aircraft, cargo helicopters, water transporters, light tractors) in order to intervene quickly in case of fire. Some equipment/systems are likely to be readily available although additional resources may need to be deployed dependant upon scale (3).
Required ancillary equipment	Fencing for prohibiting access (1). Building materials to make roads safe (widening of road hard shoulders, concrete barriers, safety fences or netting) (2).
Required utilities and infrastructure	Wardens (especially when management option is first instigated) (1). Monitoring of fire usually is normally carried out from watchtowers; mobile look-out posts would complement this surveillance/Access roads (2). Waste storage (3).
Required consumables	Barriers (and locks), information boards, fences and signs (1). Availability of sufficient quantities of water (3).
Required skills	Operators (e.g. forest workers, drivers, wardens) would have the skills required for monitoring and clearing, but must be informed carefully in advance about the objectives and the safety precautions (2). Fire fighters, including aircraft crew, would need to be informed in advance about the objectives and the safety precautions (3).
Required safety precautions	Consider respiratory protection if very dry conditions and protective clothing. Minimise risks of sparks etc. during operations (2 and 3). General occupational hygiene for fire fighters (3).
Other limitations	Requires ongoing programme of radiation monitoring to determine duration of restrictions (1). Wild animals could be vectors of contamination from contaminated forest to uncontaminated areas (there may be increases in populations because

	of restrictions on human penetration inside the forests).
Waste	
Amount and type	Vegetative waste, including woody material (2).
Possible transport, treatment and storage routes	Normal treatment of waste, including recycling, would not be applicable to contaminated material. Could consider possible volume reduction of waste by 51 Composting or 53 Incineration.
Factors influencing waste issues	The amount is highly dependant on the extent of the contaminated area, on vegetation density and type and the exact measures taken.
Doses	
Incremental dose	**Forestry workers** **Drivers of trucks transporting waste** **Fire fighters**
Intervention Costs	
Equipment	Variable costs associated with: Barriers (and locks), fences, information boards and signs (1). Tracked vehicles, tractors and trucks for waste transport (2). Fire monitoring and fighting equipment (3).
Consumables	Water supply.
Operator time	That associated with closing and erecting signage for forests and shrubland (will be variable according to area) (1). Tasks likely to take longer than expected due to the inaccessibility of some areas (2 and 3).
Factors influencing costs	Clearing can be carried out mechanically for a cost of about €500- €1000 per hectare (2). Fire fighting is estimated to cost €2000- €3000 per hectare (3). These costs will increase with the slope and the vegetation height and density (accessibility to the area).
Compensation costs	People utilising forest areas for their livelihoods: compensation for property/amenity damage and/or change.
Waste cost	Highly dependent on the amount of waste and the chosen disposal route.
Assumptions	n/a
Communication needs	Need for good information to operators on safety precautions during operations (1-3). As a majority of fires are related to human negligence, previous information for the public would greatly reinforce the management option (e.g. educational documents in schools, radio messages, signage around areas sensitive to fire initiation) (1). Provision of information to forestry workers, fire fighters and farmers on correct application of the procedure. As this management option affects both forest and agricultural environments, there needs to be a dialogue and consideration of stakeholder interests for both systems (2 and 3).
Side-effect evaluation	
Ethical considerations	Negative effects from restrictions on liberty and autonomy, (loss of possibility to gather free food). Free informed consent of workers (Radiation exposure of workers penetrating inside the forests for fuel management).
Environmental impact	Modifying the management of forests may have negative effects on their ecological balance for plant and animal species. Further regulations may be required to restore this balance in the long term (1). Clearing (2) may increase the radionuclide activity concentration of runoff waters and sediments.
Agricultural impact	Preventing sensitive forest areas from fire will also prevent fires in agricultural land (1-3).

	Growth of wild animals' populations due to restrictions on human penetration inside the forests may affect agricultural productivity (1).
Social impact	Policing the management option i.e. against trespass (information). Loss of amenity/social value. Change in public perception or use of an amenity, leisure practices. Loss of possibility to gather free food or wood.
Other side effects	Possible increase in public confidence.
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	Most of these actions are applied in Mediterranean areas every year to fight fires. Different personnel are involved dependant upon responsibility within the affected territory. Removal (or decreasing the volume) of combustible vegetation can significantly reduce the risk of fires. It is obligatory in, for instance, the south of France and can be carried out by land owners, private companies and voluntary helpers. But, as the forest could be relatively highly contaminated in a post accidental situation, there may be a relatively high radiation exposure to these personnel. To reduce this risk the fire risk management actions could be limited to the most sensitive areas.
Key references	Kashparov VA, Lundin SM, Kadygrib AM, Protsak VP, Levtchuk SE, Yoschenko VI, Kashpur VA and Talerko NM (2000). Forest fires in the territory contaminated as a result of the Chernobyl accident: radioactive aerosol re-suspension and exposure of fire-fighters. *Journal of Environmental Radioactivity*, 51, 281-298. Rafferty B and Synnott H (1998). Countermeasures applied to forest ecosystems and their secondary effects: a review of literature. Serie Documenti 6/1998. Agenzia National per la Protezione dell'Ambiente, Roma (ANPA), Italia, ISBN 884480296-1. Holländer W and Garger E (1996). Contamination of surfaces by resuspended material (International scientific collaboration on the consequences of the Chernobyl accident) EUR 16527 EN. Amiro BD, Sheppard SC, Johnston FL, Evenden WG and Harris DR (1996). Burning radionuclide question: What happens to iodine, cesium and chlorine in biomass fires? *Science of the Total Environment*, 187, 93-103. Guillitte O, Tikhomirov G, Shaw G and Vetrov V (1994). Principles and practices of countermeasures to be carried out following radioactive contamination of forest areas. *Science of the Total Environment*, 157, 399-406. Regulation CE n°2158/92 (23/07/1992). Regulation CE n°2152/2003 (17/11/2003). Regulation CE n°1727/1999 (28/07/1999). Regulation CE n°804/98 (11/04/1994).
Comments	Following a nuclear accident, if deposition occurs without precipitation in forested areas intercepted contamination by trees and bushes would be considerable. Potential forest fires could then be an important source of radionuclide re-suspension from the early to the long term. For example 40 to 70 % of the Cs stored in vegetation could be lost to the atmosphere during a fire. And the area affected by deposition of re-suspended radionuclides could extend to tens of km from the source. The extent of the re-deposition would be closely linked to the size of fire, the height of the smoke and to the wind speed. In Mediterranean areas the speed of fire progress can be up to 7-8 km h^{-1} whereas in Finland the corresponding speed is 2.5-3 km h^{-1}. This difference may enhance the consideration of proactive fire breaks in southernmost Europe. Furthermore, in post accident situations, Mediterranean areas would be even more sensitive to the risk of fire than normally as prevention actions could be limited because of the closure of forests.

	Roads, railroads, power lines and rubbish dumps represent an important potential source of fire. For example, fires originating from roads are usually due to carelessly discarded cigarettes or road traffic accidents. Fires from railways may be due to sparks, cigarettes or accidents during maintenance and/or normal operations. Damage to power lines may as well represent an important risk as could rubbish dumps which may contain various potential fire sources. If fire prevention measures have to be limited (e.g. because of high contamination levels) consideration should be given to targeting the areas mentioned above. The requirement for fire prevention measures (1) and (2) would be relatively small if the areas were regularly managed for fire prevention as part of normal practice. Quality of public information and of contaminated area monitoring may have an important influence on the effectiveness of the strategy. Consider the use of fire retardant chemicals which could be deployed by aircraft and could stop fire progression. The contaminated, high fire risk, vegetation may be better collected during wet conditions e.g. after heavy rain to avoid resuspension of radioactive material if possible. If the extent of contaminated territory was significant, manpower could be a limiting factor; grazing by farm animals may be an option – although careful consideration would have to be given to their management and entry into the foodchain.
Document History	**STRATEGY originator:** n/a **STRATEGY contributors**: n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originator:** Reales N and Gallay F (IRSN). **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; CEH (Beresford NA, Barnett CL and Howard BJ), HPA-RPD (Nisbet AF), UoI (Papachristodoulou C and Ioannides K) and STUK (Rantavaara A) provided general comments. **EURANOS peer reviewer(s):** Heikkilä T and Vainio T (Ministry of the Interior, Finland), Horppu K (private consultant, Finland).

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11 Restriction on the entry of food into the foodchain (food ban)

Objective	To remove food that is contaminated above the Council Food Intervention Limits (CFILs) from the foodchain.
Other benefits	Maintenance of confidence in food products.
Management option description	Milk, meat, eggs and crops, and processed products made of them, with activity concentrations over the intervention limit may be banned from sale. Condemnation completely removes contaminated food from the market but can leave large quantities of waste needing disposal.
Target	Milk, meat and crops.
Targeted radionuclides	**Known applicability:** All (especially short-lived radioisotopes). **Probable applicability:** - **Not applicable:** -
Scale of application	Large scale.
Contamination pathway	n/a
Exposure pathway pre intervention	Ingestion of contaminated milk, meat and crops.
Time of application	Predominantly early but possibly to long term.
Constraints	
Legal constraints	CFILs are legally binding for marketed foodstuffs. There will be legal constraints on the fate of the banned foodstuffs (see waste disposal datasheets below).
Social constraints	Retail trade/producers resistance to management option.
Environmental constraints	The fate of banned foodstuffs must be considered when food bans are introduced. Subsequent disposal of banned foodstuffs may cause a major environmental problem.
Effectiveness	
Management option effectiveness	Highly effective (up to 100%) at removing commercially produced food that is contaminated above the intervention level food from foodchain. Food contaminated below the intervention level still gets into foodchain.
Factors influencing effectiveness of procedure	Acceptability and compliance with management option.
Feasibility	
Required specific equipment	The equipment required would depend upon the radionuclide. Banning of food must be based on measured radionuclide contamination in consignments of foodstuffs produced for commercial distribution. The measurement programme would also demonstrate that the restrictions are working.
Required ancillary equipment	Additional containers and temporary storage capacity may be needed to assure that contaminated and acceptable batches of foodstuffs will not be mixed.
Required utilities and infrastructure	Extensive monitoring and surveillance programme.
Required consumables	None.
Required skills	Sufficient skilled people available to carry out the monitoring programme. Logistical experts to ensure maintenance of the food supply especially in early phase.
Required safety precautions	Radiological advice to workers (e.g. drivers bringing uncontaminated food into affected areas, monitoring personnel).
Other limitations	None.

Waste	
Amount and type	Milk, meat, eggs and crops. Long-term restrictions may also lead to slaughter and disposal of livestock from dairy producing animals.
Possible transport, treatment and storage routes	Milk may be landspread (55 Landspreading of milk and/or slurry), processed (57 Processing and storage of milk products for disposal), biologically treated (48 Biological treatment (digestion) of milk) or disposed of to sea (52 Disposal of contaminated milk to sea). Livestock carcasses may be disposed of directly by rendering (58 Rendering), incineration (53 Incineration), burial (49 Burial of carcasses) or burning on open pyres (50 Burning of carcasses). Alternatively, the carcass may be rendered and the meat and bone meal subsequently buried or incinerated at a later date. Ash would be disposed of to 54 Landfill. Crops may be ploughed in (56 Ploughing in of a standing crop), composted (51 Composting), biologically treated (47 Biological treatment (digestion) of crops), processed, landfilled (54 Landfill) or incinerated (53 Incineration). Waste products may be fed to fur producing animals since transfer to fur is negligible (although contaminated carcasses and excreta may require disposal from fur farms).
Factors influencing waste issues	Area under restrictions and duration of restrictions. Acceptability of, and compliance with, waste disposal practice. Local availability of suitable disposal routes. Legal constraints on the fate of banned foodstuffs.
Doses	
Incremental dose	None, but subsequent management of large quantities of waste crops, animal carcasses and milk will incur an additional dose. Incremental dose may be received by drivers delivering uncontaminated food.
Intervention Costs	
Equipment	Appropriate monitoring equipment to determine multiple radionuclides. Vehicles and equipment for extending distribution networks of uncontaminated foodstuffs.
Consumables	
Operator time	That associate with enforcement. That associated with sourcing alternative sources of food.
Factors influencing costs	Time and distances involved in travelling to areas under restrictions for monitoring purposes. Time and distances involved in sourcing alternative source of food.
Compensation costs	**Farmer:** for banned products. **Food industry:** for difference in costs compared to normal practices.
Waste cost	Dependent on subsequent disposal route selected for banned foodstuffs and quantities of waste produced.
Assumptions	None.

Communication needs	Likely to meet resistance from some production or retailing companies, so good stakeholder dialogue procedures will be essential. Dissemination of information about the management option its rationale and possible alternatives i.e. information explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels. Following food bans communication regarding the comparative safety of foodstuffs below intervention levels will be required, but this is likely to provide only partial reassurance. Labelling of foodstuffs with residual levels of contamination may be requested.
Side-effect evaluation	
Ethical considerations	Negative consequences for farming communities. Distribution of costs and benefits; one area may bear the economic brunt of food banning, whereas other areas benefit. The protection offered to the people would not necessarily compensate for this. Effects to consumers e.g. price increases and food shortages. Redistribution of doses from consumers to those involved in disposing of produce including individuals living close to disposal sites. If the price of 'clean' food increases in response to demand, then it is possible that poorer populations will find it harder to afford 'clean food' and there is the risk that they will resort to eating cheaper (possibly black market) contaminated food – enforcement then becomes an issue.
Environmental impact	None, although likely to be indirect environmental impacts depending on disposal route chosen for banned foodstuffs.
Agricultural impact	If predominant reason for food bans is the presence of short lived radionuclides it is likely that normal production could continue on most farms after a period sufficient for radioactive decay. If there are delays in re-stocking land, under-grazing of pasture could be a problem when animals return.
Social impact	If extensive, banning of milk, meat, eggs, crops and their derivative products may lead to market shortages and disruption of farming and the food processing industry particularly in early phase of intervention. Policing the management option and averting growth of a black market. Stigma associated with areas where the management option has been applied. Perceived contamination of all food products (and loss of confidence in crops, dairy, and meat). Potential for generating mistrust of food production systems or conversely, possible increase in public confidence that the problem of contamination is being effectively managed. Negative social and psychological impact regarding contaminated food.
Other side effects	None.
FARMING Network stakeholder opinion	Restrictions on food are generally acceptable to all stakeholder groups because if implemented quickly they will provide reassurance to the public and maintain consumer confidence in the safety of the food supplied and actions taken by authorities. Stakeholders recognised that the imposition of restrictions on the supply of food would require management options for the resulting waste foodstuffs to be well planned in advance, particularly for milk products. The current view was that disposal options were either not yet available or had very limited capacity.
Practical experience	Over a period of approximately 8 weeks following the 1957 Windscale accident, 3×10^6 l of milk contaminated with ^{131}I were disposed of from farms in an area extending to a maximum of 518 km^2 (Jackson and Jones, 1991). Condemnation of meat occurred in the fSU and Norway following the Chernobyl accident. In Norway condemned meat has been used as

	feed for fur animals.
Key references	Tveten U, Brynildsen LI, Amundsen I and Bergan T (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. *Journal of Environmental Radioactivity*, 41 (3), 233-255. Jackson D and Jones SR (1991). Reappraisal of environmental countermeasures to protect members of the public following the Windscale Nuclear Reactor accident 1957. In: Proc. of a Seminar on Comparative Assessment of the Environmental Impact of Radionuclides Released During Three Major Nuclear Accidents: Kyshtym, Windscale. Vol II. EUR 13574, 1015-1040. Commission of the European Communities, Luxembourg.
Comments	Condemnation of meat was found to be the most expensive management option in Norway after the Chernobyl accident. Because intervention limits only apply to commercial production, food bans do not fully protect the foodchain.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Radiological Protection and Research Management Division, Food Standards Agency, UK. **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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12 Selection of alternative land use	
Objective	To select crops or animals for the production of non-edible products.
Other benefits	Keeps land in production and provides income to farmer.
Management option description	Contaminated land may be used for non-food production, such as cotton/flax for fibre; rapeseed for bio-diesel; sugar beet for bio-ethanol; perennial grasses or coppice for biofuel. Agricultural land may also be used for the production of leather and wool. In extreme situations land may be used for forestry.
Target	Crops and livestock.
Targeted radionuclides	**Known applicability:** ^{134}Cs, ^{137}Cs **Probable applicability:** ^{60}Co, ^{90}Sr, ^{226}Ra **Not applicable:** The relatively short physical half-lives of the following radionuclides may preclude this radical management option: *^{89}Sr, ^{95}Nb, ^{95}Zr, ^{131}I, ^{169}Yb, ^{192}Ir* See '*comments*' for actinides.
Scale of application	Large.
Contamination pathway	Soil to plant. Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated crops, meat or milk.
Time of application	Long-term.
Constraints	
Legal constraints	External doses from non-edible products to personnel must not exceed limits. Legislation of the European Union restricts extent of various products.
Social constraints	Farmers/food industry/consumers resistance to management option.
Environmental constraints	The agricultural limitations of the affected land – this will determine the crops and practices that the land can support.
Effectiveness	
Management option effectiveness	Ingestion pathway is no longer relevant since inedible crops have replaced crops grown for the foodchain. The management option is therefore 100% effective, assuming alternative foodstuffs supplied.
Factors influencing effectiveness of procedure	Expertise in growing alternative crops and supporting different livestock. Acceptability of alternative crops or livestock to farmers. Ease of substitution of non-edible crops for farmer and associated industries. Acceptability to processors and public of using contaminated crops/animal products to make non-food products. Proof for profitability of suggested production in advance of investments. Access to other food-sources.
Feasibility	
Required specific equipment	Sowing/harvesting equipment for alternative crop type.
Required ancillary equipment	None.
Required utilities and infrastructure	Processing facilities for chosen crop/animal product.
Required consumables	Seed stock of alternative crop (availability may be limited). Stock of alternative livestock. Animal feed.
Required skills	Expertise in cultivation of alternative crop/livestock.

Required safety precautions	Consider respiratory protection for farmers if very dry conditions.
Other limitations	There must be a market for the new products.
Waste	
Amount and type	Depends on the non-food crop selected and production process. Contaminated by-products from for example the refining of rapeseed and sugar beet to bio-diesel and bio-ethanol, may be generated in processing plants. In the case of change to leather production, meat will need to be disposed of.
Possible transport, treatment and storage routes	On-site treatment plants or sewage treatment works for processing by-products.
Factors influencing waste issues	Alternative crop chosen and processing required.
Doses	
Incremental dose *Dose pathways in italics are indirectly incurred as a result of transportation of by products. There are separate datasheets that indicate the additional dose pathways arising from the management of contaminated by-products (see for example, 47 Biological treatment (digestion) of crops, 53 Incineration and 54 Landfill).*	Depends on non-food crop selected and production process. Pathways could include: **Driver:** • External exposure while transporting crops or livestock for processing. • *External exposure while transporting waste by-products to disposal site.* **Processing plant operative:** • External exposure to non-food crop at processing plant (depending on degree of automation). **Operative at wood burning power plants (from coppice):** • External exposure to the fly-ash.
Intervention Costs	
Equipment	Sowing/harvesting equipment for alternative crop type may not be available on farm and have to be hired.
Consumables	Seed. Livestock.
Operator time	Sowing/harvesting of alternative crop. Looking after new livestock. Transportation of crop or livestock to processing plant.
Factors influencing costs	Crop type. Livestock type. If new equipment is required. Training.
Compensation costs	**Farmer:** • for changes in land use on the farm • requirements for additional manpower • training and equipment • potential less economic use of land. **Processing plants:** • for accepting contaminated produce • possible decontamination of equipment.
Waste cost	Depends on by-products.
Assumptions	That there is a market for the new products. Monitoring of non-food products.

Communication needs	Farmers/operators require information on choice of crop. Dissemination of information to farmers about replacing food crops with non-food crop/livestock. Decisions on implementation need to be made by owners of the farms in the affected area. Labelling of alternative products may be required.
Side-effect evaluation	
Ethical considerations	Redistribution of dose from consumers to those involved in producing and using alternative crop and animal products. Informed consent.
Environmental impact	Change in ecosystem.
Agricultural impact	Change in crop type. Fertiliser requirements, nutrient cycling.
Social impact	Stigma/disruption to peoples' image/perception of 'countryside'. Possible loss of confidence in products. Disruption/adjustment of farming and related industrial activities/ maintenance of farming and associated communities. Alternative practices may not be as economically viable (e.g. wool and leather production versus normal animal production regimes). May impact on *public confidence* i.e.: • Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are 'safe' (may result in loss of employment in local 'cottage' industries or growth of a black market). • Increased confidence that contamination is being effectively managed.
Other side effects	Markets may be limited for alternative crop/animal products. Maintains income to the farmer. In communities affected by overproduction, diversification may be advantageous.
FARMING Network stakeholder opinion	Stakeholders unanimously agreed that alternative land use should be considered as a long-term option for areas that have to be taken out of food production. However, this rather drastic change in land management would only be acceptable under specific circumstances, as new markets for alternative products would be limited. The stakeholders favoured the use of agricultural land for biofuel production.
Practical experience	Existing commercial processes.
Key references	Alexakhin RM, Frissel MJ, Shulte EH, Prister BS, Vetrov VA and Wilkins BT (1993). Change in land use and crop selection. *Science of the Total Environment*, 137, 169-172. Vandenhove H (1999). Relevancy of short rotation coppice vegetation for the remediation of contaminated areas. Project F14-CT95-0021c (PL 960 386). Co-funded by the Nuclear Fission Safety Programme of the European Commission. RECOVER Final report 99, BLG 826. SCK.CEN, Mol, Belgium. Vandenhove H, Goor F, O'Brien S, Grebenkov A and Timofeyev S (2002). Economic viability of short rotation coppice for energy production for reuse of caesium-contaminated land in Belarus. *Biomass and Bioenergy*, 22, 421 – 443.
Comments	This management option assumes that land has been cleared of previous land use where necessary. For example, crops will have already been ploughed in (56 Ploughing in of a standing crop), composted (51 Composting) or sent for disposal. Meat-producing livestock will have been moved from contaminated land. In the event of contamination with actinides a change in land use from arable to pasture may be considered to reduce re-suspension as a

	consequence of agricultural procedures (e.g. ploughing).
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Radiological Protection and Research Management Division, Food Standards Agency, UK. **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Arapis G (Agricultural university of Athens).

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13 Application of lime to arable soils and grassland	
Objective	To reduce plant uptake of some radionuclides by addition of lime to the soil.
Other benefits	Improvement in soil fertility in some soils. Potential increase in crop yields.
Management option description	Lime may be applied to soils of low pH or low Ca status to reduce plant uptake (especially of radiostrontium). After application, treatment is most effective if land is ploughed or harrowed. It can also be applied as a top dressing to grassland.
Target	Arable soils and grassland.
Targeted radionuclides	**Known applicability:** ^{89}Sr, ^{90}Sr **Probable applicability:** ^{60}Co, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf **Not applicable:** Short half-lives of the following negate use of this management option: ^{131}I, ^{140}Ba and ^{140}La (short half-lives). Application of lime increases the mobility of: ^{75}Se, ^{95}Nb, ^{99}Mo/^{99m}Tc, ^{110m}Ag, ^{125}Sb, ^{127}Sb, ^{132}Te, ^{134}Cs, ^{137}Cs
Scale of application	Large. Areas can be identified using Geographical Information Systems (GIS) from readily available soil characteristic information.
Contamination pathway	Soil to plant.
Exposure pathway pre intervention	Ingestion of contaminated food products.
Time of application	Medium to long-term.
Constraints	
Legal constraints	Restrictions on farms with organic status. Amounts of lime that can be applied may also be limited on farms that have entered into some environmental protection schemes.
Social constraints	Public/farmers resistance to management option (depends on usual farm practice and the potential for ecosystem change/damage. If the area is, for example, a tourist area there may be resistance to a change in the ecosystem.
Environmental constraints	Lime is normally ploughed into the soil before the planting/sowing of arable crops. It may not be possible to plough or harrow soils that are excessively wet, dry or frozen without damaging soil structure. Slope/stoniness of some grassland may make it unsuitable for a tractor and spreader. Difficult to apply lime in windy conditions. Application may need to be restricted near watercourses and on flood plains – GIS could identify such areas.
Effectiveness	
Management option effectiveness	**Radiostrontium** Liming from pH 5 to pH 7 may decrease plant uptake of ^{90}Sr by 50% (factor of 2) on sandy soils, 67% (factor of 3) on loamy soils and 75% (factor of 4) on clay soils, from pH 4 to pH 6 by 83% (factor of 6) on organic soils. Liming in excess of pH 7/6 has no effect. Corrective liming lasts for at least 5 years. Maintenance liming every 5 years, to pH 7 on mineral soils and to pH 6 on organic soils, is recommended (0.5-2 tonnes CaO ha^{-1}).

Management option effectiveness (continued)	**Other radionuclides** There are no data for the effectiveness of this management option with regard to radionuclides other than Sr. However, a reduction in soil plant transfer could be expected for the other listed target radionuclides on the basis of their known chemical and environmental behaviours. **Note:** Application of lime increases the mobility of ^{75}Se, ^{95}Nb, $^{99}Mo/^{99m}Tc$, ^{110m}Ag, ^{125}Sb, ^{127}Sb, ^{132}Te, ^{134}Cs, ^{137}Cs due to change in soil pH.
Factors influencing effectiveness of procedure	Soil type and pH, cation exchange capacity, calcium status of soil. Type of lime applied (e.g. $CaCO_3$ can be more effective at changing soil pH). Whether rainfall follows lime application.
Feasibility	
Required specific equipment	Tractor with spreading device.
Required ancillary equipment	Plough or harrow.
Required utilities and infrastructure	Lime production facilities/distribution network.
Required consumables	Lime (CaO or $CaCO_3$).
Required skills	Farmers would possess the necessary skills, as this is an existing practice.
Required safety precautions	Consider respiratory protection if very dry conditions.
Other limitations	Controlled application on grasslands is needed to avoid detrimental increases in the intake of calcium by dairy cows.
Waste	
Amount and type	None – assuming applied when no standing crop, or grassland receives a top-dressing.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Farmer:** • external exposure while spreading potassium lime • external exposure, inadvertent ingestion and inhalation while ploughing.
Intervention Costs	
Equipment	Ideally 55-67 kW tractor with broadcast spreader (however, lower power tractor may be sufficient). Plough or harrow. All equipment should be available.
Consumables	Fuel (ca. 5 l ha^{-1}). Lime (1 - 8 tonnes CaO per ha).
Operator time	1 operator ca. 0.25 hr ha^{-1} (excluding loading and transport of lime).
Factors influencing costs	Repeated application may be required.
Compensation costs	To farmer for applying lime when not part of normal practice and for loss of income for non-compliance to environmental protection schemes.
Waste cost	N/A.
Assumptions	None.

Communication needs	Need for dialogue regarding selection of areas considered suitable for application of this management option especially between land owners/farmers, ecologists and public if recommended for areas not normally limed. Provision of information to farmers on appropriate application rates. Possible cost of labelling products.
Side-effect evaluation	
Ethical considerations	Self-help for farmer. Potential redistribution of dose to farmers/agricultural workers.
Environmental impact	Minimal on intensively managed arable soils as lime is routinely applied at the rates proposed. Application can change nutrient status and thus plant and animal diversity – possible changes in landscape. Grasslands are often the habitat of endangered species and a change in nutrient status may be harmful to these species. Changes in bioavailability and mobility of nutrients and pollutants may lead to effects on water quality.
Agricultural impact	Crop yield may be increased by solving acidity problems. General improvement in soil fertility. Liming prevents some diseases that attack crops. Liming may induce manganese deficiency in oats. Liming may restrict subsequent use of the land (e.g. organic farming).
Social impact	Change of ecosystem, potential environmental risks on extensively managed land. Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Liming may restrict subsequent use of the land (e.g. organic farming). Appropriate selection of priority areas for application of this management option.
Other side effects	Possible improvement of soil fertility.
FARMING Network stakeholder opinion	Of the options aimed at reducing radionuclide transfer along the soil-plant or plant-animal pathway, normal ploughing, the application of fertilisers and lime to soils, and the addition of binders or sorbents to feed were the options preferred by most stakeholders. These management options were seen to sustain farming practices and cause minimal impact on the environment. However, under some circumstances, the stakeholders recognised that the application of lime to grassland could affect animal health, which would restrict applicability.
Practical experience	Standard agricultural practice. Used widely in conjunction with NPK fertilisers in FSU following Chernobyl accident.
Key references	Nisbet AF, Konoplev AV, Shaw G, Lembrechts JF, Merckx R, Smoulders E, Vandecasteele CM, Lonjo H, Caarini F and Burton O (1993). Application of fertilisers and ameliorants to reduce soil to plant transfer of radiocaesium and radiostrontium in the medium to long term – a summary. *Science of the Total Environment*, 137, 173-182. Woodman RFM and Nisbet AF (1999). Deep ploughing, potassium and lime applications to arable land. Chilton, NRPB–M1072.
Comments	K and Mg fertilisation may be required to maintain optimal ionic equilibrium in soil and plant.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY Contributors:** Nisbet AF, Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB).

	STRATEGY peer reviewer(s): Vidal M (Universitat de Barcelona). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** n/a

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14 Application of potassium fertilisers to arable soils and grassland

Objective	To reduce plant uptake of radiocaesium by addition of potassium fertilisers to the soil.
Other benefits	Improvement in soil fertility in some soils. Potential increase in crop yield.
Management option description	Potassium fertilisers may be applied to soils of low potassium status to reduce plant uptake of radiocaesium. Potassium is applied singly or in conjunction with nitrate and phosphate fertilisers and is mixed in soil by harrowing or ploughing. Can also be applied as a top dressing to grassland.
Target	Arable soils and grassland.
Targeted radionuclides	**Known applicability:** $^{134,137}Cs$ **Probable applicability:** - **Not applicable:** -
Scale of application	Large. Areas can be identified using Geographical Information Systems (GIS) from readily available soil characteristic information.
Contamination pathway	Soil to plant
Exposure pathway pre intervention	Ingestion of contaminated food products.
Time of application	Medium to long term.
Constraints	
Legal constraints	Restrictions on the use of lime on farms with organic status. Amounts may also be limited on farms that have entered into some environmental protection schemes.
Social constraints	Public/farmers resistance to management option. This depends on usual farm practice and the potential for ecosystem change/damage. If the area is, for example, a tourist area, there may be resistance to a change in the ecosystem.
Environmental constraints	Potassium fertilisers are normally ploughed into the soil before the planting/sowing of arable crops. It may not be possible to plough or harrow soils that are excessively wet, dry or frozen without damaging soil structure. Slope/stoniness of some land may make it unsuitable for a tractor and spreader.
Effectiveness	
Management option effectiveness	Potassium is most effective when exchangeable potassium status is less than 0.5 meq $100g^{-1}$ soil. Under these conditions reduction factors of up to 5 (~80%) have been reported in the literature based on field experiments. Repeated applications of potassium may be necessary to maintain low transfer of radiocaesium. Specific effectiveness factors for soils of different potassium status are available in Woodman and Nisbet (1999).
Factors influencing effectiveness of procedure	Potassium status of the soil/soil solution. Farmers' compliance to management option, i.e. willingness to change farming practice.
Feasibility	
Required specific equipment	Tractor with spreading device.
Required ancillary equipment	Plough or harrow.

Required utilities and infrastructure	Fertiliser production facilities/distribution network.
Required consumables	Fuel, fertiliser.
Required skills	Farmers would possess the necessary skills, as this is an existing practice.
Required safety precautions	Consider respiratory protection if very dry conditions.
Other limitations	None.
Waste	
Amount and type	None – assuming applied when no standing crop, or grassland receives a top-dressing.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Farmer:** • external exposure while spreading fertiliser • external exposure, inadvertent ingestion and inhalation while ploughing.
Intervention Costs	
Equipment	All equipment should be available. Ideally 55-67 kW tractor with broadcast spreader (However, lower power tractor may be sufficient). Plough or harrow.
Consumables	Fuel (*ca.* 5 l ha^{-1}). Fertiliser as K_2O or KCl (100-200 kg K ha^{-1}), although larger applications have been made to great effect under specific scenarios previously.
Operator time	1 operator (*ca.* 0.3 hr ha^{-1}) excluding transport and loading of potassium.
Factors influencing costs	Repeated application may be required.
Compensation costs	To farmer for applying fertiliser when not part of normal practice and for loss of income for non-compliance to environmental protection schemes. Labour costs may be higher to compensate operators for exposure to radiation.
Waste cost	N/A.
Assumptions	None.
Communication needs	Dialogue regarding selection of areas considered suitable for application of this management option. Provision of information to operators on appropriate application rates. Advice may be required to dairy farmers to avoid unbalancing potassium–magnesium metabolism in livestock (from application of too much potassium). Possible cost of labelling products.
Side-effect evaluation	
Ethical considerations	*In situ* treatment of contaminated soil. Self-help for farmer. Potential redistribution of dose to farmers/ agricultural workers.
Environmental impact	Application can change nutrient status and thus plant and animal diversity – possible changes in landscape although minimal likely impact on intensively managed arable soil as potassium fertilisers are routinely applied at the rates proposed. Changes in mobility of nutrients and pollutants may lead to effects on water quality.

Agricultural impact	Assuming that this management option is carried out where soil exchangeable K is below optimum for the crop, there will be potential increase in crop yield and quality. Changes in bioavailability and mobility of nutrients and pollutants may lead to deficiencies or toxicities in plants and animals. May restrict subsequent use of the land (e.g. organic farming).
Social impact	Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged.
Other side effects	
FARMING Network stakeholder opinion	Of the options aimed at reducing radionuclide transfer along the soil-plant or plant-animal pathway, normal ploughing, the application of fertilisers and lime to soils, and the addition of binders or sorbents to feed were the options preferred by most stakeholders. These management options were seen to sustain farming practices and cause minimal impact on the environment. However, under some circumstances, the stakeholders recognised that the application of potassium to grassland could affect animal health, which would restrict applicability.
Practical experience	Routinely applied in agriculture to optimise crop yields. Used widely in conjunction with other fertilisers and lime in fSU following Chernobyl accident.
Key references	Nisbet AF, Konoplev AV, Shaw G, Lembrechts JF, Merckx R, Smoulders E, Vandecasteele CM, Lonsjo H, Carini F and Burton O (1993). Application of fertilisers and ameliorants to reduce soil to plant transfer of radiocaesium and radio strontium in the medium to long term – a summary. *Science of the Total Environment*, 137, 173-182. Smolders E, Vandenbrande K and Merckx R (1997). Concentrations of Cs-137 and K in soil solution predict the plant availability of Cs-137 in soil. *Environmental Science and Technology*, 31(12), 3432-3438. Woodman RFM and Nisbet AF (1999). Deep ploughing, potassium and lime applications to arable land, M1072, NRPB.
Comments	Potassium would normally be applied in conjunction with nitrogen (not ammonium) and phosphorus-based fertilisers. Mg fertilisation and liming may be required to maintain optimal ionic equilibrium in soil and plant. Little experience on unimproved pastures.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Vidal M (Universitat de Barcelona, Spain). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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15 Deep ploughing

Objective	To reduce radionuclide uptake by crops, including pasture.
Other benefits	Reduction in external doses from contaminated land.
Management option description	If no crop is present an ordinary single-furrow mouldboard plough can be used to invert the top 45cm of the soil profile. Much of the contamination at the surface will be buried deep in the vertical profile, which (i) will reduce radionuclide uptake by plant roots depending on their specific rooting behaviour; and (ii) reduce external exposure from the contaminants.
Target	Pasture or fallow arable land.
Targeted radionuclides	**Known applicability:** ^{90}Sr, ^{134}Cs, ^{137}Cs **Probable applicability:** ^{60}Co, ^{75}Se, ^{95}Zr, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{144}Ce, ^{192}Ir, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf **Not applicable:** This management option may increase the mobility of U. The relatively short physical half-lives (1-2 months) of the following radionuclides may preclude this radical management option: ^{89}Sr, ^{95}Nb, ^{103}Ru, ^{131}I, ^{141}Ce, ^{169}Yb
Scale of application	Large. Ploughs are often readily available, if ploughing is possible in the area. Areas suitable for ploughing could be identified using geographical information systems (GIS) and information on soil type and slope.
Contamination pathway	Soil to plant transfer.
Exposure pathway pre intervention	Ingestion of contaminated food products. External exposure from land.
Time of application	Medium to long term, provided no crop present. Ideally should be carried out as early as possible although timing is not so critical for long-lived radionuclides. If practicable, taking into account seasonal influences on farming practices, sufficient delay after contaminating deposition will reduce external doses to operators from short-lived radionuclides.
Constraints	
Legal constraints	Ploughing may be restricted under some environmental schemes.
Social constraints	Resistance to management option e.g. • topsoil burial with associated removal of flora and fauna raises wildlife issues that are likely to be contested, • contamination will be less retrievable when long-term mobility of radionuclides is not known • changes to landscape and other environmental effects.
Environmental constraints	Sandy soils are friable and may crumble during ploughing and inversion may be incomplete. Soils which are excessively wet, dry or frozen cannot be ploughed without damaging soil structure. Soil profiles must be > 0.5 m deep. Use of machinery difficult on land with >16° slope and excessively stony soils cannot be ploughed. The measure would not be acceptable in regions with thin top-soils as soil fertility and structure would be detrimentally affected.
Effectiveness	
Management option effectiveness	**Note:** this management option may result in increased mobility of U. Plant uptake reduced by up to 90% (factor of 10), averaging 50% (typically a factor of 2).
Management option effectiveness (continued)	External dose reduced by 50-95% (factors of 2-20), the highest reduction factors are for complete inversion of soil.

	Whilst observed data on the effectiveness of this measure are limited to Sr and Cs it is reasonable to expect similar reduction factors for the other targeted radionuclides as the management option results in mechanical redistribution of (contaminated) soil profile.
Factors influencing effectiveness of procedure	Efficiency of inversion of upper layer. Radionuclide distribution within soil profile after inversion. Rooting depths of different crops. Acceptability of the implementation of the management option to farmers and the public. It has been suggested that ploughing in the Chernobyl exclusion zone increased radionuclide availability, possibly due to disintegration of fuel particles.
Feasibility	
Required specific equipment	Plough (with minimum furrow width of 0.75 m).
Required ancillary equipment	Tractor (Deep ploughing requires powerful tractors e.g. 76-90 kW).
Required utilities and infrastructure	None.
Required consumables	Fuel.
Required skills	Farmers/agricultural workers are likely to possess the necessary skills but must be instructed carefully about the objectives.
Required safety precautions	Consider respiratory protection if very dry conditions.
Other limitations	High ground water level. Dose limits for farmers/agricultural workers.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Farmer:** external exposure, inadvertent ingestion and inhalation while ploughing.
Intervention Costs	
Equipment	Tractor (76-90 kW) may not be available on farm and will need to be hired. Single furrow plough should be available.
Consumables	Fuel (ca. 15 l ha^{-1}).
Operator time	1 operator per plough: 0.2 man-days ha^{-1}, i.e. 1.5 h ha^{-1}
Factors influencing costs	Work rates vary depending on soil type and conditions, field size and shape, topography and operator experience.
Compensation costs	**Farmer:** • loss of income for non-adherence to conservation schemes • for implementing management option. Labour costs may be higher to compensate operators for exposure to radiation.
Waste cost	N/A.
Assumptions	None.

Communication needs	Farmers/operators require information on this management option (i) for areas of land not normally ploughed; (ii) when ploughing is to be undertaken at non-standard times of the year. Need for dialogue regarding selection of areas for treatment. Need dialogue between farmers, ecologists and public because of potential for groundwater contamination. Dialogue regarding selection of areas considered suitable for application of this management option and to clarify the costs and benefits to farmers before decisions on implementation are made. Provision of information to operators on correct application of procedure.
Side-effect evaluation	
Ethical considerations	*In situ* treatment of contaminated soil. Self-help for farmer. Potential redistribution of dose to farmers and agricultural workers. Free informed consent and compensation for operators.
Environmental impact	The procedure imposes environmental risk i.e. brings contamination closer to the groundwater which may lead to transfer of radionuclides to other areas and affect other populations. Severely complicates subsequent removal of the contamination. Biodiversity could be affected, particularly for soil dwelling organisms. Long term changes in physical characteristics and structure of the surface horizon e.g. enhanced mineralisation of organic matter, change of nutrient loading and soil erosion. Changes in landscape.
Agricultural impact	Field drainage systems destroyed. Soil fertility markedly reduced – fertilisation may be required. Future restriction on land use: must not be deep tilled although subsequent normal ploughing (to *ca*. 25 cm) will not bring much contamination back to the surface.
Social impact	Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Contamination of soil at depth may restrict subsequent uses (e.g. tourism). Stigma associated with food products where the management option has been applied. May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products from affected areas is 'safe' (resulting in loss of employment in local 'cottage' industries or growth of a black market), • increase public confidence that the problem of contamination is being effectively managed.
Other side effects	
FARMING Network Stakeholder opinion	Stakeholder opinion on the acceptability of deep ploughing and skim and burial ploughing was divided. Deep ploughing was considered to affect soil fertility adversely and cause changes in biodiversity, particularly in soils not normally ploughed. The limited availability of powerful tractors in some parts of Europe would further limit the general applicability of deep ploughing. The issue of irretrievability of the contamination following either deep ploughing or skim and burial ploughing was a cause for concern among a minority of stakeholders who felt that the burial of radionuclides at depth could in time lead to horizontal and vertical migration within the soil, which was deemed unacceptable.
Practical experience	Used widely in fSU as a management option following the Chernobyl accident. Tested on a limited scale in Denmark.

Key references	Maubert H, Vovk I, Roed J, Arapis G and Jouve A (1993). Reduction of soil-plant transfer factors: mechanical aspects. *Science of the Total Environment*, 137, 163-167. Vovk IF, Blagoyev VV, Lyashenko AN and Kovalev IS (1993). Technical approaches to decontamination of terrestrial environments in the CIS (former USSR). *Science of the Total Environment*, 137, 49-63.
Comments	Deep ploughing should not be carried out again otherwise effectiveness of this management option would be markedly reduced.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD, UK); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Brechignac F (Institute for Radioprotection and Nuclear Safety, France). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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16 Early removal of crops

Objective	To reduce contamination of arable land and its products.
Other benefits	Reduction of external dose from land.
Management option description	Radionuclides may be retained on the surface of growing crops immediately after fallout. The transfer of this contamination to the soil may be minimised by removing such crops from the land as soon as possible after deposition and ideally before the first rainfall. The crops require disposal.
Target	Dense/leafy crops.
Targeted radionuclides	**Known applicability:** ^{60}Co, ^{75}Se, ^{89}Sr, ^{90}Sr, ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf **Probable applicability:** **Not applicable:** The relatively short physical half-lives (1-2 months) of the following radionuclides may preclude this management option as they will not represent a problem when the subsequent years crops are harvested ^{75}Se: ^{89}Sr, ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{131}I, ^{141}Ce, ^{169}Yb and ^{192}Ir
Scale of application	Large (assuming alternative livestock feed could be obtained).
Contamination pathway	Plant -soil
Exposure pathway pre intervention	Ingestion of contaminated crops. External irradiation from arable land.
Time of application	Early phase - as soon as possible after deposition and prior to subsequent rainfall.
Constraints	
Legal constraints	There will be legal constraints on the disposal of harvested crops. Welfare of animals may prevent large scale application if sufficient supply of uncontaminated feed is not available.
Social constraints	Farmers' resistance to the management option. Potential for dispute regarding the selection of areas for disposal.
Environmental constraints	The fate of harvested crops must be considered before management option is introduced. Subsequent disposal may cause a major environmental problem. There will be environmental constraints if crops are composted, sent to landfill or incinerated.
Effectiveness	
Management option effectiveness	Reduction of external dose on contaminated fields may be up to 95% (factor of 20), although 50-70% (factors of 2-4) is more likely. Greatest effectiveness is before first rainfall and if irrigation systems are closed. Experiments (Vandecasteele *et al.*, 2001) have shown that the first simulated rain, applied 6 days after contamination, removed around 50% of the intercepted radiocaesium and around 20% of radiostrontium from aerial parts of spring wheat.
Factors influencing effectiveness of procedure	Interception of radionuclide aerosols is dependent on the amount of biomass present at the time of deposition. A dense crop can intercept 25-50% of wet deposition and more if deposited as an aerosol. Occurrence of rainfall. Weather conditions. Farmers' compliance to the management option.

Factors influencing effectiveness of procedure (continued)	Time between deposition and harvest of the crops – in general the half-time of loss of contamination on undisturbed vegetation is 2-4 weeks; for ^{131}I, half-lives of less than one week were observed in Finland in May 1986. Acceptability of disposal options to other stakeholders especially if transported to uncontaminated areas. Fast decisions on the purchase of uncontaminated feed for farms in fallout area would support well timed implementation of the measure.
Feasibility	
Required specific equipment	Forage or combine harvester.
Required ancillary equipment	Tractor.
Required utilities and infrastructure	Collection and transportation of crops once harvested. Storage and disposal facilities.
Required consumables	Fuel.
Required skills	Farmers and agricultural workers would have the required skills, but must be instructed carefully about the objectives.
Required safety precautions	Consider respiratory protection if very dry conditions. Radiation risks to workers have to be communicated to them in advance.
Other limitations	Dose limits for farmers/agricultural workers.
Waste	
Amount and type	Contaminated crops: the amount will depend on stage of development. The management option will be most effective when the crops are near maturity (i.e. dense and leafy).
Possible transport, treatment and storage routes	Crops may be composted (51 Composting) in situ or at commercial facilities or disposed of to landfill (54 Landfill) or incinerated (53 Incineration). Alternatively, crops may be processed into a form suitable for storage and subsequent disposal. It is also possible, but unlikely, that crops could be processed for subsequent consumption (18 Processing of crops for subsequent consumption).
Factors influencing waste issues	Legal constraints on the fate of contaminated crops. Level of contamination of crops. Storage characteristics of crops. Volume of waste. Acceptability of subsequent waste disposal option.
Doses	
Incremental dose *Incremental doses will be incurred from the disposal of harvested crops either via composting, landfill, incineration see links above) or by 47 Biological treatment (digestion) of crops.*	**Farmer:** external exposure, inadvertent ingestion and inhalation while harvesting crops. **Driver:** external exposure while transporting harvested crops to place of disposal.
Intervention Costs	
Equipment	Minimal. Forage or combine harvesters should be readily available on the farm or could be shared.
Consumables	Fuel (*ca* 15 l ha^{-1})
Operator time	Normal time to harvest crop. Additional time depending on subsequent management of harvested crop. Transportation of crop.
Factors influencing costs	Time and distance involved in transporting crop to processing or disposal site.

Compensation costs	To farmer for loss of income from crop. To farmer if crop is composted *in situ*.
Waste cost	Dependent on subsequent disposal route selected for harvested crops and quantities of waste produced.
Assumptions	None.
Communication needs	Immediate dialogue/information regarding selection of areas for treatment. Communication of radiological protection information to workers. Dialogue on disposal options.
Side-effect evaluation	
Ethical considerations	Redistribution of dose from consumers to farmers implementing the management option, to those involved with disposal of produce including populations living close to disposal sites. Self-help for farmers. Free informed consent of workers.
Environmental impact	Dependent on subsequent disposal route chosen for harvested crops.
Agricultural impact	Disruption to farming activities. Harvesting of crops at or close to maturity is a normal agricultural practice – no additional impact.
Social impact	Disruption to the supply of crops to food industry and possible market shortages.
Other side effects	None.
FARMING Network stakeholder opinion	The stakeholder groups did not consider wide scale application of this option to be generally acceptable. Could be used under specific circumstances (i.e. mature leafy crops removed soon after deposition to stop subsequent transfer to soil), but in general the infrastructure for dealing with the subsequent waste arising could be limited.
Practical experience	Lettuce was removed (and ploughed in) in Norway after the Chernobyl accident to avoid human consumption.
Key references	Vandecasteele CM, Baker S, Forstel H, Muzinsky M, Millan R, Madoz-Escande C, Tormos J, Sauras T, Schulte and Colle C (2001). Interception, retention and translocation under greenhouse conditions of radiocaesium and radiostrontium from a simulated accident source. *Science of the Total Environment*, 278, 119-214.
Comments	
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Liland A, Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer:** Brechignac F (Institute for Radioprotection and Nuclear Safety, France). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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17 Land improvement

Objective	To reduce activity concentrations of radionuclides in animals grazing unimproved pasture.
Other benefits	Reduction in external dose from contaminated land.
Management option description	Improvement of poorer quality pasture reduces uptake of radiocaesium and radiostrontium. Improvement involves ploughing, rolling, reseeding and the application of NPK fertilisers and lime. Application of a broad spectrum herbicide prior to ploughing is recommended to destroy the existing vegetation. In some cases, drainage may be required. If only small areas are improved, fencing may also be necessary to prevent livestock grazing unimproved land.
Target	Unimproved pasture.
Targeted radionuclides	**Known applicability:** ^{90}Sr, ^{134}Cs, ^{137}Cs **Probable applicability:** ^{60}Co, ^{75}Se, ^{95}Zr, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{144}Ce, ^{192}Ir, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf **Not applicable:** Application of lime increases the mobility of: ^{75}Se, ^{95}Nb, $^{99}Mo/^{99m}Tc$, ^{110m}Ag, ^{125}Sb, ^{127}Sb, ^{132}Te Ploughing may increase the mobility of U. The relatively short physical half-lives (1-2 months) of the following radionuclides may preclude this radical management option: ^{89}Sr, ^{95}Nb, ^{103}Ru, ^{131}I, ^{141}Ce, ^{169}Yb.
Scale of application	Medium scale. Improvement of pasture should be possible on farms where suitable land is available.
Contamination pathway	Soil to plant.
Exposure pathway pre intervention	Ingestion of contaminated animal products.
Time of application	Medium to long term.
Constraints	
Legal constraints	Unimproved pastures may be within environmentally protected areas. Some practices (e.g. NPK, herbicides) might be unsuitable for use on farms with organic status.
Social constraints	If the area is perceived to be 'natural' there may be resistance to change the ecosystem and landscape. Resistance of farmer to change farming practice.
Environmental constraints	Areas of pasture with steep slopes and shallow or stony soils mean that some areas cannot be ploughed or drained. Physical characteristics that determine if a soil can be cultivated are: Slope < 12º cultivation possible Slope 12-16º some limitations Slope > 16º unsuitable for cultivation (using normal farm machinery) Depth < 0.3m unsuitable for ploughing Depth 0.3-0.5 shallow ploughing only Depth > 0.5m skim and burial/deep ploughing possible. At certain times of the year the ground is too wet for ploughing.
Effectiveness	
Management option effectiveness	**Radiocaesium** This management option was used extensively in the fSU after Chernobyl and is referred to as radical improvement. Several studies have shown that reduction factors for soil-plant transfer of radiocaesium following radical improvement, liming and fertilisation were in the range:

	Mineral soils = 2-4 (50-75%), Organic soils = 3-6 (67-83%), External dose reduction = 95% Reduction factors for soil-plant transfer of radiostrontium following discing, ploughing and reseeding were in the range 2-4 (50-75%), in the second year after treatment. **Radiostrontium** Data on the effectiveness of 'radical improvement' of 'natural meadows' is available from the fSU. Reduction factors in the range 3-6 being observed for mineral soils and 3-10 for organic soils. **Other Radionuclides** There are no data for the effectiveness of this management option with regard to radionuclides other than Cs and Sr. However, a reduction in soil plant transfer could be expected for the other listed target radionuclides on the basis of their known chemical and environmental behaviour. **Note:** (1) Application of lime increases the mobility of ^{75}Se, 75Se, ^{95}Nb, ^{99}Mo/^{99m}Tc, ^{110m}Ag, ^{125}Sb, ^{127}Sb, ^{132}Te due to change in soil pH. (2) Ploughing may result in increased mobility of U.
Factors influencing effectiveness of procedure	Soil type, nutrient status and pH. Plant species selected for reseeding. Application rates of NPK and lime. Implementation of draining. Willingness and ability of farmers to adapt to a new land management regime. It has been suggested that ploughing in the Chernobyl exclusion zone increased radionuclide availability possibly due to disintegration of fuel particles.
Feasibility	
Required specific equipment	Tractor, plough, fertiliser spreader, seeder, roller.
Required ancillary equipment	Fencing and drainage equipment (e.g. digger) may be required.
Required utilities and infrastructure	Fertiliser/lime production facilities. Access to road network in remote areas. Spare land on the farm to graze livestock while improvements are carried out.
Required consumables	Fuel, NPK fertilisers, lime, grass seed, herbicide (e.g. Glyphosate). May also require consumables associated with fencing and drainage operations.
Required skills	Agricultural workers/farmers would possess the necessary skills as these are existing practices but must be instructed carefully about the objectives.
Required safety precautions	Consider respiratory protection if very dry conditions.
Other limitations	None.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Farmer:** • external exposure, inadvertent ingestion and inhalation while ploughing • external exposure while rolling, reseeding, fertilising.

Intervention Costs	
Equipment	Tractor, mouldboard plough, sprayer, roller, fertiliser spreader, seeder and digger.
Consumables	Variable depending upon soil type and conditions, example values for improvement of upland pasture in the UK: 26 kg ha^{-1} grass seed, 70 kg ha^{-1} N fertiliser, 80 kg ha^{-1} P fertiliser, 80 kg ha^{-1} K fertiliser, 7.5 t ha^{-1} lime, 6 l ha^{-1} herbicide (e.g. Glyphosate), 7 l ha^{-1} fuel. Improvement of pastures is typically maintained on a rolling programme with NPK applied annually, lime every 5 years and land re-improved after 5-10 years.
Operator time	Variable depending upon soil type and conditions, example values for improvement of upland pasture in the UK: 1.6 h ha^{-1} ploughing, 1.3 h ha^{-1} rolling, 0.7 h ha^{-1} broadcasting seed, 0.4 h ha^{-1} broadcasting fertiliser. Installing fences. Carrying out drainage.
Factors influencing costs	Work rates vary depending on soil type and conditions, topography and operator experience. Requirements for drainage and fencing.
Compensation costs	**Farmer:** • for additional forage if required whilst improvements are being carried out. • for loss of income for non-adherence to conservation schemes. • for loss of organic farming status if improvements carried out. Labour costs may be higher to compensate operators for exposure to radiation.
Waste cost	N/A.
Assumptions	All infrastructure listed in feasibility is available.
Communication needs	Need for dialogue regarding selection of areas for treatment, between land owners/ farmers, ecologists and public.
Side-effect evaluation	
Ethical considerations	*In situ* treatment of contaminated soil. Self-help for farmer, although dependent on resources. Potential redistribution of dose from consumers to farmers/agricultural workers (although overall external doses to workers may be reduced compared to if land managed without application of this management option).
Environmental impact	Potentially high environmental risk from change of ecosystem. Ploughing, application of herbicides and fertilisers and reseeding would change the ecology of the land and biodiversity would be lost. Ploughing may lead to soil erosion. A significant increase in NPK application can lead to pollution of ground and surface waters. Erection of fencing and gates has a visual and amenity impact. Contamination will be moved closer to the water table possibly resulting in enhanced contamination of ground water.
Agricultural impact	Higher productivity of grassland. Improved grazing on farm leading to greater feed availability. Additional stock may be required to prevent undergrazing and maintain the areas of improved land. Alternatively, grass could be cut for use as stored feed. If improvement is carried out on a rolling programme there should be no significant loss of grazing. Fertilisation and liming may restrict subsequent use of the land (e.g.

	organic farming).
Social impact	Disruption to farming and other related activities (although farmer will have more improved pastures in the long term). Farmers may be unhappy with the adjustments they have to make. Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Knock-on effects for public use of amenity. May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products is 'safe' (may i.e. result in loss of employment in local industries or growth of a black market) • increased confidence that the problem of contamination is being effectively managed.
Other side effects	Availability of additional improved grazing can reduce wintering costs and result in higher prices for improved stock.
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	Radical improvement carried out in former Soviet Union after the Chernobyl and Kyshtym accidents.
Key references	Vidal M, Camps M, Grebenshikova N, Sanzharova N, Ivanov Y, Vandecasteele C, Shand C, Rigol A, Firsakova S, Fesenko S, Levchuk S, Cheshire M, Sauras T and Rauret G (2001). Soil-and-plant based countermeasures to reduce ^{137}Cs and ^{90}Sr uptake by grasses in natural meadows: the REDUP project. *Journal of Environmental Radioactivity*, 56: 139-156. Nisbet AF and Woodman RFM (1999). Options for the Management of Chernobyl-restricted areas in England and Wales. NRPB-R305. Wilkins BT, Nisbet AF, Paul M, Ivanov Y, Perepelyatnikova L, Perepelyatnikova G, Fesenko S, Sanzharova N, Spiridinov S, Lisyanski B, Bouzdalkin C and Firsakova S (1996). Comparison of data on agricultural countermeasures at four farms in the former Soviet Union. NRPB-R285.
Comments	NPK application rates traditionally used on agricultural lands may not be sufficient to maximise decrease in radiocaesium transfer to re-seeded pastures.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD, UK). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Vidal M (Universitat de Barcelona, Spain). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** Fersenko S (IAEA).

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18 Processing of crops for subsequent consumption	
Objective	To process contaminated crops to produce final food products with activity concentrations less than intervention limits.
Other benefits	Maintenance of agricultural production systems and provision of foodstuffs to consumers.
Management option description	Commercial food processing, such as washing, peeling, fermentation, distillation, blanching and canning, may achieve some reductions in the activity concentration of some processed foodstuffs. Storage of processed products will be effective for radionuclides with short physical half lives.
Target	Crops including fruits.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Small to medium.
Contamination pathway	n/a
Exposure pathway pre intervention	Ingestion of contaminated crops including fruits.
Time of application	Early to long term.
Constraints	
Legal constraints	The sale of crops intended for human consumption is subject to Council Food Intervention Limits (CFILs).
Social constraints	Public/farmers resistance to management option
Environmental constraints	None.
Effectiveness	
Management option effectiveness	The removal of inedible parts, washing and blanching are processes commonly applied prior to canning. Washing has been shown to remove between 10 % and >90 % or a range of radionuclides (including Ru, I, Sr, Cs, Am, Pu) from vegetables. In general more than 50% of radiocaesium contamination is removed during blanching or boiling. Following canning additional decontamination (~50%) occurs via transfer from product to canning solution during storage. For fruits that are consumed raw, rinsing has some effect in removing both fresh deposition and soil contamination. In general, 10-20% of Cs and Sr contamination is removed by rinsing (grapes, redcurrants, blackcurrants, lingberries, strawberries). Rinsing apples three times removed about 60% of Cs and Sr one day after deposition. In general, 30-40% of Cs and 94% of Sr contamination is removed by various techniques of juice production (pressing, pectolytic enzymation, liquefaction and extraction). Stewing (discarding juice) causes 30% reduction in radiocaesium. The reduction of radiocaesium and radiostrontium contamination by lye peeling (dipping in a hot 7-18 % KOH (lye) solution) of peach is variable, lying between 30 and 97%. Mechanical peeling of peach reduces radiocaesium contamination by 50%. Whilst there are no data for the effectiveness of food processing measures for some of the target radionuclides listed it is likely that some of the measures will be effective (e.g. washing or boiling). Alcoholic processing removes an important part of the radioactive contamination of grapes, depending on the purity of the final product, i.e.: Cs is reduced by 40% in red wine, by 30-85% in rosé wine and by 70% in white wine. Sr is reduced by 40% in red wine and by 80% in rosé wine. Pure alcohol is completely decontaminated from both radionuclides.

Management option effectiveness (continued)	Polishing of rice removes 90% of the Cs and 80 % of the Sr of the raw product. Pressing of olives into cake and oil removes 60% and 90% of Cs contamination, respectively.
Factors influencing effectiveness of procedure	Process selected, radionuclide(s) present, time lag between deposition and processing, texture of crop surface (rough and leafy will make decontamination more difficult), quantity of external edible parts of crop, storage time, volume of canning solution. Food industry/retailers compliance to processing contaminated crops.
Feasibility	
Required specific equipment	Processing plant, storage facilities for food products (for short-lived radionuclides).
Required ancillary equipment	Vehicles to transport food.
Required utilities and infrastructure	Waste treatment facilities for disposal of contaminated by-products.
Required consumables	Fuel for vehicles.
Required skills	Operators at processing plants will have the required skills.
Required safety precautions	None.
Other limitations	Availability of processing plants if there is a reluctance to move contaminated raw materials to a plant located outside an affected area. Capacity of processing plants to accept additional raw materials (i.e. crops).
Waste	
Amount and type	Food processing residuals (i.e. materials remaining after processing of primary products, such as peel and foliage). Large volumes of water and salt from blanching and boiling processes. Following canning additional decontamination occurs via transfer from the product to the canning solution during the storage period.
Possible transport, treatment and storage routes	Water containing radioactivity and salt may be handled at processing plant or held in a treatment pond. Solid residuals such as peel, foliage etc. may be converted to useful by-products depending of the type of residual. Alternatively, they could be incinerated (53 Incineration) at the processing site or disposed of to landfill (54 Landfill).
Factors influencing waste issues	Depends on crop type and type of processing selected. Legal constraints on the fate of contaminated crops. The high moisture content and readily putrescible nature of the food residuals means that waste treatment cannot be delayed.
Doses	
Incremental dose *Dose pathways in italics are indirectly incurred as a result of transportation of waste by products. Additional doses will be incurred from disposal of these wastes either at landfill sites or incinerators. There are separate datasheets for these waste disposal options. Any waste water generated during processing may be sent to a sewage treatment works.*	**Driver:** • external exposure while transporting crops to processing plant • *external exposure while transporting waste by-products to place of disposal.* **Operative at food processing plant:** • external exposure at processing plant (depending on degree of automation).
Intervention Costs	
Equipment	Minimal. Processing equipment is already available.
Consumables	Any additional processing consumables. Fuel for transportation.
Operator time	Drivers for transporting contaminated crop to process plants. Operators at processing plants if additional manpower required.

Factors influencing costs	Distance to processing plant, quantities of crops for processing.
Compensation costs	**Processing plants:** • for handling contaminated produce. **Farmers:** • if there is a loss in market value for processed crops • possible decontamination of processing equipment.
Waste cost	Dependent on subsequent disposal route for contaminated by-products.
Assumptions	That there is a market for the end product. That appropriate monitoring is carried out at processing plant.
Communication needs	Information/dialogue with industry and consumers to explain rationale of management option. Information to industry on handling of wastes. Labelling treated products.
Side-effect evaluation	
Ethical considerations	Informed consent. Distribution of costs and benefits (e.g. possible inequity due to change in prices of processed crops with lower income populations buying the treated food).
Environmental impact	None, although there could be an indirect environmental impact depending on disposal route chosen for by-products.
Agricultural impact	None.
Social impact	May impact on *public confidence* e.g.: Loss of confidence that farm produce and derivative products. Increased confidence that the problem of contamination is being effectively managed. Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade when foodstuffs can be obtained from other sources. Disruption/adjustment of farming and related industrial activities, i.e. the supply of crops to food industry and potential for market shortages. Maintenance of farming and associated communities.
Other side effects	Parts of the processing plant may become contaminated.
FARMING Network stakeholder opinion	Stakeholders unanimously agreed that there are no processing options that can be considered as generally acceptable. Options involving removal of contamination from crops, milk and meat during industrial processing were viewed by some stakeholders to be acceptable under specific circumstances. However, in countries where consumer confidence has been seriously affected by previous food scares (e.g. UK and Belgium) any process that produces marketable food from contaminated raw materials was considered to be unacceptable.
Practical experience	
Key references	BIOMASS. (2003). Modelling the transfer of radionuclides to fruit, Report of the Fruits Working group of BIOMASS Theme 3, IAEA-BIOMASS-5, Vienna, ISBN 92-0-106503-5. Green N and Wilkins BT (1995). Effects of processing on radionuclide content of foods: derivation of parameter values for use in radiological assessments. NRPB-M587. Green N (2001). The effect of storage and processing on radionuclide content of fruit. *Journal of Environmental Radioactivity*, 52, 281-290.

Key references (continued)	Katsuyama AM (ed.) (1979). A guide for waste management in the food processing industry. The Food Processors Institute, Washington, DC. Long S, Pollard D, Cunningham JD, Astasheva NP, Donskaya GA and Labetsky EV (1995). The effects of food processing and direct decontamination techniques on the radionuclide content of foodstuffs: a literature review. Part 2: Meat, fruit, vegetables, cereals and drinks. *Journal of Radioecology*, 3 (2), 15-38.
Comment	The need for measures that assure acceptable foodstuffs derived from standing crops at the time of deposition is obviously only a priority for the first harvest. In milling industry, adjusting milling yield is possible to remove the most contaminated fraction of cereal grains that is not delivered for human consumption etc. A separate datasheet (40 Dietary advice) considers provision of self-help information to the public on how radionuclide intake can be minimised including household food preparation. Processing to products with a long shelf-life may also be considered for meat contaminated with short-lived radionuclides.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer:** Pollard D (Radiological Protection Institute of Ireland). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** Arapis G (Agricultural university of Athens).

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19 Pruning / defoliation of fruit trees and vines

Objective	To prevent, or reduce, the translocation of radionuclides from shoots and leaves to fruit of perennial plants.
Other benefits	Possible reduction in deposition to soil.
Management option description	If deposition occurs when trees are in leaf, foliar interception, retention and absorption of radionuclides are the dominant processes of contamination for fruit bearing plants. Following uptake by leaves, radionuclides can be translocated to fruits and other parts of the plant. The extent to which translocation occurs depends on the radionuclide, the fruit tree species, and the phenological stage of the plant at the time of deposition. There is experimental evidence that pruning and/or defoliation by chemical, mechanical or manual methods soon after deposition can prevent or reduce the translocation of radionuclides from leaves to the other plant components and reduce the internal dose to man from ingestion of contaminated fruit. Before practical implementation of this management option could be advised more work would be required. Pruning may involve the loss of the current years crop to achieve lower radionuclide activity concentrations in subsequent years fruits.
Target	Fruit trees and vines.
Targeted radionuclides	**Known applicability:** $^{134/137}Cs$ **Probable applicability:** ^{60}Co, ^{90}Sr **Not applicable:** Short half-lives of the following negate use of this management option: ^{75}Se, ^{89}Sr, ^{95}Nb, ^{95}Zr, $^{99Mo/99m}Tc$, ^{103}Ru, ^{127}Sb, ^{131}I, ^{132}Te, ^{140}Ba, ^{140}La, ^{141}Ce, ^{169}Yb, ^{192}Ir
Scale of application	Can be carried out on a large scale where equipment/workers are or can be made available.
Contamination pathway	Direct deposition onto fruit trees. Translocation from shoots and leaves to fruit. Plant-to-soil transfer.
Exposure pathway pre intervention	Ingestion of contaminated fruit. External exposure from trees and soil.
Time of application	Should generally be carried out as early as possible (and, to prevent wash-off to soil, ideally before the first rainfall).
Constraints	
Legal constraints	Waste disposal (chemical and radioactive).
Social constraints	Farmers/operators resistance to carry out procedure
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Total defoliation of vines soon (within a few hours) after deposition of radiocaesium, reduces fruit activity by approximately 90%. Partial defoliation 2 days after deposition yields a reduction of radiocaesium in grapes by approximately 50%. The activity of grapes in the second year after deposition is *circa* 2-3 orders of magnitude lower than in the first year.
Factors influencing effectiveness of procedure	Whether or not trees are in leaf at time of deposition (season). Rainfall (between deposition and implementation of the measure) may remove contamination to the soil thereby reducing the effectiveness of this measure in minimizing soil contamination. Whilst this will decontaminate leaves (reducing the activity available for foliar absorption) it may also enhance the degree of absorption.

Factors influencing effectiveness of procedure (continued)	Time lag between deposition and implementation of the management option. Degree of pruning/defoliation. Nature of the trees (evergreen or deciduous): defoliation can not be carried out on evergreen species. Appropriate selection of priority areas. Preparedness and availability of technical staff for implementation. Acceptability of disposal/treatment procedures.
Feasibility	
Required specific equipment	**Mechanical pruning:** • topping or hedging machines • tools for collecting prunings (blowing machines etc.). **Hand pruning:** • shears and loppers. **Defoliation:** • desiccants • sprinklers.
Required ancillary equipment	Waste transport truck (or other means of transport) to repository. Dedicated sites and machinery for further treatment (incineration or composting) etc.
Required utilities and infrastructure	Dedicated sites for waste treatment.
Required consumables	Chemical dessiccants (copper sulphate, zinc sulphate) for defoliation.
Required skills	Required skills likely to be present in the farming community.
Required safety precautions	Respiratory protection and protective clothes may be recommended. Safety helmets.
Other limitations	n/a
Waste	
Amount and type	Potentially large volumes, depending on the size of the contaminated area, the vegetative stage and the degree of pruning/defoliation.
Possible transport, treatment and storage routes	Transport by e.g. trucks or rail to off-site treatment. Woody wastes could be reduced by composting (51 Composting); the effectiveness of which would be increased by pre crushing and mixing with other matter such as animal waste or paper. Alternatively, waste could be incinerated (53 Incineration), with recovery of ashes or disposed of to landfill (54 Landfill).
Factors influencing waste issues	Public acceptability and legal feasibility of waste treatment and storage route are essential.
Doses	
Incremental dose	**Farmers:** • during management option implementation and waste treatment. **Drivers and operatives:** • if generated waste is treated at off-site processing plants Influenced by measures taken to protect operators against risks such as inhalation and contamination of skin/clothes and by the time of implementation of the management option (due to the influence of short lived radionuclides).
Intervention Costs	
Equipment	Topping or hedging machines. Waste transport/ treatment equipment (variable).
Consumables	Fuel for all relevant machinery (e.g. pruning machines)

Operator time	Highly variable. Farmer for pruning/defoliation. Drivers for transporting waste to processing (incineration /composting) sites. Operatives at processing plants.
Factors influencing costs	Season, vegetation height, type of vegetation to be removed. Degree of removal, applied equipment type. Availability of equipment. Waste disposal scheme.
Compensation costs	**Farmers:** • for implementing management option • loss of income if crop lost or reduced (may persist for a number of years). **Processing plants for handling waste:** • possible need for decontamination of mechanical equipment used in pruning/defoliation • transport of waste.
Waste cost	Depends on the waste disposal method. Pre-treatment of waste to reduce their volume could greatly reduce costs.
Assumptions	Availability of the required equipment and roads. Availability of a market for the final products.
Communication needs	Provision of information for wholesalers/processors on management option and local dialogue with farmers regarding implementation to ensure acceptability of selection process for areas where the management option is applied. The short time available may preclude extensive stakeholder consultation, thus making it difficult to satisfy conditions of informed consent from operators. Potential for dispute regarding selection of management options. Need for public information of the management option aims and consequences.
Side-effect evaluation	
Ethical considerations	Free informed consent of workers (to risks of radiation exposure and/or chemical exposure). Re-distribution of dose to workers and waste disposal facilities. Inequitable distribution of costs and benefits.
Environmental impact	Environmental risk and uncertainty over expected outcomes and consequences of waste generation and treatment (chemical and radioactive). High volume of generated wastes. Substantial visual impact on landscape.
Agricultural impact	Great stress for the trees after total defoliation. Potentially significant decrease in subsequent years' productivity. Possible plant mortality.
Social impact	Stigma associated with areas and perceived contamination of products where the management option has been applied. May impact on *public confidence* i.e. • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may result in loss of employment in local industries or growth of a black market) • increase confidence that the problem of contamination is being effectively managed.
Social impact (continued)	Disruption to farming/industry and other related activities. Acceptability of future crops to food industry/consumers – needs to be a

	market for the produce in following years.
Other side effects	Mechanical tools used in management option implementation may become contaminated.
FARMING Network stakeholder opinion	Not considered by FARMING Network
Practical experience	Manual or mechanical pruning is a normal practice to shape the plant, obtain a constant yield and improve fruit quality. Defoliation is usual for peach trees and vines and is less frequently used for apple, pear and cherry trees.
Key references	Carini F (1999). Radionuclides in plants bearing fruit: an overview, *Journal of Environmental Radioactivity*, 46: 77-97. Carini F (2001) Radionuclide transfer from soil to fruit*, Journal of Environmental Radioactivity*, 52 237-279. Carini F (2003). Countermeasures for fruits. FAO/IAEA Workshop, 27-29/9/2003, Chania, Greece. Modelling the transfer of radionuclides to fruit, Report of the Fruit working group, BIOMASS Theme 3, IAEA-BIOMASS-5, Vienna, 2003. ISBN 92-0-1065035. Madoz-Escande C, Colle C and Adam C (2001). Evolution of Caesium and Strontium contamination deposited on vines*, Actes du congrès ECORAD*, 2001.
Comments	After foliar absorption, the translocation from leaves to other plant parts is rapid for caesium, while the rather immobile strontium tends to remain to the part of the plant to which it was initially applied. The degree of translocation from leaf to fruit varies between species; post Chernobyl observations demonstrated a greater leaf to shoot transfer for grapes and peaches compared to apples and pears. The period between primary deposition and harvest has a significant effect on translocation. Radionuclide uptake by roots of perennial (woody) plants, in the acute phase, is usually minimal only becoming important with time. Studies on the distribution of radionuclides within different components of fruit bearing species provide some evidence that leaves and growing shoots act as accumulation organs for strontium. However, the foliar uptake of strontium constitutes no major risk to the consumer of fruit or other edible parts of the plant, provided that no direct contamination of these food items has taken place. Experimental results suggest that radiocaesium, once introduced into the plant, can be retracted from leaves at autumn into perennial organs of deciduous fruit trees, mainly wood and roots, and translocated the next spring towards leaves, annual shoots and fruits. However, only a small fraction of the plant radiocaesium inventory is available for translocation and the process depends on a variety of factors, such as the fruit species, the vegetative stage at the time of deposition, the age of the contaminated part, the soil and plant radiocaesium reservoir etc. More work would be required before implementation of this measure could be advised.
Document History	**STRATEGY originator:** n/a **STRATEGY contributors:** n/a **STRATEGY peer reviewer(s):** n/a **EURANOS originator:** IRSN (Reales N and Gallay F) and UoI (Papachristodoulou C and Ioannides K). **EURANOS contributors:** UMB (Oughton D and Bay I) initiated social, ethical and communication inputs; CEH (Beresford NA, Barnett CL and Howard BJ) and HPA-RPD (Nisbet AF) provided general comments. **EURANOS peer reviewer:** Carini F (Universita Cattolica del Sacro Cuore).

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20 Selection of edible crop that can be processed

Objective	To select crops suitable for processing such that the final edible product has activity concentrations less than intervention levels.
Other benefits	Keeps land in production and provides income to farmer and maintenance of associated communities.
Management option description	Processing removes activity from the final food product. Sugar and oil-producing crops, for example, may be substituted for crops that do not undergo processing.
Target	Crops
Targeted radionuclides	**Known applicability:** ^{90}Sr, ^{134}Cs, ^{137}Cs **Probable applicability:** ^{60}Co, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{144}Ce, ^{226}Ra **Not applicable:** Short half-lives of the following negate use of this management option: ^{75}Se, ^{89}Sr, ^{95}Nb, ^{95}Zr, $^{99Mo/99m}$Tc, ^{103}Ru, ^{127}Sb, ^{131}I, ^{132}Te, ^{140}Ba, ^{140}La, ^{141}Ce, ^{169}Yb, ^{192}Ir. The low soil-plant transfer of the following mean that this radical the management option is likely to be inappropriate: ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf
Scale of application	Small to medium.
Contamination pathway	Soil to plant.
Exposure pathway pre intervention	Ingestion of contaminated crops.
Time of application	Medium to long term.
Constraints	
Legal constraints	The sale of products intended for human consumption is subject to Council Food Intervention Limits (CFILs).
Social constraints	The food industry/retailers and consumers' resistance to processing of contaminated crops for consumption.
Environmental constraints	The soil type/climate may limit which crops can grow.
Effectiveness	
Management option effectiveness	Processing can be very effective at removing radionuclides from the final product (e.g. sugar, oil, wine). Although data are only available for effectiveness with regard to Cs and Sr reductions. For the other listed target radionuclides could be expected to be effective from knowledge of their behaviour. The change in radionuclide content of a foodstuff due to processing may be assessed by calculating the food processing retention factor. This indicates the fraction of the radionuclide which remains in the food following processing and is shown by the equation below: Processing retention factor = Total activity of the radionuclide in the processed food (Bq) / Total activity of the radionuclide in the raw material (Bq) Some processing retention factors are listed below:

	Cs	Sr
Olive Cake	0.4	
Oil	0.1	
Grape	0.6	0.6
Red wine	0.15 – 0.7	
Rosé wine		0.2
White wine	0.3	
Fruits	0.6 – 0.7	
Juice		0.06
Rice	0.1	

	Milled rice		0.2

Factors influencing effectiveness of procedure	Crop type. Ease of substitution of new crop for the farmer and associated industries. Soil-to-plant transfer factor of crop. Processing selected. Compliance to management option. Acceptability of processing contaminated crops for consumption by the food industry/retailers and consumers.
Feasibility	
Required specific equipment	Sowing/harvesting equipment for alternative crop type (may not be available on farm). Processing equipment.
Required ancillary equipment	None.
Required utilities and infrastructure	Waste treatment facilities for disposal of contaminated by-products.
Required consumables	Fuel. Seed stock of alternative crop (availability may be limited). Processing consumables.
Required skills	Expertise in cultivation of alternative crop.
Required safety precautions	Consider respiratory protection for operators at processing plant.
Other limitations	Availability of processing plants if there is a reluctance to move contaminated raw materials to a plant located outside an affected area. Capacity of processing plants to accept additional raw materials (i.e. crops). Markets for the products could be limited.
Waste	
Amount and type	Depends on crop selected. Waste includes food processing residuals i.e. materials remaining after processing of primary products, such as peel and foliage.
Possible transport, treatment and storage routes	Solid residuals such as peel, sugar beet tops etc. may be converted to useful by-products depending of the type of residual. Alternatively, these and other by-products could be treated at the processing site, incinerated (53 Incineration) or disposed of to landfill (54 Landfill).
Factors influencing waste issues	Depends on crop type and type of processing selected. The high moisture content and readily putrescible nature of the food residuals means that waste treatment cannot be delayed.
Doses	
Incremental dose *Dose pathways in italics are indirectly incurred as a result of transportation of waste by products. Additional doses will be incurred from disposal of these wastes either at landfill sites or incinerators. There are separate datasheets for waste disposal options. Any waste water generated during processing may be sent to a Sewage Treatment Works (STW).*	**Driver:** • external exposure while transporting crops to processing plant • *external exposure while transporting waste by-products to place of disposal.* **Operative at food processing plant:** • external exposure at processing plant (depending on degree of automation).
Intervention Costs	
Equipment	Sowing/harvesting equipment for alternative crop type (may have to be hired). Processing equipment. Appropriate monitoring equipment.

Consumables	Seed. Fuel. Additional processing consumables.
Operator time	**Farmer:** sowing and cultivation of alternative crop. **Drivers:** transporting contaminated crop to processing factories. **Operators at processing plant**: additional manpower if required.
Factors influencing costs	Distance to processing plant. Quantities of crops for processing.
Compensation costs	**Farmers:** • if they receive a reduction in income because new crops have lower value. **Processing plants:** • for handling contaminated produce • possible decontamination of processing equipment.
Waste cost	Dependent on subsequent disposal route for contaminated by-products.
Assumptions	That there is a market for alternative crop. That appropriate monitoring is carried out at processing plant.
Communication needs	Information/dialogue with farmers regarding crop substitution and husbandry. Information/dialogue with consumers. Possible requirement for labelling products (41 Food labelling).
Side-effect evaluation	
Ethical considerations	Informed consent. Distribution of costs and benefits (e.g. possible inequity due to change in prices of produce and lower income populations buying the treated food and therefore the possibility of incurring a higher dose than that received by typical members of the population.
Environmental impact	Change in ecosystem.
Agricultural impact	Change in crop type. Fertiliser requirements, nutrient cycling. Disease resistance.
Social impact	May impact on *public confidence* e.g. • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may result in loss of employment in local industries or growth of a black market) • increase confidence that the problem of contamination is being effectively managed. Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade when foodstuffs can be obtained from other sources. Disruption/adjustment of farming and related industrial activities, e.g. the supply of crops to food industry and potential for market shortages. Loss of profit to producers if the treated product is not accepted by consumers. Disruption to peoples image/perception of 'countryside' e.g. where traditional crops are changed, with potential impacts on tourism etc.
Other side effects	None.
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	
Key references	Alexakhin RM, Frissel MJ, Shulte EH, Prister BS, Vetrov VA and

	Wilkins BT (1993). Change in land use and crop selection. *Science of the Total Environment*, 137, 169-172. Modelling the transfer of radionuclides to fruit, Report of the Fruits Working group of BIOMASS Theme 3, IAEA-BIOMASS-5, Vienna, 2003. ISBN 92-0-106503-5. Green N (2001). The effect of storage and processing on radionuclide content of fruit. *Journal of Environmental Radioactivity*, 52, 281-290. Wang JJ, Wang CJ, Huang CC and Lin YM (1998). Transfer factors of ^{90}Sr and ^{137}Cs from paddy soil to the rice plant in Taiwan. *Journal of Environmental Radioactivity*, 39, 23-34. Tsukada H, Hasegawa H, Hisamatsu S and Yamasaki S (2002). Rice uptake and distributions of radioactive ^{137}Cs, stable ^{133}Cs and K from soil. *Environmental Pollution*, 117, 403-409.
Comments	
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Pollard D (Radiological Protection Institute of Ireland). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** Arapis G (Agricultural university of Athens).

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21 Shallow ploughing	
Objective	To reduce radionuclide uptake by crops, including pasture.
Other benefits	Reduction in external dose from contaminated land.
Management option description	An ordinary single-furrow mouldboard plough can be used to mix the top 20-30 cm of the soil profile following crop removal or incorporation. Much of the contamination at the surface will be buried more deeply in the vertical profile, which (i) may reduce radionuclide uptake by plant roots depending on their specific rooting behaviour; and (ii) reduce external exposure from the contaminants.
Target	Pasture or arable land.
Targeted radionuclides	Known applicability: ^{90}Sr, ^{134}Cs, ^{137}Cs Probable applicability: ^{60}Co, ^{75}Se, ^{95}Zr, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{144}Ce, ^{192}Ir, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf Not applicable: This management option may increase the mobility of U. The relatively short physical half-lives (1-2 months) of the following radionuclides may preclude this radical management option: ^{89}Sr, ^{95}Nb, ^{103}Ru, ^{131}I, ^{141}Ce, ^{169}Yb
Scale of application	Large scale application where ploughing is possible. Such areas could be identified using geographical information systems (GIS) and information on soil type and altitude. Production systems, for instance animal husbandry, can prevent maximum implementation on individual farms.
Contamination pathway	Soil to plant transfer.
Exposure pathway pre intervention	Ingestion of contaminated food products. External exposure from land.
Time of application	Medium to long-term, preferably as early as possible – for arable crops this would be prior to sowing new crop. Although as far as practical a delay after contaminating deposition will reduce external doses to operators from short-lived radionuclides.
Constraints	
Legal constraints	Ploughing may be restricted under some environmental protection schemes.
Social constraints	Acceptability of making contamination less retrievable. Potential resistance where ploughing is not standard practice. Aesthetic consequences of any subsequent landscape/amenity changes.
Environmental constraints	Sandy soils are friable and may crumble during ploughing. Soils which are excessively wet, dry or frozen cannot be ploughed without damaging soil structure. Excessively stony soils cannot be ploughed. Use of machinery difficult on land with slopes >16°. Whilst steep slopes and shallow soils cannot be ploughed these are unlikely to be found within areas of arable land.
Effectiveness	
Management option effectiveness	Plant uptake reduced by 50% (factor of 2), range of 0-75% (factors 1-4). External dose reduced by 50-90% (factors of 2-10). Whilst observed data on the effectiveness of this measure are limited to Sr and Cs it is reasonable to expect similar reduction factors for the other targeted radionuclides as the management option results in mechanical redistribution of (contaminated) soil profile. **Note:** this management option may result in increased mobility of U.

Factors influencing effectiveness of procedure	Soil type and conditions. Rooting depths of different crops. Radionuclide distribution within soil profile. Resistance to management option. It has been suggested that ploughing in the Chernobyl exclusion zone increased radionuclide availability possibly due to disintegration of fuel particles.
Feasibility	
Required specific equipment	Plough.
Required ancillary equipment	Tractor.
Required utilities and infrastructure	None.
Required consumables	Fuel.
Required skills	Farmers/agricultural workers will possess the necessary skills, but must be instructed carefully about the objective.
Required safety precautions	Consider respiratory protection if very dry conditions.
Other limitations	Very high groundwater table. Dose limits for farmers/agricultural workers.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Farmer:** external exposure, inadvertent ingestion and inhalation whilst ploughing.
Intervention Costs	
Equipment	Tractor and single furrow plough are already available.
Consumables	Fuel (ca 7 l ha^{-1}).
Operator time	One operator per plough: 1.2 h ha^{-1}.
Factors influencing costs	Work rates vary depending on soil type and conditions, field size and shape, topography and operator experience.
Compensation costs	**Farmer:** • for ploughing land not normally ploughed • for loss of income from non-adherence to conservation schemes.
Waste cost	N/A.
Assumptions	None.
Communication needs	Provision of information to operators on correct application of procedure including radiological hazards. Dialogue with farmers required concerning timing and selection of fields to be ploughed and to clarify the costs and benefits before decisions on implementation are made.
Side effect evaluation	
Ethical considerations	*In situ* treatment of contaminated soil. Self-help for farmer. Free informed consent and compensation for operators. Potential redistribution of dose to farmers and agricultural workers.

Environmental impact	The procedure brings contamination closer to the groundwater. No further environmental impact on land normally ploughed. If soil has undergone conservation tillage for >5 years ploughing dilutes organic matter, reduces earthworm populations and microbial biomass. Changes in landscape. A change in the ploughing regime or in land use may cause soil erosion and affect sedimentation.
Agricultural impact	Fertilisation may be required. Pasture land will require reseeding.
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' (resulting in loss of employment in local 'cottage' industries or growth of a black market) • increase public confidence that the problem of contamination is being effectively managed. For land not normally ploughed there may be a changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Disruption to farming and other related activities (e.g. tourism). Contamination of the soil may restrict subsequent uses. Aesthetic consequences of any subsequent landscape/amenity changes.
Other side effects	Could improve some soils that have been infrequently managed and have become compacted. Severely complicates subsequent removal of the contamination.
FARMING Network Stakeholder opinion	Of the options aimed at reducing radionuclide transfer along the soil-plant or plant-animal pathway, normal ploughing, the application of fertilisers and lime to soils, and the addition of binders or sorbents to feed were the options preferred by most stakeholders.
Practical experience	Tested widely in fSU following the Chernobyl accident. Tested on a limited scale in Denmark.
Key references	Fesenkoa S, Jacobb P, Alexakhina R, Sanzharovaa NI, Panova A, Fesenkoa G and Cecillec L (2001) Important factors governing exposure of the population and countermeasure application in rural settlements of the Russian Federation in the long term after the Chernobyl accident. *Journal of Environmental Radioactivity*, 56, 77–98. Maubert H, Vovk I, Roed J, Arapis G and Jouve A (1993). Reduction of soil-plant transfer factors:mechanical aspects. *Science of the Total Environment*, 137, 163-167. Salt CA and Rafferty B (2001). Assessing potential secondary effects of countermeasures in agricultural systems: a review. *Journal of Environmental Radioactivity*, 56, 99-114. Vandecasteele CM, Bakerb S, Forstelc H, Muzinskyc M, Milland R, Madoz-Escandee C, Tormose J, Saurasf T, Schulteg E and Collee C (2001). Interception, retention and translocation under greenhouse conditions of radiocaesium and radiostrontium from a simulated accidental source. *Science of the Total Environment*, 278,199-214. Vovk IF, Blagoyev VV, Lyashenko AN and Kovalev IS (1993). Technical approaches to decontamination of terrestrial environments in the CIS. *Science of the Total Environment*, 137, 49-63.
Comments	Ploughing is more effective when carried out in conjunction with fertiliser and lime application (see 17 Land improvement). Potassium and calcium reduce uptake of radiocaesium and radiostrontium.
Document History	**STRATEGY originat**or: Nisbet AF (HPA-RPD).

	STRATEGY contributors: Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Brechignac F (Institute for Radioprotection and Nuclear Safety, France). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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22 Skim and burial ploughing

Objective	To reduce radionuclide uptake by crops, including pasture.
Other benefits	Reduction in external doses from contaminated land.
Management option description	If no crop is present, a specialist plough with two ploughshares can be used to skim off a thin layer of contaminated topsoil (*ca.* 5 cm; adjustable) and bury it at a depth of about 45cm. The deeper soil layer (*ca.* 5-50cm) is lifted by the other ploughshare and placed at the top without inverting the 5-45cm horizon. Direct exposure and root uptake from the contaminants are reduced and effect on soil fertility minimised.
Target	Pasture or fallow arable soil.
Targeted radionuclides	**Known applicability:** ^{90}Sr, ^{134}Cs, ^{137}Cs **Probable applicability:** ^{60}Co, ^{75}Se, ^{95}Zr, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{144}Ce, ^{192}Ir, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf **Not applicable:** This management option may increase the mobility of U. The relatively short physical half-lives (1-2 months) of the following radionuclides may preclude this radical management option: ^{89}Sr, ^{95}Nb, ^{103}Ru, ^{131}I, ^{141}Ce, ^{169}Yb
Scale of application	Large scale where ploughing is possible – ploughs are not readily available but can be delivered over a period of time. Areas suitable for ploughing could be identified using geographical information systems (GIS) and information on soil type and slope.
Contamination pathway	Soil to plant.
Exposure pathway pre intervention	Ingestion of contaminated food products. External exposure from land.
Time of application	Medium-long term. Ideally should be carried out as early as possible. In practice it is more likely to be carried out in the medium – long term because only a limited number of these specialist ploughs are available. Timing of application is not so critical for radiocaesium, but for some other radionuclide-soil type combinations, efficiency reduces with time due to movement down the soil profile.
Constraints	
Legal constraints	Skim and burial ploughing would not be permitted under various agri-environmental agreements.
Social constraints	Farmers' resistance to management option.
Environmental constraints	Sandy soils are friable and may crumble during ploughing. Soils that are excessively wet, dry or frozen cannot be ploughed without damaging soil structure. Soil profiles must be > 0.5 m deep. Use of machinery difficult on land with > 16^{o} slope and excessively stony soils cannot be ploughed.
Effectiveness	
Management option effectiveness	Reduction of contamination by about 83-92%, if optimised according to contaminant distribution in the soil. Reduction in soil-to-plant transfer by a 90% (factor of 10). Reduction in external dose of around 94%. Whilst observed data on the effectiveness of this measure are limited to Sr and Cs it is reasonable to expect similar reduction factors for the other targeted radionuclides as the management option results in mechanical redistribution of (contaminated) soil profile. **NB.** This management option may result in increased mobility of U

Factors influencing effectiveness of procedure	Efficiency of inversion of upper layer. Radionuclide distribution within soil profile after inversion. Fertility of new top soil. Rooting depths of different crops. Efficient use of equipment and conduct of procedures. Compliance to management option, i.e. willingness and ability of farmers to adapt to a new procedure. It has been suggested that ploughing in the Chernobyl exclusion zone increased radionuclide availability possibly due to disintegration of fuel particles.
Feasibility	
Required specific equipment	Skim and burial plough (limited availability).
Required ancillary equipment	Tractor (Skim and burial ploughing requires powerful tractors e.g. 90 kW which are not necessarily widely available).
Required utilities and infrastructure	Road network for transporting plough.
Required consumables	Fuel.
Required skills	Can be carried out by farmers or agricultural contractors who are familiar with ploughing, but additional instruction will be required to meet objectives.
Required safety precautions	Consider respiratory protection if very dry conditions.
Other limitations	Shallow soils. High groundwater table. Dose limits for farmers/agricultural workers.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Farmer:** external exposure, inadvertent ingestion and inhalation whilst ploughing.
Intervention Costs	
Equipment	Skim and burial plough shared between a number of farms. Tractor (min. 90 kW) shared between a number of farms.
Consumables	Fuel (ca. 15 l ha^{-1}).
Operator time	1 operator per plough: 0.4 man-days ha^{-1}, i.e. (3 h ha^{-1}).
Factors influencing costs	Work rates vary depending on soil type and conditions, field size and shape, topography and operator experience. Number of skim and burial ploughs available.
Compensation costs	To farmer for carrying out skim and burial ploughing. To farmer for loss of income for non-adherence to conservation schemes and lost production. Labour costs may be higher to compensate operators for exposure to radiation.
Waste cost	N/A.
Assumptions	None.
Communication needs	Dialogue with operators regarding selection of areas, correct way to carry out skim and burial ploughing, especially (i) for areas of land not normally ploughed; (ii) when ploughing is to be undertaken at non-standard times of the year.

	Need dialogue between farmers, ecologists and public because of potential for groundwater contamination.
Side-effect evaluation	
Ethical considerations	*In situ* treatment of contaminated soil. Self-help for farmer. Potential redistribution of dose to farmers and agricultural workers. Free informed consent and compensation for operators.
Environmental impact	The procedure brings contamination closer to the groundwater and there is a risk that radionuclides will be transferred to other areas and affect other populations. Changes in physical characteristics of the surface horizon. Enhanced mineralisation of organic matter. Soil erosion. Biodiversity could be affected, particularly for soil dwelling organisms. Future restriction on land use: must not be deep tilled. Changes in landscape. Potential for ecosystem change/damage.
Agricultural impact	Soil fertility may be affected by the inversion of the top 5cm of soil. Fertilisation may therefore be required. Field drainage systems destroyed.
Social impact	Stigma associated with food products where the management option has been applied. May impact on *public confidence* i.e., • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may result in loss of employment in local 'cottage' industries or growth of a black market) • increase public confidence that the problem of contamination is being effectively managed. For land not normally ploughed there may be a changed relationship to the countryside and potential loss of amenity resulting from changes in peoples' perception of land as 'natural' to being 'unnatural' or in some way damaged. Aesthetic consequences of any subsequent landscape/amenity changes. Topsoil burial may cause removal of flora and fauna which raises wildlife issues that are likely to be contested. Disruption to farming and other related activities (e.g. tourism). Contamination of soil at depth may restrict subsequent uses. Acceptability of making contamination less retrievable when long-term mobility of radionuclides is not known.
Other side effects	
FARMING Network stakeholder opinion	Stakeholder opinion on the acceptability of deep ploughing and skim and burial ploughing was divided. Skim and burial ploughing would be even more restricted because the specialist ploughshare is currently only available in Denmark. The issue of irretrievability of the contamination following either deep ploughing or skim and burial ploughing was a cause for concern among a minority of stakeholders who felt that the burial of radionuclides at depth could in time lead to horizontal and vertical migration within the soil, which was deemed unacceptable.
Practical experience	Used in fSU as a management option following the Chernobyl accident but on a fairly limited scale. Also tested in Denmark on a small scale (typically 1000-2000 m^2 areas).

Key references	Hubert P, Annisomova L, Antsipov G, Ramsaev V and Sobotovitch V (ed.) (1996). Strategies of decontamination. Final report APAS-COSU 1991-1995: ECP4 Project. European Commission, EUR 16530 EN. Roed J, Andersson KG and Prip H (1996). The Skim and Burial Plough: A new implement for reclamation of radioactively contaminated land. *Journal of Environmental Radioactivity*, 33 (2), 117-128.
Comments	The method severely complicates contaminant removal. Subsequent ordinary ploughing (to ca. 25cm) will not redistribute contaminants.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD, UK); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Brechignac F (Institute for Radioprotection and Nuclear Safety, France). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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23 Topsoil removal	
Objective	To reduce radionuclide uptake by crops, including pasture.
Other benefits	Reduction in external dose from contaminated land.
Management option description	If no crop is present, the top 2-5 cm is removed using road construction equipment such as a bobcat or mini-bulldozer. In this way, much of the contamination is removed. When the amount of waste is taken into consideration management option is only applicable on a small scale.
Target	Pasture or fallow arable land.
Targeted radionuclides	**Known applicability:** ^{60}Co, ^{75}Se, ^{90}Sr, ^{95}Zr, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{192}Ir, ^{226}Ra, ^{235}U ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf **Probable applicability: -** **Not applicable:** The relatively short physical half-lives (1- 2 months) of the following radionuclides may preclude this radical management option: ^{89}Sr, ^{95}Nb, ^{103}Ru, ^{131}I, ^{141}Ce, ^{169}Yb
Scale of application	Small scale (amount of waste produced limits scale of application)
Contamination pathway	Soil to plant transfer.
Exposure pathway pre-intervention	Ingestion of contaminated food products. External exposure from land.
Time of application	Medium to long term. Should be carried out as soon as possible, but significant reductions are still possible in the long term for relatively immobile radionuclides such as caesium. There is a tendency for the more mobile radionuclides such as strontium to move down the soil profile with time.
Constraints	
Legal constraints	Cultural heritage protection, especially in conservation areas or equivalent.
Social constraints	Resistance to: Topsoil removal (together with associated flora and fauna). Aesthetic consequences of amenity/landscape changes. Waste disposal options.
Environmental constraints	Soils that are shallow and stony cannot always be treated. Can be difficult to use large machinery on wet, peaty soils. On heavy clay soils, decontamination may be limited to times of the year when the soil is workable. Sandy structureless soils cannot be removed effectively as a thin layer. Large negative consequences for the environment.
Effectiveness	
Management option effectiveness	90-97% of the activity is removed.
Factors influencing effectiveness of procedure	Optimisation of thickness of removed layer. Vertical radionuclide distribution. Soil texture. Presence of vertical cracks in the soil. Operator skill ensuring contamination is not ploughed into clean surface during removal. Time between deposition and implementation (for downward migration). Acceptability of the implementation of the management option to farmers and the public. Appropriate selection of priority areas.

Feasibility	
Required specific equipment	Bobcat mini bulldozer or bulldozer.
Required ancillary equipment	Vehicle to transport waste.
Required utilities and infrastructure	Suitable disposal site (see comments). Roads to transport waste.
Required consumables	Fuel.
Required skills	Can be carried out by already skilled operators such as municipal workers and additional operators could be instructed within a day. Possible need for radiation protection training of workers.
Required safety precautions	Consider respiratory protection if very dry/dusty conditions.
Other limitations	Dose limits for workers.
Waste	
Amount and type	If 5 cm of topsoil is removed, 70 kg m^{-2} of waste would be produced. Contamination will be around 20 Bq m^{-3} (removed soil) per Bq m^{-2} (ground surface contamination).
Possible transport, treatment and storage routes	Disposal to landfill (54 Landfill) sites or purpose built repositories.
Factors influencing waste issues	Contamination level of waste. Volume of waste. Acceptability of waste disposal options. Location of disposal site especially if outside affected area.
Doses	
Incremental dose	**Operative removing soil:** external exposure, inadvertent ingestion and inhalation while removing soil surface. **Driver:** external exposure while transporting soil to landfill.
Intervention Costs	
Equipment	Bobcat or bulldozer shared between a number of farms. Vehicle to transport waste.
Consumables	Fuel for bobcat (ca 40 l ha^{-1}). Transporters.
Operator time	Typically some 50-100 h ha^{-1}, including loading to waste transport truck, but excluding waste transport and work at repository.
Factors influencing costs	Type of equipment. Soil type and conditions, field size and shape, topography and operator experience. Distances of contaminated site to equipment hire and to disposal site.
Compensation costs	**Farmer:** loss of grazing areas and re-establishment of vegetation. **Operative removing soil/driver:** labour costs may be higher to compensate operators for exposure to radiation.
Waste cost	Transport to landfill site and subsequent landfill costs (including landfill tax). Siting and building of purpose-built repository.
Assumptions	None.
Communication needs	Need for dialogue regarding selection of areas for treatment. Dialogue regarding selection of areas considered suitable for application of this management option. Provision of information to operators on objectives of procedure.
Side-effect evaluation	
Ethical considerations	Potential redistribution of dose to workers, as well as inequity due to

	redistribution of dose to populations living close to waste disposal areas. Free informed consent of workers.
Environmental impact	Risk of soil erosion. Soil biota affected. Loss of biodiversity. Changes in landscape. Large volumes of waste generated.
Agricultural impact	Soil fertility may be affected by the loss of top 5cm of soil. Fertilisation may be required. The underlying soil may be compacted with implications for subsequent cultivation. Vegetation needs to be re-established.
Social impact	Stigma associated with affected areas. Disruption to farming and other related activities (e.g. tourism). Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. May increase public confidence and trust to authorities ("something is being done"). May decrease public confidence to food industry; perceived contamination of food products (crops, dairy, meat) where the management option has been applied. Potential for dispute regarding waste disposal sites.
Other side effects	None.
FARMING Network stakeholder opinion	The stakeholder groups did not consider wide scale application of any of these options to be generally acceptable. Could be used under specific circumstances (i.e. topsoil removed when area affected is very small), but in general the infrastructure for dealing with the subsequent waste could be limited.
Practical experience	Used in fSU as a management option following the Chernobyl accident. It was also used on a small scale after the Goiania, Palomares and Mayak accidents.
Key references	Andersson KG (1996). Evaluation of Early Phase Nuclear Accident Clean-up Procedures for Nordic Residential Areas. NKS Report NKS/EKO-5(96)18, ISBN 87-550-2250-2, 93p. Andersson KG and Roed J (1999). A Nordic Preparedness Guide for Early Clean-up in Radioactively Contaminated Residential Areas. *Journal of Environmental Radioactivity*, 46, 2, 207-223. Fogh CL, Andersson KG, Barkovsky AN, Mishine AS, Ponamarjov AV, Ramzaev VP and Roed J (1999). Decontamination in a Russian Settlement. *Health Physics*, 76 (4), 421-430. Roed J, Andersson KG, Barkovsky AN, Fogh CL, Mishine AS, Olsen SK, Ponomarjov AV, Prip H, Ramzaev VP and Vorobiev BF (1998). Mechanical decontamination tests in areas affected by the Chernobyl Accident. Risø-R-1029, ISBN 87-550-2361-4, 101 p.
Key references (continued)	Vovk IF, Blagoyev VV, Lyashenko AN and Kovalev IS (1993). Technical approaches to decontamination of terrestrial environments in the CIS (former USSR). *Science of the Total Environment*, 137, 49-63.
Comments	Management option limited by requirement for waste disposal facilities - suitable sites for disposal of excavated radiologically contaminated materials is an acknowledged problem worldwide with (some) landfill sites currently not accepting radiologically contaminated waste because of public concern. Topsoil removal would not be justified for short-lived nuclides.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD).

	STRATEGY contributors: Mercer JA and Hesketh N (HPA-RPD, UK); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Brechignac F (Institute for Radioprotection and Nuclear Safety, France). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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24 Addition of AFCF to concentrate ration	
Objective	To reduce activity concentrations of radiocaesium in meat or milk to below intervention levels.
Other benefits	Reduction in quantities of animal produce that will need to be disposed of. Normal animal management/grazing regimes can be used. Potential for additional reduction of radiocaesium uptake from soil to grass and other crops through using manure containing AFCF for fertilisation (see Howard *et al.,* 2001).
Management option description	Ammonium-ferric hexacyano-ferrate (AFCF, Giese-salt) is an effective radiocaesium binder, which may be added to the diet of dairy cows, sheep and goats as well as meat producing animals to reduce radiocaesium transfer to milk and meat by reducing absorption in the gut. It can be added to the diet of animals as a powder or incorporated into pelleted feed. Dairy animals are generally fed a concentrate ration when they are milked (usually twice daily) – incorporation of AFCF into the concentrate ration would allow administration daily. Meat producing animals would only need to be fed AFCF-concentrates for a suitable period prior to slaughter.
Target	Meat and milk producing animals. Inappropriate for free grazing livestock (most applicable to dairy animals as these tend to be fed twice-daily as part of normal farming practice).
Targeted radionuclides	**Known applicability**: $^{134,137}Cs$ **Probable applicability:** - **Not applicable:** Specific to radiocaesium
Scale of application	Large.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated milk or meat.
Time of application	Medium to long term (requirement to obtain and distribute AFCF makes it unlikely to be applicable to early phase).
Constraints	
Legal constraints	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). On 14th October 2001 permanent authorisation was given by the European Communities for AFCF to be used as a feed additive for the purposes of binding radiocaesium (Regulation 2013/2001). This allows the addition of AFCF to the daily ration at levels between 1 and 15 mg kg^{-1} body weight. May not be allowed under some organic production regimes. Possible requirement for labelling products.
Social constraints	Acceptability to farmers/herders, food industry and consumers of using an additional feed additive to remove contamination from the gut of livestock.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	For cows receiving 3g AFCF per day an 80-90% reduction of radiocaesium contamination in milk and a 78% reduction of radiocaesium contamination in meat. For sheep receiving 1g AFCF per day an 87% reduction of radiocaesium contamination in meat.

Management option effectiveness (continued)	For pigs and calves receiving 2g AFCF per day a 90% reduction in radiocaesium contamination in meat (Giese, 1988 and 1989). More variable reduction rates for reindeer as difficult to control inputs. Administration rates of 1 mg kg^{-1} body weight d^{-1} have resulted in a 60% reduction in radiocaesium transfer from diet.
Factors influencing effectiveness of procedure	Effective administration of the concentrate. Amount of AFCF ingested to animal daily. Greater effectiveness when farmer/herders use commercially prepared concentrates. Effectiveness may be more variable if mixed as a powder into home produced rations. Initial activity concentration and the biological half-life of radiocaesium in the animal. Period of adaptation to pelleted feed may be required. Farmers' compliance to the management option.
Feasibility	
Required specific equipment	None.
Required ancillary equipment	None.
Required utilities and infrastructure	Concentrate manufacturing plants with the ability to add AFCF to feed pellets.
Required consumables	Concentrates with AFCF.
Required skills	Farmers/herders would possess the necessary skills.
Required safety precautions	None for concentrates but hazard datasheet recommendations would need to be followed by feed manufacturer.
Other limitations	Cannot be fed on a daily basis to free-grazing animals. May be used for free ranging animals in combination with confining them to enclosures (which may be especially applicable to reindeer). Current production facilities for AFCF may be rate limiting if large quantities required.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	None.
Intervention costs	
Equipment	None.
Consumables	Cost of AFCF. Example cost for pelleted feed containing 0.1% AFCF imported from Germany in Norway is €0.27 EUR per kg feed (*c*. 2003).
Operator time	Farmer may need to mix the AFCF in the feed.
Factors influencing costs	Production cost for the concentrates with AFCF. Transportation costs.
Compensation costs	To the farmer/herder to compensate for the extra costs associated with buying concentrates with AFCF.
Waste cost	N/A.
Assumptions	None.
Communication needs	Possible requirement for labelling products directly or indirectly affected by application of the management option.
Side-effect evaluation	
Ethical considerations	
Environmental impact	Whilst some soils may contain bacteria or fungi capable of degrading cyanide, toxic levels of HCN should not arise under field conditions.

Agricultural impact	Less impact as conventional farming practices can be maintained without severe disruption. Change in production status for organic farms.
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are 'safe' (may i.e. result in loss of employment in local 'cottage' industries or growth of a black market), • increase confidence that the problem of contamination is being effectively managed.
Other side effects	Can maintain the production of meat and milk without disrupting the normal farming practices.
FARMING Network stakeholder opinion	Of the options aimed at reducing radionuclide transfer along the soil-plant or plant-animal pathway, normal ploughing, the application of fertilisers and lime to soils, and the addition of binders or sorbents to feed were the options preferred by most stakeholders. These management options were seen to sustain farming practices and cause minimal impact on the environment.
Practical experience	Used frequently after the Chernobyl accident in Norway with good results for cows and goats and reindeer; in the FSU a different hexacyanoferrate compound (Ferrocyn) has been used. Less and variable data available for pigs and poultry.
Key references	Garmo TH and Grønnerud TB (eds.) (1992). Radioaktivt nedfall fra Tsjernobylulykken. Norges landbruksvitenskapelige Forskningsråd, Oslo, 1992. Radioactive deposition after the Chernobyl accident. Norwegian Agricultural Scientific Research Council, Oslo, 1992 (in Norwegian). Giese WW (1988). Ammonium-ferric-cyano-ferrate(II) (AFCF) as an effective antidote against radiocaesium burdens in domestic animals and animal derived foods. *Br. Vet. Journal*, 144, 363. Giese WW (1989). Countermeasures for reducing the transfer of radiocaesium to animal derived foods. *Science of the Total Environment*, 85, 317-327. Hove K (1993). Chemical methods for reduction of the transfer of radionuclides to farm animals in semi-natural environments. *Science of the Total Environment*, 137 235-248. Howard BJ, Beresford NA and Voigt G (2001). Countermeasures for animal products: a review of effectiveness and potential usefulness after an accident. *Journal of Environmental Radioactivity*, 56, 115-137. IAEA (1994). Handbook of parameter values for the prediction of radionuclide transfer in temperate environments. IAEA Technical Report Series No. 364. Pearce J (1994). Studies on any toxicological effects of Prussian Blue compounds in mammals – a review. *Food Chem. Toxicol.*, 32, 577-582. Salt CA and Rafferty B (2001). Assessing potential secondary effects of countermeasures in agricultural systems: a review. *Journal of Environmental Radioactivity*, 56, 99-114. Hove K, Staaland H and Pedersen O (1991). Hexacyanoferrates and bentonite as binders of radiocaesium for reindeer. *Rangifer*, 11 (2), 43-48. Tveten U, Brynildsen LI, Amundsen I and Bergan TDS (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. *Journal of Environmental Radioactivity*, 41 (3), 233-255.

Comments	Detailed toxicological studies have shown that AFCF has no adverse affects on animal or human health. Faeces from treated animals will be more contaminated than for untreated animals. This can give higher external dose for the person responsible for handling the slurry/manure although this is not believed to reach levels of concern in practice (for animals grazing outdoors this is not an issue). Studies have shown that the radiocaesium uptake in plants from soils fertilised with manure from treated animals is lower than the uptake from soils fertilised with manure from untreated animals (Garmo and Grønnerud, 1992)). Live-monitoring prior to slaughtering can be a good supplement to control the effectiveness of the management option for each animal or a selection within a herd/flock.
Document History	**STRATEGY originator:** Liland A (NRPA) **STRATEGY contributors:** Nisbet AF, Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Pearce J (Department of Agriculture and Rural Development, Northern Ireland, UK); Brynildsen L (Ministry of Agriculture, Norway). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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25 Addition of calcium to concentrate ration

Objective	To reduce the activity concentration of radiostrontium in milk to below intervention levels.
Other benefits	Reduction in quantity of milk that will need to be disposed of. Normal animal management/grazing regimes can be used.
Management option description	The absorption of radiostrontium from an animal's diet is controlled by the level of dietary calcium intake. Additional calcium (as calcium carbonate) may be added to the daily ration of lactating animals to reduce radiostrontium transfer to milk. This is most easily achieved by adding Ca to concentrate ration fed to (most) milk producing animals at milking time.
Target	Milk producing animals.
Targeted radionuclides	**Known applicability**: ^{89}Sr, ^{90}Sr **Probable applicability:** ^{140}Ba, ^{226}Ra **Not applicable:** -
Scale of application	Large.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated milk.
Time of application	Medium to long term (requirement to manufacture and distribute Ca enriched feeds makes it unlikely to be a applicable to early phase).
Constraints	
Legal constraints	The sale of milk intended for human consumption is subject to Council Food Intervention Limits (CFILs). The feeding of diets in excess of 1-2% Ca as dry matter intake is advised against for prolonged periods. However, it is likely that in most western European countries the Ca intake of animals could be doubled without exceeding these advised levels. Possible requirement for labelling products.
Social constraints	Farmers/public resistance to the management option.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Doubling of calcium intake results in reductions of approximately 50% in the transfer of radiostrontium to milk - the absorption of radiostrontium (and hence transfer to milk) being inversely proportional to calcium intake. Whilst no experimental data are available it is highly likely that this management option would be similarly effective for ^{140}Ba and ^{226}Ra (as they belong to the same periodic table group as Sr and Ca).
Factors influencing effectiveness of procedure	Effective administration of the calcium in concentrate. Animal's dietary intake prior to calcium supplementation and its calcium requirements. Whilst in theory every doubling of Ca intake would reduce Sr concentration in milk by 50 % there are maximum advised Ca intakes over long term. Farmers/public compliance to the management option.
Feasibility	
Required specific equipment	None.
Required ancillary equipment	None.
Required utilities and infrastructure	Most likely to be fed with concentrate during milking.
Required consumables	Calcium supplements or pelleted concentrates with enriched levels of Ca or natural feeds rich in calcium.

Required skills	Farmers would already possess the necessary skills because of experience with other additives.
Required safety precautions	None.
Other limitations	High levels of calcium intake can influence the absorption of other essential nutrients; the dietary Ca/P ratio should not exceed 7:1 for prolonged periods. Cannot be fed on a daily basis to free-grazing animals.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	None.
Intervention Costs	
Equipment	None.
Consumables	Calcium supplements.
Operator time	Farmer may need to mix the calcium in the feed.
Factors influencing costs	Production cost for the concentrates with calcium. Transportation costs. Policing the management option.
Compensation costs	**Farmer:** compensation for the extra costs associated with buying concentrates with added calcium.
Waste cost	N/A.
Assumptions	None.
Communication needs	Possible cost of labelling.
Side-effect evaluation	
Ethical considerations	
Environmental impact	None.
Agricultural impact	No adverse effects if advised Ca intakes (1-2% of dry matter intake) are not exceeded. Conventional farming practices can be maintained without severe disruption. Change in production status for organic farms.
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' (may i.e. result in loss of employment in local 'cottage' industries or growth of a black market), • increase in confidence that the problem of contamination is being effectively managed.
Other side effects	Can maintain milk production without disrupting the normal farming practices.
FARMING Network stakeholder opinion	Of the options aimed at reducing radionuclide transfer along the soil-plant or plant-animal pathway, normal ploughing, the application of fertilisers and lime to soils, and the addition of binders or sorbents to feed were the options preferred by most stakeholders. These management options were seen to sustain farming practices and cause minimal impact on the environment. However, under some circumstances, the stakeholders recognised that the administration of calcium supplements to livestock could affect animal health, which would restrict applicability.

Practical experience	None.
Key references	Beresford NA, Mayes RW, Hansen HS, Crout NMJ, Hove K and Howard BJ (1998). Generic relationship between calcium intake and radiostrontium transfer to milk of dairy ruminants. *Radiation and Environmental Biophysics*, 37, 129-131. Beresford NA, Mayes RW, Colgrove PM, Barnett CL, Bryce L, Dodd BA and Lamb CS (2000). A comparative assessment of the potential use of alginates and dietary calcium manipulation as countermeasures to reduce the transfer of radiostrontium to the milk of dairy animals. *Journal of Environmental Radioactivity*, 51, 321-342.
Comments	In many countries, farmers will have values of Ca in the feeds they use (both commercial and home grown). In the long-term these could be used to optimise the use of Ca as a management option on a farm by farm basis. In the shorter term Ca intakes could be enhanced by farmers adding Ca-supplement to feed directly; however in the longer term it may be more efficient/effective to incorporate enhanced Ca into pelleted feeds during manufacture.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Pearce J, Department of Agriculture and Rural Development, Northern Ireland, UK. **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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26 Administration of AFCF boli to ruminants

Objective	To reduce activity concentrations of radiocaesium in meat or milk to below intervention levels.
Other benefits	Reduction in quantities of animal produce that will need to be disposed of. Normal animal management/grazing regimes can be maintained.
Management option description	Slow release boli containing ammonium iron hexacyanoferrate (AFCF, Giese-salt), an effective radiocaesium binder, have been developed to reduce the gut uptake of radiocaesium by ruminants in agricultural and semi-natural environments. Boli are particularly favourable for infrequently handled free-grazing animals such as sheep and semi-domesticated reindeer: they can be administered when animals are gathered for routine handling operations. Boli are administered to meat producing animals 2-3 months prior to slaughter, and to dairy animals every 2-3 months.
Target	Milk and meat producing ruminants.
Targeted radionuclides	**Known applicability:** $^{134,137}Cs$ **Probable applicability:** - **Not applicable:** Specific to radiocaesium
Scale of application	Distributed to all ruminants eating contaminated feed – especially suitable to free-grazing/infrequently handled animals.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated milk and meat.
Time of application	Medium to long-term (lack of established production facilities/stockpiles means that is not a potential management option for application in the early-phase).
Constraints	
Legal constraints	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). On 14th October 2001 permanent authorisation was given by the European Communities for AFCF to be used as a feed additive for the purposes of binding radiocaesium (Regulation 2013/2001). The use of boli to administer additives is currently being debated within the EC (Regulation 1831/2003 applicable from 18th October 2004); outcomes of these discussions may have an impact on the status of AFCF-boli. AFCF boli may not be permitted under some organic production regimes. Possible requirement for labelling products.
Social constraints	Acceptability to farmers, food industry and consumers of using an additional feed additive to remove contamination from the gut of livestock. There has been reluctance to use boli by reindeer herders in Sweden and Norway, cattle owners in the fSU and sheep farmers in the UK.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Up to 80% reduction in lamb and reindeer meat and goat milk, and up to 70% reduction in cow's milk. Effectiveness can be variable depending upon time between administration and slaughter – a reduction of 50-65% over a period of 9-11 weeks can be expected for sheep administered 3 waxed boli.

Factors influencing effectiveness of procedure	Effective administration of the boli. Concentration of AFCF in boli and number of boli used. The presence of a wax coating on the boli increases the release period from 2 to 3 months. Time between boli administration and slaughter (or live-monitoring) and biological half-life of radiocaesium in treated animal species. It is possible that some animals may not be collected for administration – and hence not administered boli. Marking treated animals (e.g. with lanolin based marker fluids) may provide reassurance that animals have been treated. However, treated animals can still regurgitate boli. Farmers' compliance to the management option.
Feasibility	
Required specific equipment	For sheep, cows and goats the farmer can administer by hand or adapt dosing guns used for other intra-ruminal devices. For reindeer a specifically designed instrument is needed for placing the boli in the rumen.
Required ancillary equipment	If being administered remote from farmstead in areas where animals would not normally be gathered and handled, corrals and fences will be needed.
Required utilities and infrastructure	Factory to manufacture AFCF boli. Currently there are no commercial facilities making boli within western Europe.
Required consumables	Boli with AFCF. Liquid paraffin. (Swallowing is eased by immersing boli in it prior to administration).
Required skills	Farmer would have required skills for sheep, cows and goats with little additional training. For reindeer it is important that a veterinarian, using the instrument specifically designed for this purpose, places the bolus in the rumen. Reindeer deaths have been reported in Norway due to poor administration techniques. Skills would need to be developed within manufacturing industry to make AFCF-boli on large-scale.
Required safety precautions	None.
Other limitations	Boli have to be of a suitable size to administer to target group of animals. For instance, standard Norwegian sheep boli were too large to be administered to hill lambs in areas of the UK affected by the Chernobyl accident (suitable smaller boli were developed and given limited field testing). Current production facilities for AFCF may be rate limiting if large quantities required.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	None.
Intervention costs	
Equipment	Approximately €60 EUR per applicator for reindeer (Norwegian example *c*. 2003).
Consumables	Approximately €2 EUR per bolus with AFCF for sheep (Norwegian example manufactured by university; *c*. 2003). Liquid paraffin.

Operator time	For farm ruminants: the bolus can be administered by the farmer. In Norway it is estimated that administration of 2 boli to sheep by a trained farmer takes 30 seconds per animal. For reindeer: a team of at least three persons is needed; two reindeer breeders holding the animal down, and one veterinarian placing the bolus in the rumen. Forty-five reindeer per hour can be treated by an experienced team. Additional time would be required to collect animals – although ideally this would be fitted into normal management practices. However, this will not always be possible (for instance, the time at which reindeer are normally gathered during summer (for marking) calves are too small for boli administration. Hence additional gathering of the animals may be required.
Factors influencing costs	Cost of producing AFCF boli. Fuel price in the affected area. Distance the veterinarian has to travel. If not possible to fit into normal management practices, costs associated with extra gathering of free-ranging animals.
Compensation costs	**Farmers/herders:** • for time to gather animals • for time to administer boli. (20 EUR per reindeer treated has been given in Norway) • cost of boli.
Waste cost	None.
Assumptions	None.
Communication needs	Requirement for labelling products.
Side-effect evaluation	
Ethical considerations	Animal welfare: Reindeer deaths have been reported due to wrong techniques when administering the boli.
Environmental impact	Whilst some soils may contain bacteria or fungi capable of degrading cyanide, toxic levels of HCN should not arise under field conditions.
Agricultural impact	Limited impact as conventional farming practices can be maintained without severe disruption although may impact more on reindeer herders. Change in agricultural production status (especially organic).
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' (resulting in loss of employment in local 'cottage' industries or growth of a black market). • increased public confidence that the problem of contamination is being effectively managed.
Other side effects	Can maintain the production of meat and milk without disrupting the normal farming practices.
FARMING Network stakeholder opinion	Of the options aimed at reducing radionuclide transfer along the soil-plant or plant-animal pathway, normal ploughing, the application of fertilisers and lime to soils, and the addition of binders or sorbents to feed were the options preferred by most stakeholders. These management options were seen to sustain farming practices and cause minimal impact on the environment.
Practical experience	Used in production systems in Norway and the fSU after the Chernobyl accident. In fSU a different hexacyanoferrate compound (Ferrocyn) was used. Tested on a number of upland farms in UK.

Key references	Giese WW (1988). Ammonium-ferric-cyano-ferrate(II) (AFCF) as an effective antidote against radiocaesium burdens in domestic animals and animal derived foods. *Br. Vet. Journal*, 144, 363. Howard BJ, Beresford NA and Voigt G (2001). Countermeasures for animal products: a review of effectiveness and potential usefulness after an accident. *Journal of Environmental Radioactivity*, 56, 115-137. Nisbet AF and Woodman RFM (2000). Options for the Management of Chernobyl-restricted areas in England and Wales. *Journal of Environmental Radioactivity*, 51, 239-254. Pearce J (1994). Studies on any toxicological effects of Prussian Blue compounds in mammals – a review. *Food Chem. Toxicol.*, 32, 577-582. Tveten U, Brynildsen LI, Amundsen I and Bergan TDS (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. *Journal of Environmental Radioactivity*, 41 (3), 233-255. Beresford NA, Hove K, Barnett CL, Dodd BA, Fawcett RH and Mayes RW (1999). The development and testing of an intraruminal slow-release bolus designed to limit radiocaesium absorption by small lambs grazing contaminated pastures. *Small Ruminant Research*, 33, 109-115. Hansen HS, Hove K and Barvik K (1996). The effect of sustained release boli with ammoniumiron(III)-hexacyanoferrate)II) on radiocesium accumulation in sheep grazing contaminated pasture. *Health Physics*, 71, 705-712. Hove K, Staaland H, Pedersen Ø, Ensby T and Sæthre O (1991). Equipment for placing a sustained release bolus in the rumen of reindeer. *Rangifer*, 11, 49-52. Hove K and Hansen HS (1993). Reduction of radiocaesium transfer to animal products using sustained release boli with ammoniumiron(III)-hexacyanoferrate(II). *Acta vetinaria scandinavia*, 34, 287-297. Ratnikov AN, Vasiliev AV, Krasnova EG, Pasternak AD, Howard BJ, Hove K and Strand P (1998). The use of hexacyanoferrates in different forms to reduce radiocaesium contamination of animal products in Russia. *Science of the Total Environment*, 223, 167-176.
Comments	Detailed toxicological studies have shown that AFCF has no adverse affects on animal or human health. Live-monitoring prior to slaughtering can be a good supplement to control the effectiveness of the management option.
Document History	**STRATEGY originator:** Liland A (NRPA). **STRATEGY contributors:** Nisbet AF, Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Pearce J (Department of Agriculture and Rural Development, Northern Ireland, UK); Brynildsen L (Ministry of Agriculture, Norway). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** Skuterud L (NRPA).

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27 Administration of clay minerals to feed

Objective	To reduce activity concentrations of radiocaesium in meat or milk to below intervention levels.
Other benefits	Some clay minerals may also reduce radiostrontium absorption. Reduction in quantities of animal produce that will need to be disposed of. Normal animal management/grazing regimes can be used.
Management option description	Clay minerals (i.e. bentonites, vermiculites, zeolites) can be added to fodder to reduce gut uptake of radiocaesium by farmed livestock.
Target	Meat and milk producing animals. Inappropriate for free grazing livestock (most applicable to dairy animals as these tend to be fed twice-daily as part of normal farming practice).
Targeted radionuclides	**Known applicability:** $^{134,137}Cs$ **Probable applicability:** - **Not applicable:** -
Scale of application	Large.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated meat and milk.
Time of application	Medium to long term (requirement to secure suitable sources of clay minerals and preferable incorporation into pelleted rations means that this management option is unlikely to be feasible in the short-term).
Constraints	
Legal constraints	The sale of milk and meat is subject to Council Food Intervention Limits (CFILs). Bentonite is a legal feed additive in some countries to prevent scouring. Labelling may be required.
Social constraints	Public/farmers resistance to management option. Acceptability of method with respect to animal welfare issues.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Bentonite is moderately effective at reducing levels of radiocaesium in milk and meat of various animals. For radiocaesium: reductions of about 50% can be achieved by a dose of about 0.5 g kg^{-1} body weight per day. A maximum reduction of about five-fold can be achieved at a administration rate of 1-2g kg^{-1} body weight per day.
Factors influencing effectiveness of procedure	Effective administration of the clay minerals. As the administration rate increases the greater the reduction of radionuclides in milk or meat. However, loss of appetite and weight have been observed if a too much clay is given. Period of adaptation to pelleted feed may be required. Initial activity concentration and the biological half-life of radiocaesium in the animal. Clay minerals from different sources have different binding capacities. Compliance to the management option.
Feasibility	
Required specific equipment	None.
Required ancillary equipment	None.
Required utilities and infrastructure	Transportation of clay minerals from extraction site, and subsequent storage facilities. Ideally a factory to incorporate clay minerals into pelleted feed rations during manufacture.

Required consumables	Clay minerals. Transportation costs.
Required skills	Farmers/herders would possess the necessary skills to add clay minerals to feed provided instructions were given.
Required safety precautions	None.
Other limitations	Cannot be fed on a daily basis to free grazing animals. May be used for free ranging animals in combination with confining them to enclosures (maybe especially applicable to reindeer). Some problems reported in Sweden in the industrial incorporation of bentonite into feed pellets (at 2.5% by weight). However, bentonite has been previously incorporated into feeds as an anti-scouring agent.
Waste	
Amount and type	None
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	None.
Intervention Costs	
Equipment	None.
Consumables	Clay minerals. Fuel for transportation of clay minerals.
Operator time	If clay minerals were not provided to the farmer/herder already incorporated in feed, the farmer/herder would need to mix the clay minerals with the feed. Additional time would be required to oversee that each animal ingested an appropriate amount.
Factors influencing costs	Production cost for the concentrates with added clay. Transportation costs.
Compensation costs	**Farmer:** for additional work.
Waste cost	N/A.
Assumptions	None.
Communication needs	Possible requirement for labelling products directly or indirectly affected by application of the management option.
Side-effect evaluation	
Ethical considerations	Animal welfare issues associated with feeding atypically high quantities of clay minerals.
Environmental impact	Effect of extracting large quantities of clay minerals on the landscape if quarry is not already in operation. In early –medium phase clay minerals would be sourced from existing quarries for speed. Possible trace element deficiency in pasture if 'large' quantities of e.g. zeolite are spread to land with slurry/manure.
Agricultural impact	May be necessary to provide additional water. Limited impact as conventional farming practices can be maintained without severe disruption. Change in production status for organic farms.
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' (may i.e. result in loss of employment in local 'cottage' industries or growth of a black market), • increased confidence that the problem of contamination is being effectively managed.

	May impact on the 'natural' perception of some products.
Other side effects	Can maintain the production of meat and milk without disrupting normal farming practices.
FARMING Network stakeholder opinion	Of the options aimed at reducing radionuclide transfer along the soil-plant or plant-animal pathway, normal ploughing, the application of fertilisers and lime to soils, and the addition of binders or sorbents to feed were the options preferred by most stakeholders. These management options were seen to sustain farming practices and cause minimal impact on the environment.
Practical experience	Bentonite was used in Sweden after Chernobyl, for reindeer in conjunction with clean feed. However, the cost was considered to be high relative to the additional 'effect' over clean feeding so the practice was discontinued. Bentonite was used in Norway the first year after the Chernobyl accident in concentrates for sheep, goats, cattle and reindeer but was substituted with AFCF from the second year due to higher effectiveness and easier handling of AFCF.
Key references	Unsworth EF, Pearce J, McMurray CH, Moss BW, Gordon FJ, and Rice D (1989). Investigations of the use of clay minerals and Prussian Blue in reducing the transfer of dietary radiocaesium to milk. *Science of the Total Environment*, 85, 339-347. Voigt G (1993). Chemical methods to reduce the radioactive contamination of animals and their products in agricultural ecosystems. *Science of the Total Environment*, 137, 205-225. Åhman B, Forberg S and Åhman G (1990). Zeolite and bentonite as caesium binder in reindeer feed. *Rangifer*, Special Issue No.3, 73-82. Åhman B (1996) Effect of bentonite and ammonium-ferric(III)-hexacyanoferreate(II) on uptake and elimination of radiocaesium in reindeer. *Journal of Environmental Radioactivity*, 31, 29-50.
Comments	It may be most effective to incorporate clay minerals into pelleted feeds at manufacture. This avoids loss of binder in feeding troughs. As with the use of all feed additives the faeces from treated animals will be more contaminated than for untreated animals. This can give higher external dose for the person responsible for handling the manure although this is not believed to reach levels of concern in practice. Live-monitoring prior to slaughtering can be a good supplement to control the effectiveness of the management option for each animal or a selection within a herd/flock. Radiostrontium**:** Clay minerals have also been suggested as feed-additive binders for radiostrontium. In comparatively recent studies Hansen, Saether, Asper and Hove (1995, IAEA-SM-339/198P. pp. 719-721) tested a range of different clay minerals in dairy goats. Of these only sodium-aluminiumsilicate (Zeolite A (Na)), which is widely used in the chemical industry, administered at a rate of 0.5g kg^{-1} live weight d^{-1} was effective, reducing the radiostrontium activity concentration in milk by ca. 40%. However, this compound influences the absorption of a number of essential elements, and the potential implications have not been adequately considered. If zeolite were to be advised as a management option for Sr, further work would be required to determine if trace mineral metabolism was adversely affected.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Pearce J (Department of Agriculture and Rural Development, Northern Ireland, UK). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH

	(Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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28 Change of hunting season

Objective	To reduce internal dose to consumers by changing/restricting the hunting season to a period when the contamination levels in game meat are low.
Other benefits	Traditional hunting for game can be preserved; the amount of condemned meat will be reduced.
Management option description	Hunting is usually restricted to certain periods of the year. Due to seasonal variation in diet the contamination levels in some game species will vary significantly with season. By changing or restricting the hunting season to the time of year when the contamination levels in the game meat will be lowest, the internal dose to humans consuming game meat will be reduced. A ban on or a delay in hunting may be applicable in the short term due to ingestion of surface deposition on plants and to allow decay of short lived radionuclides.
Target	Game.
Targeted radionuclides	**Known applicability:** All (in long-term predominantly $^{134,137}Cs$) **Probable applicability:** - **Not applicable:** -
Scale of application	Large.
Contamination pathway	Plant to animal.
Exposure pathway	Ingestion of contaminated meat.
Time of application	Early to long term.
Constraints	
Legal constraints	In most countries EU countries hunting seasons have a legal status and are set according to breeding seasons. Hunting therefore cannot be conducted at these times of year and the capacity to change the seasons is limited.
Social constraints	Resistance from hunters. Acceptability of changing hunting seasons raises wildlife issues, which are likely to be contested if seasons start earlier or occur later than normal.
Environmental constraints	Changed hunting season must not coincide with breeding season; different hunting seasons for male and female animals could be used (as is now the case for many species).
Effectiveness	
Management option effectiveness	If used as a long-term measure with respect to radiocaesium activity concentrations in meat at the optimised hunting time can be as low as 15% (wild reindeer) to 35% (moose) of that expected during the traditional hunting season.
Factors influencing effectiveness of procedure	If used as a short-term measure to allow decay of short lived radionuclides effectiveness will be dependent upon time delay between deposition and allowing hunting. Availability of suitable information channels. In long-term, with respect to radiocaesium, fungi availability to game before and during hunting (varies by year, time of hunting and site). Shortening the hunting season (e.g. cutting the last few days or weeks) may have little effect on dose as fewer animals remain. However, the entry of the most contaminated meat into the foodchain would be avoided. Hunters' compliance with the management option.
Feasibility	

Required specific equipment	Different seasons may require alternative equipment, for instance to remove carcasses in northern countries.
Required ancillary equipment	None.
Required utilities and infrastructure	Communication lines.
Required consumables	Dependent on communication method.
Required skills	Communication skills.
Required safety precautions	If hunting season is shortened then there may be an increased number of hunters visiting forests during a shorter season which may have an adverse effect on their safety.
Other limitations	None.
Waste	
Amount and type	None. Waste in the form of contaminated carcasses would only be produced if hunting/fishing season is significantly reduced in length or excluded completely and a management programme is initiated that involves culling to maintain stocks at appropriate levels.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	None.
Intervention costs	
Equipment	Alternative equipment due to seasonal differences.
Consumables	Dependent on communication method.
Operator time	Dependent on communication method.
Factors influencing costs	Infrastructure available for communication and exchange of information during processing of information, decision-making and implementation of management option.
Compensation costs	**Hunters:** for unused hunting licences.
Waste cost	None.
Assumptions	None.
Communication needs	Guidance for hunters (possible requirement for rapid distribution).
Side-effect evaluation	
Ethical considerations	
Environmental impact	Impact on ecosystem (due to lack of game management), population dynamics, breeding, mortality/birth rate, competition etc. The continuous management of large game species through hunting licenses is of utmost importance to keep the number of animals at a sustainable level. It is therefore important to keep hunting (culling) under all circumstances even if the meat does not enter the foodchain.
Agricultural impact	May cause an increase in the numbers of herbivores which may have impact on grassland, forestry etc. Increase in predator numbers may have impact on farm animal husbandry. Possible increased grazing on agricultural lands if hunting season delayed, especially if extended over winter when food sources may be low.
Social impact	Loss of traditional activities.
Other side effects	Reduced financing of game management due to cancellation of hunting licences.
FARMING Network Stakeholder opinion	Not considered by FARMING Network.

Practical experience	Has been tested/used in Sweden after the Chernobyl accident for moose and roe deer with positive effect, especially for roe deer (see Johanson, 1994).
Key references	Avila R (1999). Radiocaesium transfer to roe deer and moose, SSI-news (a newsletter from the Swedish radiation protection institute), volume 7, number 2. Johanson KJ (1994). Radiocaesium in game animals in the Nordic countries. In: Dahlgaard, H. (Ed.). Nordic radioecology – The transfer of radionuclides through Nordic ecosystems to man. Studies in Environmental Science 62, Elsevier, Oxford, 1994, pp.287-301. Howard BJ, Wright SM, and Barnett CL (eds.) (1999). Spatial analysis of vulnerable ecosystems in Europe: Spatial and dynamic prediction of radiocaesium fluxes into European foods (SAVE), Summary and final report, Contract FI4PCT950015, European Commission.
Comments	Lower slaughter weights if the hunting is performed earlier than usual. If hunting takes place in summer, hygiene problems in handling of meat would occur due to higher outdoor temperature. If restricted to winter, harsh climate may make hunting less attractive in some countries.
Document History	**STRATEGY originator:** Liland A (NRPA). **STRATEGY contributors:** Nisbet AF, Mercer JA and Hesketh N (HPA-RPD); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Rantavaara A (Radiation and Nuclear Safety Authority, Finland; Barikmo J (Directorate for Nature Management, Norway). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** n/a

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29 Clean feeding	
Objective	To reduce activity concentrations of radionuclides in milk and meat to below intervention levels.
Other benefits	Reduces amount of milk and meat in excess of intervention limits requiring disposal.
Management option description	Provide animals with less or uncontaminated feedstuffs. Target animals may be those grazing contaminated pastures or already housed animals which would otherwise be receiving contaminated diets. Livestock may be fenced in enclosures or housed to prevent grazing of contaminated pasture. The animals are then given nutritionally balanced diets comprising uncontaminated and/or less contaminated feed so that the final animal product has activity concentrations less than the Council Food Intervention Limits (CFIL). For milk producing animals clean feeding will need to be continuous whilst pasture activity concentrations would result in milk exceeding CFILs. For meat producing animals clean feeding is only required for a suitable period prior to slaughter (depending upon initial activity concentrations and biological half-lives). Management option is also suitable for semi-domesticated reindeer.
Target	All livestock (especially grazing animals) that are destined for the foodchain.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Large scale application, although dependent on supply of suitable clean feed at a reasonable price.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated milk and meat.
Time of application	Early to long term.
Constraints	
Legal constraints	The sale of milk and meat intended for human consumption is subject to CFILs. Standards of animal husbandry and welfare and regulations governing feed storage would need to be observed. Some certification schemes (e.g. organic production or 'free range') may be contravened. Local regulations on the use and sitting of buildings. In some countries there may be an upper age limit over which animals may not enter the foodchain (e.g. Over Thirty Month Scheme for beef cattle in UK). Some conservation schemes only allow grassland management to take place at certain times of the year to protect nesting birds etc. Stocking rates may also be defined within some conservation schemes. Regulations on the management of agricultural discharges; e.g. the management option will result in the production of manure/slurry on which there may be legal restrictions with regard to when it can be spread to land.
Social constraints	Resistance of farmer/herder to management option. Acceptability to food industry/consumers of changes in the quality of the food product (e.g. the feeding of high levels of cereal concentrates to lambs can result in the body fat being soft and flabby, colour may also be affected).

Environmental constraints	Housing of livestock produces large volumes of slurry/manure. This must be stored and disposed of to land at times when 'conventional' pollution (from manure/slurry) would not occur (e.g. suitable weather conditions).
Effectiveness	
Management option effectiveness	Will effectively reduce the contamination in meat and milk according to the animal's biological half-life for a given radionuclide. Combination of long biological and physical half-lives will limit the effectiveness of this management option for actinides and ^{90}Sr if used with previously contaminated animals. Management option may reduce amount of waste (contaminated) milk and meat by 100 %.
Factors influencing effectiveness of procedure	Farmers/herders willingness and ability to adapt to the new regime. Capacity for feed measurements and live monitoring. Availability and level of contamination of alternative feeds. Rate at which alternative diet is introduced and duration of feeding regime. If grazing stopped and the new (less contaminated) diet comprises root crops and cereals a period of adaptation of two weeks is desirable. This is less important if the uncontaminated diet contains silage and hay. Biological half-life of specific radionuclide – livestock species combination. Willingness and ability of livestock to adapt to new regime. The requirement for clean feeding and the availability of conserved feed will be dependent on the time of year that an accident occurs. For example, in winter there would be little impact for housed livestock being fed stored feeds. Finishing lambs grazing forage crops however would have to be housed and given conserved clean feed. Late spring would be the worst time for a contamination event, since cattle and lambs would be grazing outside and no new hay or silage would have been harvested. If the accident was later in summer animals could be fed hay or silage that had been cut before the accident. For some of the alternative diets, reduction in grazing is only worth considering for restrictions lasting more than a few weeks because of time required to introduce alternative diets.
Feasibility	
Required specific equipment	Live monitoring equipment. Fencing in or housing livestock to administer alternative diets should be possible on most livestock farms (particularly dairy and systems where animals are normally housed). Existing fences or farm buildings could be used to house livestock prior to sale, although some would require modification to penning and feeding arrangements or ventilation. New, purpose built sheds could also be considered if period of clean feeding warranted this. Storage facilities for clean feed. Storage facilities for slurry/manure. Feeding and drinking troughs, and possibly shelters for these where being used outdoors.
Required ancillary equipment	Slurry tanks and manure spreading equipment. Possibly animal transporters and vehicles to deliver feed. Forage harvester to cut grass for pasture management (see below).
Required utilities and infrastructure	Water. Power supply. Ventilation.

Required consumables	Alternative feeds. Organic feed may be required to maintain organic status of some farms. In the case of reindeer provision of some lichen from uncontaminated areas may be preferable to allow adaptation of gut flora to concentrate/forage diet during winter. Straw for bedding.
Required skills	Farmers/herders would possess the necessary skills as housing/coralling animals is an existing practice. Some reindeer herders are not used to corralling and/or supplementary feeding and may therefore need instruction.
Required safety precautions	General precautions for animal handling.
Other limitations	Must ensure that alternative diets are nutritionally balanced and introduced at a rate such that gut flora can adapt.
Waste	
Amount and type	A programme of grassland management must be implemented while livestock are fenced or housed to (i) ensure that intervention levels are not exceeded when the animals are reintroduced to pasture; (ii) ensure pasture quality is maintained. This involves cutting and disposing of contaminated grass before animals are returned to pasture. Slurry/manure produced while livestock are fenced in/housed.
Possible transport, treatment and storage routes	The cut grass may be composted (51 Composting) and the compost subsequently applied to the land. Alternatively, silage may be made from the harvested biomass. Such silage could later be fed to non-critical stock or stored for an extended period to allow for radioactive decay. If the critical radionuclide was ^{131}I (or other radionuclides with short physical half-lives), then the normal feed storage period of 6-12 month would more than suffice. If harvested biomass is stored for composting or silage making, care must be taken to control any liquid effluent produced because it is likely to be contaminated. For less contaminated pastures, an alternative to composting or ensilage of harvested pasture biomass, is to cut the pasture repeatedly and leave the cut material *in situ*. Slurry/manure should be stored and landspread at appropriate times.
Factors influencing waste issues	Level of contamination in cut pasture. The spreading of compost back on farmland is only reasonable if the storage period is sufficient for the most important radionuclides to decay, or if the land was used for non-food production. When land is frozen or waterlogged, slurry/manure cannot be spread and must be stored to avoid water pollution. The storage capacity on farms needs to be sufficient to handle the extra quantities of slurry/manure. In summer, slurry/manure could possibly be applied to pasture that would otherwise be grazed, so areas for spreading may be greater.
Doses	

Incremental dose *Incremental doses will be incurred from the disposal of grass mowings and slurry/manure either by composting (51 Composting) or landspreading (55 Landspreading of milk and/or slurry). There are separate datasheets for these waste disposal options.*	**Farmer/herder while collecting livestock:** • external exposure while collecting livestock from pasture • external dose whilst maintaining animals. **Farmer while mowing grass:** • external exposure and inhalation while mowing grass. **Farmer while ensiling:** • external exposure and inhalation while ensiling grass. **Farmer while feeding (other) livestock:** • external exposure, inadvertent ingestion and hand skin exposure from silage (harvested as part of grassland management) while feeding livestock which are not the target of this management option.
Intervention Costs	
Equipment	Modification to housing. Construction of new housing, fences and/or feed storage facilities. Forage harvester.
Consumables	Uncontaminated feed. Cost of replacing foodstuffs that would normally have been used during the winter. Additional concentrates may be required to nutritionally balance the alternative diets. Fuel for animal/feed transport.
Operator time	**Farmer/herder:** • obtaining uncontaminated feed (and harvesting grass pre-deposition) • looking after animals not normally housed/fenced • implementation of the alternative feeding regime • collection, storage and disposal of slurry/manure • cutting and disposal (e.g. composting, silage making) of contaminated grass • time required for construction of additional enclosures, housing etc.
Factors influencing costs	Availability of housing, fences, feeds, machinery and manpower. The period of clean feeding required will be influenced by initial activity concentration of livestock, biological half-life and activity concentration of replacement feed.
Compensation costs	**Farmer/herder:** • using up stores of alternative feed • additional work • loss of income from not adhering to conservation schemes.
Waste cost	Farmer time cutting and composting contaminated grass and landspreading additional slurry/manure.
Assumptions	Monitoring of animals is carried out following periods of clean feeding – these costs need to be added to this management option (see 32 Live monitoring).
Communication needs	Explaining management option to farmers/herders. Ensuring communication re harvesting of grass in pre-deposition phase.
Side-effect evaluation	
Ethical considerations	Self-help for farmers/herders. Animal welfare issues if animals are housed in the summer when temperature and ventilation could be a problem (e.g. humidity/high levels of ammonia in buildings). Animal welfare issues may also arise when enclosures are used (e.g. parasite burden, general animal hygiene).

Environmental impact	Inappropriate disposal of additional slurry/manure could lead to pollution of water courses. Possible changes in landscape due to citing of new buildings.
Agricultural impact	Reduced grazing on fields. If clean feeding occurs in areas with a high stocking rate surface vegetation will be destroyed. Greater volumes of manure/slurry.
Social impact	Disruption to people's image/perception of 'countryside' e.g. if there are no animals in the fields, with potential impacts on tourism etc. May impact on public confidence e.g., • loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' (resulting in loss of employment in local 'cottage' industries or growth of a black market) • increased public confidence that the problem of contamination is being effectively managed. Maintenance of traditional ways of life. Sami reindeer herders are the only indigenous population in Europe. Reindeer herding is their traditional livelihood, economically significant and basis of their culture.
Other side effects	
FARMING Network stakeholder opinion	The provision of clean feed to livestock was considered to be the preferred option for reducing the amount of radionuclides ingested. It was acceptable to all stakeholder groups because it would sustain farming practices and thereby minimise the impact on farmers' livelihoods and disruption to the food industry. Stakeholders were concerned that the supplies of clean feed could be limited for accidents occurring at certain times of the year, especially in early spring. Importation from outside an affected area would overcome such a problem, although this could be expensive.
Practical experience	Clean feeding is still in use in Norway and Sweden due to the Chernobyl accident for sheep, reindeer and some cattle grazing unimproved pastures.
Key references	Åhman B (1999). Transfer of radiocaesium via reindeer meat to man - effect of countermeasures applied in Sweden following the Chernobyl accident. *Journal of Environmental Radioactivity*, 46, 113-120. Brynilsen L and Strand P (1994). A rapid method for the determination of radioactive caesium in live animals and carcasses and its practical application in Norway after the Chernobyl accident. *Acta Veterinaria Scandinavica*, 35, 401-408. Howard B, Beresford N and Hove K (1991). Transfer of radiocaesium to ruminants in natural and seminatural ecosystems and appropriate countermeasures. *Health Physics*, 61 (6), 715-725. Heiskari U and Nieminen M (2004). Different grass fodders in the winter feeding of reindeer. Finnish Game and Fisheries Research Institute, Fish and Game reports No. 314 (In Finnish, English abstract). Maijala V and Nieminen M (2004) The all year feeding of reindeer and its profitability. Finnish Game and Fisheries Research Institute, Fish and Game reports No. 304 (In Finnish, English abstract). Shaw S, Green N, Hammond DJB and Woodman RFM (2001). Management options for food production systems affected by a nuclear accident. 1. Radionuclide behaviour during composting. NRPB-R328. Smith J, Nisbet AF, Mercer JA, Brown J and Wilkins BT (2002). Management options for food production systems affected by a nuclear accident: Options for minimising the production of contaminated milk. NRPB-W8. Tveten U, Brynildsen LI, Amundsen I and Bergan TDS (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. *Journal of Environmental Radioactivity*, 41(3), 233-255.

Comments	Sheltering of animals prior to and during deposition is dealt with in a separate datasheet (6 Short-term sheltering of dairy animals). For extensive farming systems, pasture management is not common practice. In this case, clean feeding can be imposed after unimproved pasture grazing for a given time period prior to slaughter. There is a tendency for more traditional systems based on grazed and ensiled pasture to be replaced by whole crop maize silage and perennial ryegrass. Such management systems are less amenable to modification to accommodate clean feeding regimes. Management option could be combined with a harvesting of grass in the pre-deposition phase to increase feed stocks. However, it is unlikely that there would be sufficient time to harvest grass prior to deposition using normal practices (e.g. large bale silage making generally requires 2 days). There may also be restrictions on available labour to harvest grass given animal housing would need to be prepared and livestock gathered.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Mayes B (Macaulay Land Use Research Institute, UK) and Brynildsen B (Ministry of Agriculture, Norway). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Åhman B (Swedish University of Agricultural Sciences).

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30 Decontamination techniques for milk	
Objective	To remove contamination from milk and return this milk to the foodchain.
Other benefits	To reduce quantity of contaminated milk to be disposed of. Maintenance of farming and associated communities.
Management option description	Techniques are available for removing radionuclides from milk on a large scale; these include magnetic separation, ion exchange, electrodialysis and ultrafiltration. A relatively new method, 'MAG*SEP^{SM}', uses specially coated magnetic particles that selectively remove radioactive contaminants from aqueous liquids, through selective adsorption and magnetic filtration.
Target	Milk.
Targeted radionuclides	**Known applicability:** ^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs **Probable applicability:** - **Not applicable:** ^{131}I and ^{140}Ba are not included in the target radionuclide list above as short physical half-lives are likely to preclude the use of this management option
Scale of application	Small to medium.
Contamination pathway	n/a
Exposure pathway pre intervention	Ingestion of contaminated milk.
Time of application	Medium to long term if decontamination equipment not stored for contingency purposes.
Constraints	
Legal constraints	After treatment, milk intended for human consumption is subject to Council Food Intervention Limits (CFILs). There will be legal constraints on the fate of used exchange resins/ MAG*SEP^{SM} resins / ultrafiltration membranes / electrodialysis membranes and salt solutions. Labelling of milk produced by decontamination procedures may be required.
Social constraints	Economic viability. The consumer's perception of decontamination of milk may be similar to that of the practice of food irradiation which consumers have firmly rejected over the years. Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade/consumers when foodstuffs can be obtained from other sources. Resistance to the management option by the dairy industry/public.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Ion exchange can result in the removal of up to 90% of the radionuclides. Ultra-filtration can result in the removal of over 99% of caesium. MAG*SEP^{SM} resins can remove over 99% of caesium. Electrodialysis can result in the removal of up to 90% of the radionuclides; available information on effectiveness is limited to Cs, Sr, I and Ba (^{131}I and ^{140}Ba are not included in the target radionuclide list above as short physical half-lives are likely to preclude the use of this management option).
Factors influencing effectiveness of procedure	The decontamination process selected. Radionuclide(s) present. Acceptability of management option to dairy industry/public.

Feasibility	
Required specific equipment	Decontamination unit – lack of immediate availability means that this measure is unlikely to be feasible in early phase.
Required ancillary equipment	None.
Required utilities and infrastructure	Somewhere to site the decontamination unit, i.e. dairy.
Required consumables	Exchange resins/ MAG*SEP^{SM} resins / ultra-filtration membranes / electrodialysis membranes and salt solutions as required.
Required skills	Specific training in the techniques would be required for dairy personnel using the decontamination units. Specific training on the handling of waste.
Required safety precautions	Dose monitoring of workers handling spent resins/sorbents/filters may be necessary.
Other limitations	Currently (2005), there are no decontamination units available for use outside the Ukraine. Unless stored as part of contingency plans, such units would need to be imported resulting in delays in implementation. The manufacturers suggest that it would take up to three weeks for a separation unit to be set up to treat milk on an industrial scale.
Waste	
Amount and type	Used exchange resins/ MAG*SEP^{SM} resins / ultrafiltration membranes / electrodialysis membranes and salt solutions. Aqueous waste may also arise from regeneration of exchange resins and sorbents.
Possible transport, treatment and storage routes	Disposal to 54 Landfill.
Factors influencing waste issues	Dependent on quantity of resins used. Typically for ^{137}Cs 20kg of resins are used to treat 100 batches of milk (each batch representing 1 metric ton of milk). If radionuclide concentrations are well in excess of the CFIL, waste stream may be very contaminated. Disposal of such materials would be subject to individual national regulations but might require licensing.
Doses	
Incremental dose *There is a separate datasheet describing the incremental dose pathways associated with 54 Landfill as a disposal option for the used resins.*	**Tanker driver:** external exposure while transporting contaminated milk to decontamination unit. **Operative at decontamination unit:** external exposure from decontamination unit and disposing of resins/membranes etc.
Intervention Costs	
Equipment	Decontamination units.
Consumables	Exchange resins/ MAG*SEP^{SM} resins/ultra-filtration membranes/ electrodialysis membranes and salt solutions.
Operator time	Tanker driver. Installation and operation of decontamination units and disposal of consumables.
Factors influencing costs	Volume of resins/membranes required. Quantities of milk. Contamination levels in milk.
Compensation costs	**Farmer or milk purchaser:** loss of market value for decontaminated milk. **Milk processor (dairy):** handling contaminated milk.
Waste cost	Landfill costs and tax.
Assumptions	That there is a market for the end product. That appropriate monitoring is carried out at dairy.

Communication needs	Labelling of milk produced by decontamination procedures may be required. Information and training for operators. Consumer response regarding acceptability of final product is likely to be highly dependant upon the provision of relevant information.
Side-effect evaluation	
Ethical considerations	Redistribution of dose from consumers to operators of decontamination units and those involved in the disposal of resins etc., including populations around waste facilities. Distribution of costs and benefits (e.g. possible inequity due to change in prices of decontaminated milk with lower income populations buying the treated milk).
Environmental impact	Minimal.
Agricultural impact	None.
Social impact	Possible loss of confidence in products/potential for generating mistrust of food production system. Rejection of the treated milk or decrease in market price. Conversely, possible increase in public confidence that the problem of contamination is being effectively managed. Disruption/adjustment of farming and related industrial activities (e.g. to the supply of milk and potential market shortages.
Other side effects	Ion exchange and electrodialysis can result in adverse effects on the nutritional quality or organoleptic properties of the milk. MAG*SEP^{SM} does not adversely affect milk quality.
FARMING Network stakeholder opinion	Stakeholders unanimously agreed that there are no processing options that can be considered as generally acceptable. Options involving removal of contamination from crops, milk and meat during industrial processing were viewed by some stakeholders to be acceptable under specific circumstances. However, in countries where consumer confidence has been seriously affected by previous food scares (e.g. UK and Belgium) any process that produces marketable food from contaminated raw materials was considered to be unacceptable.
Practical experience	MAG*SEP^{SM} was used on an industrial scale to decontaminate milk in the Ukraine following the Chernobyl accident: the nutritional quality, colour and smell was not affected.
Key references	Long S, Pollard D, Cunningham JD, Astasheva NP, Donskaya GA and Labetsky EV (1995). The effects of food processing and direct decontamination techniques on the radionuclide content of foodstuffs: a literature review. Part 1: milk and milk products. *Journal of Radioecology*, 3,1, 15-30. Mercer J, Nisbet AF and Wilkins BT (2002). Management options for food production systems affected by a nuclear accident: 4 Emergency monitoring and processing of milk. NRPB-W15. Patel AA and Prasad SR (1993). Decontamination of radioactive milk – a review. *International Journal of Radiation Biology*, 63 (3), 405-412.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Pollard D (Radiological Protection Institute of Ireland). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N

	and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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31 Distribution of saltlicks containing AFCF

Objective	To reduce activity concentrations of radiocaesium in meat or milk of free-grazing animals to below intervention levels.
Other benefits	Reduction in quantities of animal produce that will need to be disposed of. Normal animal management/grazing regimes can be maintained.
Management option description	In salt deficient areas the intake of salt by grazing animals may be sub-optimal and saltlicks are annually placed on pastures to supplement their intake. Ammonium iron hexacyanoferrate (AFCF, Giese-salt), an effective radiocaesium binder, can be added to such licks (at 2.5%) to reduce the uptake of radiocaesium in the animals gut.
Target	Milk and meat producing animals.
Targeted radionuclides	**Known applicability:** $^{134,137}Cs$ **Probable applicability:** - **Not applicable:** Specific to radiocaesium
Scale of application	Large.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated milk or meat.
Time of application	Medium to long-term.
Constraints	
Legal constraints	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). On 14th October 2001 permanent authorisation was given by the European Communities for AFCF to be used as a feed additive for the purposes of binding radiocaesium (Regulation 2013/2001). May not be allowed under some organic production regimes. Labelling may be required.
Social constraints	Resistance to the management option. Acceptability by farmers/herders, food industry and consumers to using an additional feed additive to reduce uptake from the gut of livestock.
Environmental constraints	Only likely to be effective in areas where animals are salt deficient. In coastal areas the pastures will naturally contain sodium, and the animals' are unlikely to utilise saltlicks.
Effectiveness	
Management option effectiveness	Around 50% reduction in uptake of radiocaesium. However, there is considerable variation in effectiveness between animals within a given flock/herd (due to willingness to visit saltlicks). Depending upon deposition levels and husbandry routines may be most effective targeted to period prior to slaughter.
Factors influencing effectiveness of procedure	Requirement of animals' for additional salt. Frequency of the animals' use of the saltlick. Biological half-life of animal. Spatial application rate and stocking density. Compliance to management option. Effective administration of the saltlicks.
Feasibility	
Required specific equipment	None.
Required ancillary equipment	

Required utilities and infrastructure	Saltlick distribution is an existing practice in areas where this management option would be effective. Manufacturing plants willing to incorporate AFCF into their products.
Required consumables	Saltlicks containing 2.5 % AFCF.
Required skills	Existing animal husbandry practice. Some training/development in manufacturing plants making large quantities of AFCF-saltlicks.
Required safety precautions	None.
Other limitations	Current production facilities for AFCF may be rate limiting if large quantities required.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	None.
Intervention costs	
Equipment	None.
Consumables	AFCF.
Operator time	None. The saltlicks are distributed on pastures independent of whether AFCF is needed or not.
Factors influencing costs	Production costs. Transportation costs. As an example for use in Norway saltlicks with AFCF are produced in Germany and cost €30.6 EUR (including delivery to Norway) for a 10 kg saltlick compared with €4 for a standard saltlick. One 10 kg saltlick is sufficient for 20 sheep over 3 months, or for 20 dairy cows during 10 days.
Compensation costs	**Farmer/herder:** costs associated with buying saltlicks with AFCF. **Producers:** loss of income if treated product is not accepted by consumers.
Waste cost	N/A.
Assumptions	None.
Communication needs	Possible requirement for labelling products directly or indirectly affected by application of the management option.
Side-effect evaluation	
Ethical considerations	
Environmental impact	Whilst some soils may contain bacteria or fungi capable of degrading cyanide, toxic levels of HCN should not arise under field conditions.
Agricultural impact	Possible change in production status (i.e. organic farming).
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products from affected areas is ‘safe’ (may i.e. result in loss of employment in local ‘cottage’ industries or growth of a black market) • increased confidence that the problem of contamination is being effectively managed. Foodstuffs may not be acceptable to the retail trade when “clean” foodstuffs can be obtained from other sources. Disruption/adjustment of farming and related industrial activities, e.g. supplies to food industry and potential for market shortages.

	May impact on the 'free-range' or 'natural' perception of some meat products.
Other side effects	Can maintain the production of meat and milk without disrupting the normal farming practices.
FARMING Network stakeholder opinion	Of the options aimed at reducing radionuclide transfer along the soil-plant or plant-animal pathway, normal ploughing, the application of fertilisers and lime to soils, and the addition of binders or sorbents to feed were the options preferred by most stakeholders. These management options were seen to sustain farming practices and cause minimal impact on the environment.
Practical experience	Widely used in Norway since 1989 and still in use for cows, sheep, goats and reindeer grazing unimproved pastures. Has proven effective, easily practicable and cheap. Suggestion that more AFCF saltlicks should have been distributed on reindeer pastures than were used in Norway post-Chernobyl (this would increase operator time and transport costs – helicopter and/or specialised vehicles potentially being required).
Key references	Giese WW (1988). Ammonium-ferric-cyano-ferrate(II) (AFCF) as an effective antidote against radiocaesium burdens in domestic animals and animal derived foods. *Br. Vet. Journal*, 144, 363. Hove K (1993). Chemical methods for reduction of the transfer of radionuclides to farm animals in semi-natural environments. *Science of the Total Environment*, 137, 235-248. Hove K, Hansen HS and Strand P (1990). Experience with the use of caesium binders to reduce radiocaesium contamination of grazing animals. In: S. Flitton and E.W Katz (Eds.), Environmental contamination following a major nuclear accident. International Atomic Energy Agency, Vienna, IAEA-SM-306/36, 2 (1990), pp. 181-189. Pearce J (1994). Studies on any toxicological effects of Prussian Blue compounds in mammals – a review. *Food Chem. Toxicol.*, 32, 577-582. Tveten U, Brynildsen LI, Amundsen I and Bergan TDS (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. *Journal of Environmental Radioactivity*, 41 (3), 233-255.
Comments	Detailed toxicological studies have shown that AFCF has no adverse affects on animal or human health. As noted above AFCF-saltlicks are only appropriate in areas with a salt deficiency. However, licks are also used to supplement micronutrient supply and these could be used as a method of AFCF administration. Furthermore, supplementary feeding (energy) blocks are distributed in some areas of semi-natural pasture. AFCF has been successfully added to the formulation of these blocks without detrimentally affecting the structure of the block. Such blocks (which have yet to be field-tested) could provide an alternative to salt licks. Powder containing AFCF gets lumpy when stored (the Ministry of Trade and Industry in Norway keep a 3-year rolling stock). Live-monitoring prior to slaughtering can be a good supplement to control the effectiveness of the management option for each animal or a selection within a herd/flock.
Document History	**STRATEGY originator:** Liland A (NRPA). **STRATEGY contributors:** Nisbet AF, Mercer JA and Hesketh N (HPA-RPD); Thørring H and Bergan T (NRPA); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Pearce J (Department of Agriculture and Rural Development, Northern Ireland, UK); Brynildsen L (Ministry of Agriculture, Norway). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been

	revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** n/a

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32 Live monitoring	
Objective	To determine whether activity concentration in animals are below the intervention limits and/or optimisation of other management option techniques.
Other benefits	Reassurance.
Management option description	Live monitoring can establish the contamination level of gamma-emitters in the animals before slaughtering and can be used to confirm that intervention limits are not exceeded in livestock destined for the foodchain. Live monitoring of animals may be carried out on the farm and also at slaughterhouses. A rapid, simple, inexpensive and effective method of monitoring contamination for gamma-emitting radionuclides is to use a portable, preferably lead-shielded, NaI detector, linked to (or with integral) single or multi-channel analysers. If the activity concentration is above the intervention level for animals on the farm, management options such as 29 Clean feeding, or 24 Addition of AFCF to concentrate ration can then be used to lower the activity concentration before slaughter. The practice of live monitoring will thus reduce the need for meat condemnation.
Target	Meat-producing livestock (e.g. cattle, sheep, goats and reindeer)
Targeted radionuclides	**Known applicability:** ^{134}Cs, ^{137}Cs **Probable applicability:** ^{60}Co, ^{75}Se, ^{99}Mo/^{99m}Tc, ^{131}I, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{127}Sb, ^{132}Te, ^{140}Ba, ^{140}La, ^{144}Ce **Not applicable**: Radionuclides with no effective photon emissions (i.e. beta and alpha emitters) and radionuclides with low photon energies (e.g. ^{141}Ce, ^{235}U, ^{238}Pu, ^{239}Pu, and ^{241}Am).
Scale of application	Large scale when monitors are available.
Contamination pathway	n/a
Exposure pathway pre intervention	Ingestion of contaminated meat.
Time of application	Early to long term. At times when livestock are being moved from a contaminated area, just before slaughter or to design management option strategies.
Constraints	
Legal constraints	Meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). Guidelines for animal welfare must be followed.
Social constraints	Resistance by farmer/herder.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Can be highly effective (near 100 %) at excluding meat above intervention level from foodchain.
Factors influencing effectiveness of procedure	Accuracy of monitoring result will be influenced by the equipment and techniques being used. Effectiveness can be maintained by including a uncertainty margin into the estimated radionuclide concentration at which animals are rejected for entry into the foodchain (see radiocaesium below).

Factors influencing effectiveness of procedure (continued)	**Radiocaesium** Accuracy of calibration and detector type; uncertainty on measurement may mean that a rejection level much below the intervention limit is used (e.g. in the UK where the post Chernobyl intervention level for radiocaesium is 1000 Bq kg^{-1} sheep with an estimated activity concentration of 645 Bq ^{137}Cs kg^{-1} are currently (2004) not allowed to enter the human food as a consequence of detector uncertainty). Adequate shielding of monitors is preferable to avoid impractically high background counts in highly contaminated areas or areas with high natural background. Duration of counting time. Weather conditions – equipment needs to be weatherproof (i.e. resistant to low temperatures (potentially to -20°C), snow etc. under field conditions); rapid temperature shocks to the detector should be avoided. **Other Radionuclides** Whilst in theory live-monitoring may be possible for all gamma-emitting radionuclides with an energy sufficiently high to detect there is little field experience of trying to determine levels in meat for radionuclides other than Cs. **The following may be problematic/need consideration.** • Radionuclides with low gastrointestinal (GIT) absorption factors – activity in the GIT may dominate the detector reading. • Determination of activity concentrations in liver rather than muscle for some radionuclides (e.g. ^{110m}Ag, ^{60}Co). • Mixed deposits would present problems if using NaI detectors (especially single channel analysers). • Requirement to establish protocols, make equipment available and train staff may preclude use for shorter-lived radionuclides.
Feasibility	
Required specific equipment	Portable, preferably lead-shielded, NaI detector linked to single- or multi- channel analyser with battery supply – calibrated for animals being monitored. Detector and analyser should preferably be as weatherproof as possible.
Required ancillary equipment	Restraints for livestock (e.g. cattle crush) will be required whilst monitoring some animals (e.g. reindeer).
Required utilities and infrastructure	Suitable penned area to contain livestock before monitoring. Good administrative support.
Required consumables	Paint and ear tags to mark failed animals.
Required skills	Monitoring would be carried out by trained personnel. Animal handling experience/training would also be preferred. Ideally, team would consist of two people with farmer providing assistance (catching animals etc.). More people may be required if large animals (e.g. cattle, horses) or less tame (e.g. reindeer) are being monitored.
Required safety precautions	General precautions for animal handling. Potential for electric shock if used in wet conditions.
Other limitations	Depending on scale of accident, availability of NaI detectors may be limited. Consider time required to manufacture/repair existing kits and calibrate. Similarly, there may be a shortage of trained personnel. Consider time required to carry out training. These limitations mean that this measure is largely a mid to long term measure.
Waste	
Amount and type	None.

Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Monitoring operatives (potentially including animal owners):** inadvertent ingestion, and external exposure from land while working in a contaminated area and from livestock while monitoring.
Intervention Costs	
Equipment	Portable, preferably lead-shielded and weatherproof, NaI detector linked to single- or multi- channel analysers. New equipment will need to be purchased to meet demand.
Consumables	Fuel for monitoring vehicles. Running costs for repairs and maintenance of detectors. Appropriate animals to calibrate detector.
Operator time	Work rates should take into account: travel time to/from an area and between farms. Time required to set up equipment, including taking background readings. Time required to monitor livestock. Number of staff per team.
Factors influencing costs	Margin of uncertainty associated with the live-monitor estimate. Distances to farms/herds. Numbers of animals.
Compensation costs	**Farmers/herders:** for assisting during monitoring and for unmarketable livestock because activity concentrations in the meat are in excess of the intervention level.
Waste cost	None.
Assumptions	None.
Communication needs	Dialogue with farmer/herders. Farmer/herder and buyers of animals need to be aware of the implications of the measurement data, particularly for those animals exceeding intervention levels. Possible requirement for labelling products that have been subject to live monitoring.
Side-effect evaluation	
Ethical considerations	Precautionary and reduces uncertainties. Partially self-help for farmer/herder, especially if performed with training. Animal welfare must not be compromised by extra time spent at, or waiting to be monitored or in travelling long distances to be monitored. Monitoring involving removal of young livestock from lactating dams may have animal welfare implications (e.g. mastitis).
Environmental impact	None.
Agricultural impact	No direct impact other than a disruption to normal practice. However, a monitoring result in excess of the intervention limit (with any associated uncertainty) may result in slaughter/sale times being delayed until activity concentrations fall below intervention levels. This represents a loss of flexibility in marketing practice and may also result in the production of overfat animals.
Social impact	Depending upon results, the management option could be either reassuring or depressing for the farmer/herder. Stigma associated to affected area.

	May impact on *public confidence* e.g., • increased confidence that the problem of contamination is being effectively managed. • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may result in loss of employment in local industries or growth of a black market).
Other side effects	Information on activity levels in livestock and how this changes between years.
FARMING Network stakeholder opinion	Live monitoring was favoured by all stakeholders because it provides reassurance to consumers that contaminated meat is not entering the foodchain. Certain drawbacks were highlighted however, making it only acceptable to some stakeholders under specific circumstances. For example, in the event of an accident, the supplies of appropriately calibrated equipment and trained personnel would be limited.
Practical experience	Combined with 29 Clean feeding, live-monitoring is the main method of managing the entry of meat into the foodchain in the former Soviet Union. Used in Norway (from 1987) and the UK (from 1986) until present (2004) for monitoring sheep from Chernobyl in restricted areas. Soon after the Chernobyl accident also used for monitoring cattle and goats in Norway. Used in Norway (from 1987) and Sweden (from 1988) until present (2004) to monitor reindeer from Chernobyl restricted areas. Ireland and Sweden monitor carcasses at slaughterhouses.
Key references	Åhman B (1999). Direct monitoring of radiocaesium in live reindeer and reindeer carcasses. In: Søgaard-Hansen, J., Damkjær, A. eds, Proceedings of the 12th ordinary meeting of the Nordic Society for Radiation Protection, Skagen, Denmark, 23-27 August 1999. pp 159-162. Risø National Laboratory, Roskilde. Brynildsen L and Strand P (1994). A rapid method for the determination of radioactive caesium in live animals and carcasses and its practical application in Norway after the Chernobyl accident. *Acta Vetrinaria Scandinavica*, 35, 401-408. Firsakova SK (1993). Effectiveness of countermeasures applied in Belarus to produce milk and meat with acceptable levels of radiocaesium after the Chernobyl accident. *Science of the Total Environment*, 137, 199-203. Meredith RCK, Mondon KJ and Sherlock JC (1988). A rapid method for the in vivo monitoring of radiocaesium activity in sheep. *Journal of Environmental Radioactivity*, 7, 209-214. Nisbet AF and Woodman RFM (1999). Options for the management of Chernobyl restricted areas in England and Wales. NRPB-R305.
Comments	Can be used to confirm/optimise effectiveness of other management options.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Liland A, Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Radiological Protection and Research Management Division, Food Standards Agency, UK; L. Brynildsen, Ministry of Agriculture, Norway. **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for

	adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Åhman B (Swedish University of Agricultural Sciences).

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33 Manipulation of slaughter times

Objective	To reduce activity concentrations of radionuclides in meat (including offal) to below intervention levels.
Other benefits	Reduces need for clean feeding and quantities of contaminated meat requiring disposal.
Management option description	In the early to medium phase manipulation of slaughter times may be used to either: (1) Minimise the entry of radionuclides into animal derived food products by slaughtering soon after deposition. (2) To reduce activity concentrations in meat as a consequence of physical decay of short-lived radionuclides, or losses from the tissues (biological half-life) by adopting a longer finishing period than normal combined with provision of uncontaminated feeds. In the longer term seasonal variation in the radionuclide content of animals diets, and hence meat, may be exploited (i.e. slaughtering occurring at a time of year when the contamination levels are low).
Target	Meat producing livestock including farmed animals, free grazing sheep and semi-domesticated reindeer.
Targeted radionuclides	**Known applicability:** All (in long-term predominantly $^{134,137}Cs$) **Probable applicability:** - **Not applicable:** -
Scale of application	Small to large scale depending upon recommended implementation (i.e. slaughter soon after deposition v's delaying slaughter).
Contamination pathway	Plant to animal transfer.
Exposure pathway pre intervention	Ingestion of contaminated meat.
Time of application	Early to long term. Early for immediate slaughter, medium – late for livestock undergoing prolonged fattening. Annually for free grazing animals for as long as the activity concentrations in meat are above intervention levels for ordinary animal management.
Constraints	
Legal constraints	Meat intended for human consumption is subject to Council Food Intervention Limits (CFILs). Some environmental protection schemes limit grazing intensity at times through the year. Animal welfare considerations (e.g. if immediate slaughter is used humane practices would have to be maintained). With respect to reindeer herding by the Sami peoples there are protocols within Nordic countries which commit the governments of Norway, Sweden and Finland to preserve and develop the means of livelihood, language, culture and way of life of the Sami population.
Social constraints	Farmer/herder resistance to the management option.
Environmental constraints	
Effectiveness	
Management option effectiveness	**Early phase** Variable following prolonged fattening period. Combination of long biological and physical half-lives will limit the effectiveness of this management option for actinides if used with previously contaminated animals.
Management option effectiveness (continued)	**Radiocaesium (Long term)** **free ranging sheep, goats and cattle:**

	If the animals graze pastures where fungi can be abundant in certain years, the slaughter can be brought forward to the end of July/beginning of August to avoid the peak contamination in meat in September due to mushroom consumption in August and September (in some countries). This can give 75-80% reduction in sheep meat contamination in mushroom rich years. Even where fungi consumption is not important Cs levels in free-ranging sheep are generally higher in summer. **Reindeer:** A reduction in meat contamination of up to 85% if the animals are slaughtered in September instead of the traditional slaughter in Nov-Jan when lichens form the majority of the diet.
Factors influencing effectiveness of procedure	Timing of slaughter compared to deposition. Composition of short-lived radionuclides within deposition. Activity concentrations in feed provided over fattening period. Rate of change of activity concentrations in grazed herbage. Biological half-life, which is animal, organ and radionuclide specific. Compliance with the management option.
Feasibility	
Required specific equipment	Abattoir or slaughtering equipment on farm for immediate slaughter (early phase).
Required ancillary equipment	Extra fencing of areas for animal collection and possibly holding until slaughter (in which case water would be required). Live monitoring equipment.
Required utilities and infrastructure	Transport to take animals to abattoir. Storage/deep freeze facilities could be required if large numbers of animals are slaughtered at the same time (especially if used as an early phase precautionary measure). Transport to gather reindeer.
Required consumables	Feed for prolonged fattening period.
Required skills	Slaughtering would be carried out by licensed slaughtermen with necessary skills. Herders/farmers would possess other skills required.
Required safety precautions	
Other limitations	Immediate slaughter. Capacity of local slaughterhouses to cope with large numbers of animals presented for slaughter shortly after deposition. Ability to gather free ranging animals quickly. Attention must be paid to any drugs which have been administered to the animals; there are prescribed periods before which animals drugs can enter the foodchain (up to 60 days post administration). The increase in animal numbers on the farm could cause logistical problems with regard to accommodation and also have implications for animal welfare and stocking rate/herd size agreements. For reindeer logistical problems of gathering animals in autumn when snowmobiles cannot be used.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Farmers/herders:** external dose if management option requires gathering of animals soon after deposition.

Intervention Costs	
Equipment	Additional cold storage facilities if many animals slaughtered in short time period as early phase management option.
Consumables	Additional feed for prolonged fattening. Cartridges for captive bolts etc.
Operator time	Extra work by farmer/herder arranging immediate slaughter (including gathering of free ranging animals) or prolonged fattening period. Additional work by abattoir operators or on-farm slaughtermen. Additional effort required to gather animals at times different to normal practice.
Factors influencing costs	Scale of revised slaughtering programme and length of prolonged fattening. Shortage of clean feed. Age of animal following delay to slaughter. If radionuclides accumulating within offal (e.g. Ru in kidney or Ag in liver) are the cause for concern it may be possible to dispose of these organs at slaughter. This would remove the need for delaying slaughter time.
Compensation costs	**Farmer/herder** **Immediate slaughter:** • lower slaughter weight of young animals if the slaughter is performed earlier than usual. Meat from such animals is likely to have a lower fat content and hence poorer flavour. Furthermore, the conventional jointing of carcasses may not be feasible and bulk slaughtering of animals is likely to reduce market value. **Planned delay in slaughtering time:** • poorer meat quality if the slaughter is performed later than usual – it will be fatty and tough, • there may be a need to change product description, e.g. lamb may have to be classified as mutton. For both younger and older animals, it is likely that a greater than normal proportion of the carcass would have to be used for low grade meat products, such as mince, sausages and pies, than for prime cuts, • lower price for fur/pelt if the slaughter is performed at a time when the quality is poorer, • additional feed over prolonged fattening period if necessary, • extra work.
Waste cost	None.
Assumptions	None.
Communication needs	Dialogue with farmers/herders is necessary to ensure understanding of the reasons and conduct of slaughter, and to identify means of ameliorating negative consequences of management option on other farming and related activities. Effective communication would be especially important if used as an early phase precautionary measure.
Side-effect evaluation	
Ethical considerations	Animal welfare must not be compromised by extra time spent at, or waiting to be sent to slaughterhouses prior to slaughter, or in travelling long distances to remote slaughterhouses. Early slaughter involving removal of young livestock from lactating dams may have animal welfare implications (e.g. mastitis). Self-help.
Environmental impact	Possible changes in vegetation communities due to changes in grazing pressure.
Agricultural impact	Reduced grazing on fields if immediate slaughter or increased grazing if

	fattening period prolonged. Early slaughter of young livestock may mean that animals that would otherwise have been retained for breeding are not. Altering slaughtering periods can have profound consequences for annual cycles of farming/herding activity e.g. with respect to availability of manpower, provision of feed over longer periods etc. Markets may be prone to seasonal gluts and shortages.
Social impact	Altering slaughtering periods can have profound consequences for annual cycles of farming/herding activity e.g. availability of manpower, provision of feed over longer periods etc. May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may i.e. result in loss of employment in local 'cottage' industries or growth of a black market), • increased confidence that the problem of contamination is being effectively managed. Disruption/adjustment of farming and related industrial activities, e.g. the supply of meat to food industry and potential market shortages. Disruption to people's image/perception of 'countryside' with potential impacts on tourism etc. Sami reindeer herders are the only indigenous population in Europe. Reindeer herding is their traditional livelihood, economically significant and basis of their culture.
Other side effects	Possible positive impact on biodiversity if grazing period is shortened. Possible negative impact if grazing too intense.
Farming network Stakeholder opinion	Considerable divergence of opinion was apparent between national groups. The manipulation of slaughter time either prior to (or soon after) deposition or after a prolonged fattening period was in principle acceptable to some stakeholders. However, others felt that animal welfare issues and changes in the nutritional value of the meat would make this option unacceptable.
Practical experience	Used in Norway after the Chernobyl accident for sheep, but other management options like the use of saltlicks/boli with AFCF (31 Distribution of saltlicks containing AFCF and 26 Administration of AFCF boli to ruminants) and 29 Clean feeding are now dominating. Still in use in Norway for reindeer.
Key references	Åhman B and Åhman G (1990) Levels of 137Cs in reindeer bulls in July/August and September and the effect of early slaughter. *Rangifer*, Special Issue No.5, 34-38. Åhman B (1999). Transfer of radiocaesium via reindeer meat to man - effect of countermeasures applied in Sweden following the Chernobyl accident. *Journal of Environmental Radioactivity*, 46, 113-120. Beresford NA, Barnett CL, Crout NMJ and Morris CC (1996). Radiocesium variability within sheep flocks - relationships between the Cs-137 activity concentrations of individual ewes within a flock and between ewes and their progeny. *Science of the Total Environment*, 177, 85-96. Dahlgaard H (Ed.) (1994). Nordic radioecology – The transfer of radionuclides through Nordic ecosystems to man. Studies in Environmental Science 62, Elsevier, Oxford. Howard BJ (1993). Management methods for reducing radionuclide contamination of animal food production semi-natural ecosystems. *Science of the Total Environment*, 137, 249-260. Gaare E and Staaland H (1994). Pathways of fallout radiocaesium via reindeer to man. In: Dahlgaard H (ed.) Nordic radioecology – The transfer of radionuclides through Nordic ecosystems to man. Studies in Environmental Science 62, Elsevier, Oxford, p. 303-334. Mehli H (1996). Radiocaesium in grazing sheep – A statistical analysis of

	variability, survey methodology and long term behaviour. StrålevernRapport 1996:2. Østerås: Norwegian Radiation Protection Authority.
Comments	For a policy of immediate slaughter to be adopted, there must be contingency plans in place to cope with the legal and practical logistics of transporting thousands of animals at short notice. The possible consequences of a short delay in slaughtering time could be very serious if animals had already become directly contaminated by the deposit or ingested newly contaminated vegetation. It is very unlikely that thousands of animals could be slaughtered over a short time period, under humane conditions that allow the carcasses to enter the human foodchain. Pigs reared and fattened outdoors would be subject to similar constraints as those of ruminant livestock described above. However, the early or late slaughter of pigs may not result in the same penalties with regard to the cash value of the carcass since there are a number of economically viable conventional slaughter weights (i.e. porkers, cutters, baconers and heavy hogs). Thus bringing forward or prolonging the age of slaughter may simply mean changing the slaughter weight category. Immediate slaughter of reindeer is unlikely to be required if deposition occurs in winter months as fallout will be retained by dry snow cover and not enter the reindeer foodchain.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Liland A, Thørring H and Bergan T (NRPA); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer(s):** Mayes B (Macaulay Land Use Research Institute, UK); Brynildsen L (Ministry of Agriculture, Norway). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** Åhman B (Swedish University of Agricultural Sciences).

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34 Processing of milk for subsequent human consumption

Objective	To produce milk products with activity concentrations less than intervention levels from contaminated liquid milk that would be suitable for human consumption with or without a period of storage.
Other benefits	To reduce quantity of contaminated milk for disposal. Maintenance of farming and associated communities.
Management option description	Processing would permit milk contaminated at levels above the Council Food Intervention Limits (CFILs) to be used for human consumption. Processing raw milk into butter and cheese may be used to reduce activity concentration of radiocaesium and radiostrontium (i.e. starting with milk with activity concentrations in excess of the CFIL an activity concentration in the end product which is below the appropriate CFIL can be obtained). For ^{131}I and any other appropriate short-lived radionuclides, transformation into products with longer shelf-life such as cheese, UHT milk and canned goods is effective due to the short physical half lives. Processing nevertheless produces contaminated by-products. NOTE: Only milk and cream are subjected to the CFIL for 'dairy produce' all other products derived from milk are subjected to the CFIL for 'other foodstuffs'. The CFIL for dairy produce is lower than that for other foodstuffs.
Target	Milk.
Targeted radionuclides	**Known applicability:** ^{60}Co, ^{75}Se, ^{89}Sr, ^{90}Sr, ^{95}Nb, ^{95}Zr, ^{99}Mo/^{99m}Tc, ^{103}Ru, ^{110m}Ag, ^{125}Sb, ^{127}Sb, ^{131}I, ^{132}Te, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{140}La, ^{141}Ce, ^{169}Yb, ^{192}Ir **Probable applicability:** - **Not applicable:** -
Scale of application	Small to medium scale.
Contamination pathway	n/a
Exposure pathway pre intervention	Ingestion of contaminated milk.
Time of application	Early to medium term.
Constraints	
Legal constraints	The sale of dairy products intended for human consumption is subject to CFILs.
Social constraints	Resistance of driver to transport contaminated milk. Resistance of processing plant to accept contaminated milk. Resistance of consumers
Environmental constraints	None, although there could be an indirect environmental impact depending on disposal route chosen for by-products.
Effectiveness	
Management option effectiveness	Milk products prepared by isolating the fat and/or protein components from the aqueous fraction tend to be depleted in radiocaesium and radioiodine compared with raw milk. Examples are butter, cream, hard cheese, Greek "feta" cheese, cottage cheese, casein and whey protein concentrates. Radiostrontium closely follows the behaviour of calcium. Hence, products such as cottage cheese, cream and butter, which are relatively low in calcium, tend to have low levels of radiostrontium while high calcium products such as skim milk and cheese have higher levels of radiostrontium. However, the transfer of radiostrontium during cheese making is affected by the method of coagulation used. If rennet coagulation is used the transfer of radiostrontium to the cheese is usually increased. If acid coagulation is used the transfer of radiostrontium to the cheese whey is increased. The change in radionuclide content of a foodstuff due to processing may be assessed by one of two approaches as defined below:

Processing retention factor (F_r) = Total activity of the radionuclide in the processed food (Bq)/ Total activity of the radionuclide in the raw material (Bq).

Ratio of the activity concentration in processed food : to the activity concentration in raw milk = (**F_f**).

F_r and F_f values for various milk products:

	F_r	**F_f**
Radioiodine		
Milk powder	1.00	8.33
Cheese (rennet)	0.08-0.53	0.67-4.42
Cheese whey (rennet)	0.5-0.9	0.56-1.0
Cheese (acid)	0.22-0.27	2.20-2.7
Cheese whey (acid)	0.6-0.7	0.75-0.88
Cream	0.03-0.19	0.38-2.38
Butter	0.01-0.76	0.25-19.0
Skim milk	0.8-0.95	0.87-1.03
Cottage cheese (rennet)	0.05	0.45
Cottage cheese (acid)	0.2	2.00
Radiocaesium		
Milk powder	1.00	8.33
Cheese (rennet)	0.04-0.23	0.33-1.92
Cheese whey (rennet)	0.75-0.95	0.83-1.06
Cheese (acid)	0.11-0.12	1.10-1.20
Cheese whey (acid)	0.75-0.90	0.94-1.13
Cream	0.02-0.25	0.25-3.13
Butter	0.003-0.49	0.08-12.3
Skim milk	0.85-0.99	0.92-1.08
Cottage cheese (rennet)	0.01-0.1	0.09-0.91
Cottage cheese (acid)	0.1	1.00
Radiostrontium		
Milk powder	1.00	8.33
Cheese (rennet)	0.1-0.8	0.83-6.67
Cheese whey (rennet)	0.2-0.9	0.22-1.0
Cheese (acid)	0.04-0.08	0.40-0.8
Cheese whey (acid)	0.7-0.9	0.88-1.13
Cream	0.02-0.25	0.25-3.13
Butter	0.0025-0.36	0.06-9.0
Skim milk	0.75-0.96	0.82-1.04
Cottage cheese (rennet)	0.03-0.3	0.27-2.73
Cottage cheese (acid)	0.07-0.2	0.70-2.2

F_r values are taken from Long *et al.* (1995) and IAEA (1994); F_f values are estimated from the quoted F_r values and average processing efficiency given by these references (where the processing efficiency is the ratio of the weight of processed food to that of the weight of raw milk).

Effectiveness of processing into storable products such as UHT (ultra high temperature) milk will vary depending upon physical half-life and time stored prior to sale.

Factors influencing effectiveness of	Radionuclide(s) present, fat content of milk, process selected.

procedure	In cheese manufacture radiostrontium transfer is affected by the method of coagulation used: if rennet coagulation is used the transfer of radiostrontium is usually increased. Acceptability and marketability of end product. Farmers/industry compliance with the management option.
Feasibility	
Required specific equipment	Milk processing plant Special facilities may be required for milk products undergoing storage.
Required ancillary equipment	Milk tankers.
Required utilities and infrastructure	Waste treatment facilities licensed to accept contaminated by-products.
Required consumables	Fuel for tankers.
Required skills	Operators at milk processing plants will have the required skills.
Required safety precautions	Consider respiratory protection if appropriate for operators (e.g. production of skim milk powder).
Other limitations	Capacity of processing plants within the affected area to accept additional raw milk for processing. There might be reluctance to move contaminated milk to a processing plant located outside a contaminated area that would affect total capacity.
Waste	
Amount and type	Percentage by mass of waste by-products generated in the production of various milk products for consumption: Cheese = 88% is cheese whey. Butter = 52% is buttermilk Cream = 90% is skim milk Cottage cheese = 85% cottage cheese whey Milk powder/skim milk powder = no contaminated by-product just 80-90% water Contaminated water from washing and rinsing of tankers.
Possible transport, treatment and storage routes	Dairy effluent plant and sewage treatment works.
Factors influencing waste issues	Type of milk processing undertaken. High biological oxygen demand (BOD) associated with milk.
Doses	
Incremental dose *Pathways in italics are for the subsequent transportation of waste for storage or disposal. The waste by-products from processing would undergo biological treatment: there is a separate datasheet for the 48 Biological treatment (digestion) of milk that outlines the additional dose pathways.*	**Driver:** • external exposure while *transporting contaminated milk* to processing plant. • *external exposure while transporting milk products to storage facility.* • *external exposure while transporting contaminated waste by-products for storage and disposal.* **Dairy operative:** • external exposure to milk (dependant on the location of the control room from the machinery) at processing plant. **Operative at storage facility:** • external exposure from stored milk products.
Intervention Costs	
Equipment	Minimal. Processing equipment already available.
Consumables	Additional consumables required to process raw milk. Fuel for transportation.
Operator time	Tanker driver. Additional operators at processing plant if required.

Factors influencing costs	Distance to processing plant. Quantity of milk for processing. Length of storage time.
Compensation costs	**Farmer/milk purchaser:** if there is a loss of market value for processed milk products. **Processing plants:** for handling contaminated milk and if equipment required decontamination.
Waste cost	Cost of disposal of by-products to sewage treatment plants if not carried out *in situ* at processing plant.
Assumptions	There is a market for the end products. Appropriate monitoring is carried out at processing plant.
Communication needs	Labelling of treated products. Dialogue with industry and consumers to explain that dairy produce may contain less activity than raw milk. Information to industry on handling of wastes.
Side-effect evaluation	
Ethical considerations	Informed consent. Distribution of costs and benefits (e.g. possible inequity due to change in prices of processed milk with lower income populations buying the treated product).
Environmental impact	None, although there could be an indirect environmental impact depending on disposal route chosen for by-products.
Agricultural impact	None.
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' (may i.e. result in loss of employment in local 'cottage' industries or growth of a black market). • increase confidence that the problem of contamination is being effectively managed.
Social impact (continued)	Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade when foodstuffs can be obtained from other sources. Disruption/adjustment of farming and related industrial activities. Disruption to the supply of milk to food industry and potential for market shortages.
Other side effects	Parts of the processing plant may become contaminated.
FARMING Network stakeholder opinion	Stakeholders unanimously agreed that there are no processing options that can be considered as generally acceptable. Options involving removal of contamination from crops, milk and meat during industrial processing were viewed by some stakeholders to be acceptable under specific circumstances. However, in countries where consumer confidence has been seriously affected by previous food scares (e.g. UK and Belgium) any process that produces marketable food from contaminated raw materials was considered to be unacceptable.
Practical experience	Milk above national intervention limits accepted for processing in the former Soviet Union (post Chernobyl accident).
Key references	Long S, Pollard D, Cunningham JD, Astasheva NP, Donskaya GA and Labetsky EV (1995). The effects of food processing and direct decontamination techniques on the radionuclide content of foodstuffs: a literature review. Part 1: milk and milk products. *Journal of Radioecology*, 3 (1), 15-30. Mercer J, Nisbet AF and Wilkins BT (2002). Management options for food production systems affected by a nuclear accident: 4 Emergency monitoring and processing of milk. NRPB-W15. Wilson L, Bottomley R and Sutton P (1988). Transfer of radioactive

	contamination from milk to commercial dairy products. *Journal of the Society of Diary Technology*, 41 (1), 10-13. IAEA (1994). Guidelines for agricultural countermeasures following an accidental release of radionuclides. Technical Report Series No. 363. IAEA (1994). Handbook of parameter values for the prediction of radionuclide transfer in temperate environments. Technical Report Series No. 364.
Comments	The processing of milk into dairy products suitable for the foodchain does not remove the need for disposal of other higher activity by-products. These, like the liquid milk from which they were derived, may also have high biological oxygen demands. Processing to products with a long shelf-life may also be considered for meat contaminated with short-lived radionuclides.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY** contributors**:** Mercer JA and Hesketh N (HPA-RPD); Hunt J (ULANC); Oughton DH (UMB). **STRATEGY peer reviewer:** Pollard D (Radiological Protection Institute of Ireland). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** Fersenko, S. (IAEA).

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35 Salting of meat

Objective	To produce meat products with activity concentrations less than intervention levels from contaminated raw meat.
Other benefits	To reduce quantity of meat requiring disposal. Maintenance of farming and associated communities.
Management option description	Meat producing livestock that have been slaughtered with activity concentrations of radiocaesium above intervention levels may undergo salting either at commercial facilities or in the home. Salting of meat can achieve some reductions in the final activity concentration of radiocaesium and radiostrontium in meat. Meat pieces (200g) are soaked in dilute NaCl brine (5%) using two successive treatments of 2 days each.
Target	Meat
Targeted radionuclides	**Known applicability:** ^{134}Cs, ^{137}Cs, ^{89}Sr, ^{90}Sr **Probable applicability:** - **Not applicable:** Does not reduce the concentration of the following radionuclides in meat: ^{60}Co, ^{95}Nb, ^{95}Zr, ^{125}Sb, ^{127}Sb, ^{132}Te, ^{140}Ba, ^{140}La, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf. The relatively short physical half-lives of the following radionuclides may preclude the use of this management option: ^{99}Mo/^{99m}Tc, ^{131}I
Scale of application	Small to medium.
Contamination pathway	n/a
Exposure pathway pre intervention	Ingestion of contaminated meat.
Time of application	Medium to long term.
Constraints	
Legal constraints	The sale of meat intended for human consumption is subject to Council Food Intervention Limits (CFILs).
Social constraints	Public/producers resistance to management option.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	After soaking in salt solution, radiocaesium and radiostrontium contamination of meat may both be reduced by >80% (although effectiveness may be as low as a reduction of 10% in case of radiocaesium).
Factors influencing effectiveness of procedure	Size of the meat pieces treated - if large pieces a maximum reduction in radiocaesium contamination of 40-50% can be expected. Concentration of salt solution. Length of treatment.
Feasibility	
Required specific equipment	Food processing plant to carry out salting of meat.
Required ancillary equipment	Vehicles to transport contaminated meat to processing plant.
Required utilities and infrastructure	Waste treatment facilities for disposal of by-products.
Required consumables	Fuel for vehicles, additional salt.
Required skills	Operators at processing plants should have the required skills.
Required safety precautions	None.
Other limitations	Capacity of processing plants, willingness to accept contaminated meat.
Waste	
Amount and type	Large volumes of contaminated salt solution.
Possible transport, treatment and storage routes	On-site treatment plants and sewage treatment works.
Factors influencing waste issues	Quantity of meat being treated and its level of contamination.

Doses	
Incremental dose *Dose pathways in italics are indirectly incurred as a result of transportation of wastewater. Any waste water generated during processing will either be treated on site or at a sewage treatment works.*	**Driver:** • external exposure while transporting contaminated meat to the processing plant, • *external exposure while transporting wastewater to sewage treatment works.* **Meat processing plant operatives:** • external exposure, inadvertent ingestion and hand skin exposure from meat at processing plant, • inadvertent ingestion of meat juices while cutting up meat.
Intervention Costs	
Equipment	Commercial processing equipment is already available.
Consumables	Fuel to transport meat. Additional salt/brine to process additional volumes of meat.
Operator time	Drivers for transporting contaminated meat to commercial facilities. Operators at processing plant if additional manpower required.
Factors influencing costs	Quantity of meat. Distance to processing plant.
Compensation costs	**Farmers:** if receive reduction in income because processed meat has a lower value. **Processing plants:** for handling contaminated meat and if equipment subsequently requires decontamination.
Waste cost	Cost of disposal of salt solutions to sewage treatment plant.
Assumptions	That there is a market for the end products. That appropriate monitoring is carried out at processing plant.
Communication needs	Labelling of treated meat. Dialogue with industry and consumers to explain the rationale of the management option.
Side-effect evaluation	
Ethical considerations	Informed consent. Distribution of costs and benefits (e.g. possible inequity due to change in price of salted meat, with lower income populations buying the treated food).
Environmental impact	Disposal of salt solution should have minimal environmental impact.
Agricultural impact	None.
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may result in loss of employment in local 'cottage' industries or growth of a black market), • increased confidence that the problem of contamination is being effectively managed.
Social impact (continued)	Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade when foodstuffs can be obtained from other sources. Disruption/adjustment of farming and related industrial activities. Disruption to the supply of meat to food industry and potential for market shortages.
Other side effects	Soaking meat in brine can affect its nutritional value removing water soluble vitamins and water-soluble and salt soluble proteins. Flavour of the meat may be adversely affected.
FARMING Network stakeholder opinion	Stakeholders unanimously agreed that there are no processing options

	that can be considered as generally acceptable. Options involving removal of contamination from crops, milk and meat during industrial processing were viewed by some stakeholders to be acceptable under specific circumstances. However, in countries where consumer confidence has been seriously affected by previous food scares (e.g. UK and Belgium) any process that produces marketable food from contaminated raw materials was considered to be unacceptable.
Practical experience	None.
Key references	Petaja E, Rantavaara A, Paakkola O and Puolanne E (1992). Reduction of radioactive caesium in meat and fish by soaking. *Journal of Environmental Radioactivity*, 16, 273-285. Long S, Pollard D, Cunningham JD, Astasheva NP, Donskaya GA and Labetsky EV (1995). The effects of food processing and direct decontamination techniques on the radionuclide content of foodstuffs: A literature review. *Journal of Radioecology*, 3, 1, 15-38. Smith JT, Voitsekhovitch OV, Håkanson L and Hilton J (2001). A critical review of measures to reduce radioactive doses from drinking water and consumption of freshwater foodstuffs. *Journal of Environmental Radioactivity*, 56, 11-32.
Comments	The texture of meat is not altered significantly and the salt content is only increased slightly. The technique is also applicable to contaminated fish.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Nisbet AF, Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Liland A, Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Pollard D (Radiological Protection Institute of Ireland); Harbitz O (NRPA); Brynildsen L (Ministry of Agriculture, Norway). **EURANOS** originator**:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** Fersenko S (IAEA).

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36 Selective grazing regime

Objective	To reduce activity concentrations of radionuclides in meat and milk to below intervention levels.
Other benefits	Reduction in quantities of contaminated animal produce that will need to be disposed of.
Management option description	Optimising the grazing management of farm animals so that pastures with the least contaminated vegetation are used in the most appropriate way. For instance, for dairy (rather than meat animals) or for meat animals before slaughter to allow contamination levels to fall to below intervention levels at slaughter. Livestock can also be physically excluded from highly contaminated areas by erection of temporary fences. Animals can also be moved from highly contaminated farms to pastures on farms with lower deposition/activity concentrations in vegetation.
Target	Meat and milk producing animals.
Targeted radionuclides	**Known applicability:** ^{134}Cs, ^{137}Cs **Probable applicability:** ^{60}Co, ^{75}Se, ^{110m}Ag, ^{89}Sr, ^{90}Sr, ^{169}Yb, ^{192}Ir **Not applicable:** - The relatively short physical half-lives of the following radionuclides may preclude this radical management option: ^{99}Mo/^{99m}Tc, ^{127}Sb, ^{131}I, ^{132}Te, ^{140}Ba, ^{140}La. Low feed to meat transfer of the following radionuclides makes implementation of this management option unlikely: ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{141}Ce, ^{144}Ce, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf
Scale of application	Large.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated meat and milk.
Time of application	Medium to long term.
Constraints	
Legal constraints	After selective grazing has been carried out milk and meat would still be subject to Council Food Intervention Limits (CFILs). Depends on land status (i.e. conservation areas, National Parks).
Social constraints	Willingness of farmer to participate. Willingness of farmers at receiving farms to accept contaminated stock.
Environmental constraints	There may be restrictions on where temporary fences can be erected e.g. in National Parks and Environmentally Sensitive Areas.
Effectiveness	
Management option effectiveness	Can be highly effective (up to 100%).
Factors influencing effectiveness of procedure	The availability of nuclide specific monitoring data on the farm on which to base the management option. The availability of land providing less contaminated pasture – the area of cultivated grasslands is limited, and usually commensurate with the normal stocking rate of domestic animals for each farm. Initial activity concentration in animals, biological half-life of radionuclide and activity concentrations in vegetation on the pasture animals are removed to. Compliance to the management option.
Feasibility	
Required specific equipment	Monitoring equipment to assess contamination status of land. Machinery to aid construction of fences to temporarily restrict access of animals to contaminated land.
Required ancillary equipment	Transportation of livestock to less contaminated areas.

Required utilities and infrastructure	None.
Required consumables	Fuel for transportation and construction machinery.
Required skills	Farmer should have necessary skills.
Required safety precautions	None.
Other limitations	Domestic animal production cannot be managed at remote sites if there if no suitably experienced people available to look after the animals.
Waste	
Amount and type	None.
Possible transport, treatment and storage routes	None.
Factors influencing waste issues	N/A.
Doses	
Incremental dose	**Farmer:** external exposure and inadvertent ingestion and inhalation of dust while erecting fencing.
Intervention Costs	
Equipment	Fencing.
Consumables	Fuel.
Operator time	Time to erect fencing. Time to herd animals and transport them to less contaminated areas.
Factors influencing costs	Size of contaminated area to be fenced off. Location of less contaminated land with respect to the contaminated farm.
Compensation costs	**Farmer:** • for extra labour required in moving animals to less contaminated pasture, • for lost grazing areas, • for accepting stock from other farms.
Waste cost	None.
Assumptions	None.
Communication needs	Information/dialogue with farmers.
Side-effect evaluation	
Ethical considerations	Self-help for farmer. Knock-on effects for public use of amenity if areas that are fenced off.
Environmental impact	Change in biodiversity of fenced area.
Agricultural impact	Undergrazing of fenced areas of pasture.
Social impact	Stigma associated to affected areas. May impact on *lic confidence* e.g., • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may result in loss of employment in local 'cottage' industries or growth of a black market), • increased confidence that the problem of contamination is being effectively managed. Disruption to farming and other related activities (e.g. tourism). Credibility of management option suggestions may be at risk if a measure does not comply with existing resources on farms.
Other side effects	Minor risk of excreta acting as mechanism of contamination of uncontaminated pastures. (See Crout *et al*., 1991).
FARMING Network stakeholder opinion	Considerable divergence of opinion was apparent between national groups. Selective grazing was viewed favourably in the UK, whereas

	under both northern and southern European climatic conditions alternative pastures on which to graze livestock would be extremely limited. In Belgium, the availability of grassland would also be restricted due to the intensive nature of Belgian food production systems.
Practical experience	Used widely in the fSU and also employed in Norway. Used in the uplands of UK, in combination with 32 Live monitoring, to produce lamb with activity concentrations <CFIL.
Key references	Crout NMJ, Beresford NA and Howard BJ (1991). The radioecological consequences for lowland pastures used to fatten upland sheep contaminated with radiocaesium. *Science of the Total Environment*, 103, 73-87. Nisbet AF and Woodman RFM (2000). Options for the management of Chernobyl-restricted areas in England and Wales. *Journal of Environmental Radioactivity*, 51, 239-254. Prister BS, Perepelyatnikov GP and Perepelyatnikova LV (1993). Countermeasures used in the Ukraine to produce forage and animal food products with radionuclide levels below intervention limits after the Chernobyl accident. *Science of the Total Environment*, 137, 183-198.
Comments	
Document History	**STRATEGY originator:** Nisbet A (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD); Beresford NA and Howard BJ (CEH); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Protection and Research Management Division, Food Standards Agency, UK. **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** n/a

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37 Slaughtering of dairy livestock

Objective	To remove the source of contaminated milk (i.e. dairy animals) from the foodchain.
Other benefits	Maintains consumer confidence in food products.
Management option description	Slaughtering could be considered for those dairy animals whose milk would, because of unavailability of clean feed (or other appropriate management option) be so contaminated that it would be considered unfit for human consumption for a significant proportion of their productive life. It could also be considered on animal welfare grounds in areas where stock-keepers were evacuated leaving animals unmilked and possibly unfed. Condemnation completely removes contaminated food from the market but can leave large quantities of animal waste needing disposal.
Target	Dairy animals.
Targeted radionuclides	**Known applicability:** ^{60}Co, ^{75}Se, ^{89}Sr, ^{90}Sr, ^{110m}Ag, ^{134}Cs, ^{137}Cs, ^{192}Ir **Probable applicability:** - **Not applicable:** The relatively short physical half-lives and or low transfers from feed to diet of the following radionuclides is likely to preclude this use of this radical management option: ^{95}Nb, ^{95}Zr, ^{99}Mo/^{99m}Tc, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{127}Sb, ^{131}I, ^{132}Te, ^{140}Ba, ^{140}La, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf
Scale of application	Small to medium scale depending on severity of accident.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated milk.
Time of application	Early to medium term.
Constraints	
Legal constraints	Slaughter of animals is likely to be subject to animal welfare acts in each Member State. It must be conducted by veterinarians or licensed slaughtermen. If being used as a welfare measure for animals in abandoned areas, access to them will be governed by dose limits.
Social constraints	Resistance to slaughter due to the impact on the farming community and cost. Resistance to the selection process for areas where management option is to be applied. Resistance of public to large scale slaughter of animals.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Highly effective (i.e. 100%) at removing contaminated animal products from the foodchain.
Factors influencing effectiveness of procedure	Acceptability of and compliance with management option. Appropriate selection of priority areas. Availability of licensed slaughtermen to visit farms in immediate aftermath of accident. Availability of transport to take dairy animals to abattoirs.
Feasibility	
Required specific equipment	Abattoir or slaughtering equipment on farm.
Required ancillary equipment	Vehicles for transport of livestock to abattoir if necessary.
Required utilities and infrastructure	Disposal routes for carcasses e.g. incinerators, rendering plants, burning and burial sites.

Required consumables	Fuel for transport to abattoir if necessary. Cartridges for captive bolts etc.
Required skills	Slaughtering would be carried out by licensed slaughtermen with necessary skills.
Required safety precautions	None above normal for handling and slaughtering of livestock. If being used on animal welfare grounds in conjunction with evacuation of population, health physics advice/monitoring and protective clothing will be required.
Other limitations	Capacity of disposal routes.
Waste	
Amount and type	Condemned livestock carcasses.
Possible transport, treatment and storage routes	Disposal by: incineration (53 Incineration), burial (49 Burial of carcasses), burning (50 Burning of carcasses), rendering (58 Rendering). In Norway condemned meat (banned after 'normal' slaughtering) has been used as feed for fur producing animals.
Factors influencing waste issues	Acceptability of and compliance with waste disposal practice. Legislative issues, e.g. in the UK burning or burial of carcasses on the farm is prohibited by the Animal By Product Order 1999 except if it is a place where access is difficult or in certain limited circumstances.
Doses	
Incremental dose	**Driver:** external exposure while transporting livestock to abattoir. **Operative at abattoir:** external exposure while slaughtering livestock.
Intervention Costs	
Equipment	Slaughtering equipment already available. Additional transport for carcasses to be taken to abattoir if required.
Consumables	Fuel for transport. Cartridges for slaughter.
Operator time	Time to slaughter cattle at abattoir or on-farm and to transport livestock to abattoir.
Factors influencing costs	Whether slaughter is carried out at abattoir or on farm.
Compensation costs	**Farmer:** compensation to farmer for milk unable to be sold, for loss of dairy animals and for maintaining pastures if all stock is removed. **Abattoir:** decontamination of slaughtering equipment if necessary.
Waste cost	Transportation of carcasses to rendering/ incineration plant or burial/burning site. Costs of the chosen disposal route; incineration, rendering, burning and burial.
Assumptions	None.
Communication needs	Media interest is likely to be high. Cost of communicating both the management option and its objectives and rationale to farmers, and the public through multiple channels (e.g. advisory centre, leaflets, internet), preferably as part of emergency management planning; requirement for updating as situation develops.
Side-effect evaluation	
Ethical considerations	Distribution of costs and benefits. Animal welfare issues regarding slaughter. Political, production related and animal welfare motives should be transparent to all stakeholders before decisions on implementation are made.
Environmental impact	Indirect effect depends on disposal route selected for carcasses.

Agricultural impact	If the entire herd/flock is slaughtered, under-grazing of pasture will occur.
Social impact	May impact on public confidence e.g., • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may i.e. result in loss of employment in local industries and growth of a black market), • increased confidence that the problem of contamination is being effectively managed. Stigma associated with the area affected. Disruption of farming and associated communities, disruption to people's image/perception of 'countryside' e.g. if there are no animals in the fields, with potential impacts on tourism. Market shortages of milk and dairy products. Negative psychological impact especially on farming community. Market shortages.
Other side effects	None.
FARMING Network stakeholder opinion	The option might be considered only in cases involving animal welfare issues, although subsequent disposal of carcasses was a matter of concern among stakeholders.
Practical experience	Slaughtering of cattle has been carried out in the UK and other European countries following the condemnation of beef because of BSE. On a larger scale there has been slaughter and burning/burial of complete farm stocks (ruminants and pigs) as a consequence of the foot and mouth epidemic in the UK. Herds and flocks were also slaughtered and disposed of in many other Member States including France, Belgium, Germany and the Netherlands.
Key references	Smith J, Nisbet AF, Mercer JA, Brown J and Wilkins BT (2002). Management options for food production systems affected by a nuclear accident: Options for minimising the production of contaminated milk. NRPB-W8. Tveten U, Brynildsen LI, Amundsen I and Bergan T (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. *Journal of Environmental Radioactivity*, 41 (3), 233-255.
Comments	It is debatable whether any situation could arise whereby the milk of dairy stock would be so contaminated that it would be unfit for human consumption throughout the productive life of the animal. The measure has high secondary costs and could not be considered to be an approach to sustainable restoration.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD, UK); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Mayes B (Macaulay Land Use Research Institute, UK). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

	EURANOS peer reviewer(s): n/a

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38 Suppression of lactation before slaughter

Objective	To reduce the volume of milk requiring disposal before dairy animals are slaughtered.
Other benefits	None.
Management option description	If a decision has been made to slaughter dairy livestock because the period of lost production is too long, methods for suppressing lactation should be used to reduce volumes of waste milk requiring disposal. Synthetic oestrogens are effective at inhibiting milk production, although many forms are currently banned by the EU for food producing animals. Progestogens or prostaglandins could also be considered. The more natural method of drying off involve the abrupt cessation of milking, accompanied by provision of poor quality feed, removal of concentrates from the diet and restricted access to water. For high yielding cows the drying off method would be to reduce the frequency of milking over a two-week period.
Target	Dairy animals.
Targeted radionuclides	**Known applicability:** ^{60}Co, ^{75}Se, ^{89}Sr, ^{90}Sr, ^{110m}Ag, ^{134}Cs, ^{137}Cs, ^{192}Ir **Probable applicability:** - **Not applicable:** The relatively short physical half-lives and or low transfers from feed to diet of the following radionuclides is likely to preclude this use of this radical management option: ^{95}Nb, ^{95}Zr, ^{99}Mo/^{99m}Tc, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{127}Sb, ^{131}I, ^{132}Te, ^{140}Ba, ^{140}La, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf
Scale of application	Small to large.
Contamination pathway	Plant to animal.
Exposure pathway pre intervention	Ingestion of contaminated milk.
Time of application	Early to medium term.
Constraints	
Legal constraints	Hormonal treatments using synthetic oestrogens are not permitted for food producing animals in the EU. However, if a decision has been made to slaughter dairy livestock, hormonal treatments may be used to reduce the volumes of waste milk arising before slaughter. There are animal welfare issues associated with the suppression of lactation and these should be taken into consideration.
Social constraints	Farmers' resistance to management option. Opposition by the public to using hormone treatments due to the perception that hormones would damage the environment.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Both hormone treatments and drying-off naturally can be considered as 100% effective if lactation is ceased. The time taken to achieve this depends on the method adopted but can take up to 2 weeks. The shorter the period that drying-off is achieved over, the greater the potential for animal welfare problems to evolve. Suppression of lactation can also be regarded as being highly effective if the rate of milk production is greatly reduced but not ceased.
Factors influencing effectiveness of procedure	The method used to suppress lactation. If hormonal, the type of treatment selected. The daily milk yield/stage of lactation of the dairy animal. Acceptability of suppressing lactation and methods used to achieve it.
Feasibility	
Required specific equipment	None.

Required ancillary equipment	None.
Required utilities and infrastructure	None.
Required consumables	Synthetic oestrogens, progestogens or prostaglandins. Long acting antibiotic for udders (in case of mastitis) if more natural methods of drying off used.
Required skills	Farmers would possess necessary skills for drying off 'naturally' in preparation for calving/lambing/kidding. Some instruction may be required for administering hormonal treatments.
Required safety precautions	None.
Other limitations	None.
Waste	
Amount and type	Milk contaminated with radionuclides will be produced until milk production ceases. Levels are likely to be in excess of the CFIL and will require disposal. If synthetic oestrogens have been used, all milk will require disposal irrespective of radionuclide content.
Possible transport, treatment and storage routes	Disposal by: landspreading (55 Landspreading of milk and/or slurry), biological treatment (48 Biological treatment (digestion) of milk), processing into a milk product suitable for storage prior to disposal (57 Processing and storage of milk products for disposal), and disposal to sea (52 Disposal of contaminated milk to sea).
Factors influencing waste issues	High biochemical oxygen demand (BOD) level associated with milk.
Doses	
Incremental dose	None.
Intervention Costs	
Equipment	None.
Consumables	Depending on method of suppression of lactation used: hormonal treatments, long acting antibiotic for udders.
Operator time	Less time would be spent milking, but an increased amount of time might be spent controlling animal welfare issues.
Factors influencing costs	Method used to suppress lactation.
Compensation costs	**Farmer:** for loss of milk production.
Waste cost	Dependent on disposal route for milk chosen.
Assumptions	Availability of synthetic oestrogens, progestogens or prostaglandins.
Communication needs	Dialogue with farmers/herders is necessary to a) ensure understanding of the reasons and conduct of slaughter, and b) identify means of ameliorating negative consequences of management option on other farming and related activities. Debate and dialogue is required on ethical premises of this management option. Effective communication would be especially important if used as an early phase precautionary measure. Requirement for updating as situation develops.
Side-effect evaluation	
Ethical considerations	Animal welfare issues. The process of drying-off in a situation other than for preparation for calving/lambing/kidding and the next lactation cycle has associated animal welfare concerns. For high milk producing animals the drying-off method should be applied gradually over a longer time period as they are more likely to experience discomfort and pain than lower yielding animals. Self-help. Distribution of costs/benefits between rural and urban population.

Environmental impact	Pollution issues related to hormone treatments e.g. if waste milk is allowed to contaminate waterways. Synthetic oestrogens are known to persist in waterways causing endocrine disruption to fish.
Agricultural impact	Possible risk of abortion associated with some methods of drying off. Loss of milk production.
Social impact	May impact on *public confidence* e.g., • loss of confidence that farm produce and derivative products from affected areas is 'safe' (may result in loss of employment in local industries and growth of a black marked), • increase confidence that the problem of contamination is being effectively managed. Disruption of milk production at dairy farms and to the supply of milk to food industry and market shortages. Disruption to people's image/perception of 'countryside' as natural. Negative psychological impact.
Other side effects	None.
FARMING Network stakeholder opinion	Overall negative feeling due to politics and practicalities, but some consideration for use in given in certain circumstances. Hormonal treatments using synthetic oestrogens are not permitted for food producing animals in the EC; Greek and Finnish stakeholders found the use of oestrogens unacceptable. In Belgium it was felt that oestrogen use may be allowed, in a crisis situation, by governmental decision although concerns over oestrogen levels in food products (if animals returned to lactation or slaughtered for consumption) and potential foetal development problems were raised. UK, Belgian and Finish stakeholders were concerned that the rapid drying off of high yielding cattle would have animal welfare issues (pain and mastitis). Whilst Belgian stakeholders considered drying off an acceptable measure prior to slaughter. In the UK it was generally felt that capacity for immediate slaughter would be sufficient to negate the need for drying off. The Finnish group did not regard it necessary to slaughter cows earlier than normal if they can be returned to production.
Practical experience	
Key references	Smith J, Nisbet AF, Mercer JA, Brown J and Wilkins BT (2002). Management options for food production systems affected by a nuclear accident: Options for minimising the production of contaminated milk. NRPB-W8. Didcot: National Radiological Protection Board.
Comments	Further research is required to establish the most appropriate methods of drying off dairy animals at different stages of lactation. As drying off is normally in preparation for calving and the next lactation cycle, an artificial dry period would mean that problems would be encountered in initiating the next lactation cycle. However, the suppression of lactation is only considered here if it is to be followed by slaughtering. If dairy animals are also used in meat production then the suppression of lactation could be of benefit although the use of oestrogens to achieve this would not be possible under current legislation.
Document History	**STRATEGY originator:** Nisbet AF (HPA-RPD). **STRATEGY contributors:** Mercer JA and Hesketh N (HPA-RPD, UK); Beresford NA and Howard BJ (CEH); Thørring H and Bergan T (NRPA); Hunt J (ULANC), Oughton DH (UMB). **STRATEGY peer reviewer(s):** Mayes B (Macaulay Land Use Research Institute, UK). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically

	evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer:** n/a

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39 Compensation scheme

Objective	Provision of financial support for persons affected either by radiation exposures or by social and economic side effects of management options
Other benefits	Greater equity in the distribution of costs and benefits following management option implementation.
Management option description	Introduction of compensation or insurance scheme. For people having higher exposures (including management option operators), this could be in the form of direct monetary compensation for increased risk, guarantee of a lump sum payment should illness arise, or some form of general medical insurance. Compensation may also be provided for other negative side effects of management options, such as economic loss and social or lifestyle disturbance. For whole communities rather than individuals, indirect compensation in the form of community benefits (e.g. schools or communal facilities) can be an alternative to direct monetary payments.
Target	Individuals or groups with high exposures (either ongoing or foreseen) or social disruption.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Limited by financial commitment to support scheme.
Contamination pathway	n/a
Exposure pathway pre intervention	n/a
Time of application	Medium to long term
Constraints	
Legal constraints	Primary legislation probably required. Liability and compensation issues.
Social constraints	Resistance to management option based on ethical and political grounds.
Environmental contraints	N/A
Effectiveness	
Management option effectiveness	While not having an effect on dose, can provide a means of ameliorating some of the effects of high exposure (both psychological and physical) or management option disruption.
Factors influencing effectiveness of procedure	Appropriate design and administration; ability to identify individuals receiving or having received high doses. Compliance of public/workers to be more highly exposed than others. Abuse of compensation system e.g. false claims.
Feasibility	
Required specific equipment	Monitoring equipment to determine exposure levels (likely to be in use for other activities, e.g. medical check ups).
Required ancillary equipment	Administrative equipment.
Required utilities and infrastructure	Health and administrative services.
Required consumables	
Required skills	Design and implementation of compensation system.
Required safety precautions	
Other limitations	Competition for funding.
Waste	
Amount and type	N/A
Possible transport, treatment and storage routes	N/A

Factors influencing waste issues	N/A
Doses	
Incremental dose	Within statutory limits, which could be revised. But in case of ongoing exposures additional dose is no greater than if compensation is not provided.
Intervention Costs	
Equipment	N/A
Consumables	Administrative.
Operator time	Administrative.
Factors influencing costs	Efficiency of administration.
Compensation costs	Dependent on scale and limits of scheme. Compensation rates for dangerous work would provide a useful source of information.
Waste cost	N/A
Assumptions	
Communication needs	Publicising scheme. Dialogue ensuring informed consent.
Side-effect evaluation	
Ethical considerations	More equitable distribution of benefits and costs. Specific focus on worst affected individuals and/or groups. Extension of benefits to non-radiation related consequences. Ideologically dependent on acceptability of compensation for higher doses. Compensation could be seen as 'bribery' (e.g. workers paid to stay in contaminated regions). Perception of authority manipulation of worse off/exploitable groups.
Enviromental impact	N/A
Agricultural impact	Enables continued use of areas of high exposure.
Social impact	Encourages economically dependent population in/around affected regions. Shift to individual rather than collective responsibility may influence effectiveness of other collective measures. Can lead to perception of self as "victim". Badly managed compensation schemes in the fSU have been linked to social and economic problems in some fSU societies (see Petryna *et al.,* 2002; UNDP, 2002 below).
Other side effects	
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	Employment incurring higher exposures routinely attracts higher rates of pay; compensation for industrial sickness is also routine. Medical/insurance schemes are also used in worker situations (e.g. France, UK). In the case of non-radiological effects, compensation for economic losses or social disruption has been used extensively in Europe and fSU, both after Chernobyl and in connection with other agricultural emergencies (e.g., Foot and Mouth, BSE), albeit with varying degrees of success. For example, after foot and mouth in the UK there was a criticism that compensation actually increased inequity between farmers and was open to abuse.
Key references	United Nations Development Programme (UNDP) and UNICEF (2002). The Human Consequences of the Chernobyl Nuclear Accident – A Strategy for Recovery. http://www.undp.org/dpa/publications/chernobyl.pdf. Petryna A (2002). Life exposed. Princeton University Press, Princeton. Oughton D, Bay I, Forsberg E-M, Kaiser M (2002). Value judgements and trade-offs in management of nuclear accidents: using an ethical matrix in practical decision-making. Presented at "VALDOR" 2001: Stockholm.

Comments	At least four different cases need to be considered: • workers such as fire-fighters exposed in emergencies, • workers whose work locations involve higher doses e.g. factories in areas of high contamination, • people who live in areas of high contamination, but are not relocated, • those whose livelihoods are dependent on produce from affected areas. Employment incurring higher radiation routinely attracts higher rates of pay and compensation for industrial sickness.
Document History	**STRATEGY originator:** Oughton D (UMB) and Hunt J (ULANC). **STRATEGY contributors:** - **STRATEGY peer reviewer(s):** Manchester Metropolitan University (Mythen G); HPA-RPD (Morrey M). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Mutadis (Wallaert V).

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40 Dietary advice	
Objective	Dose reduction by giving people advice on how to reduce their radionuclide intake.
Other Benefits	Help people maintain their way of life. Enables informed choice.
Management option description	Provision of advice to people on ways to restrict their dietary radionuclide intake. For example, advice to reduce consumption of specific foodstuffs (e.g. game, mushrooms etc.), not to drink water from private supplies, or to prepare food in ways that reduce contamination levels (e.g. washing and peeling vegetables and fruit, brining fish, cooking meat etc.). Advice may vary from suggestions as to which foodstuffs can be eaten without restrictions, which would be okay to eat occasionally, and which should be avoided completely. In the early phase, communication would be largely media based (e.g. newspapers, internet); in later phases specialised leaflets could also be made available, including material prepared for specific population sub-groups. The management option might need to be supplemented with monitoring (see 42 Local provision of monitoring equipment).
Target	Critical groups who may have higher radionuclide intake as a consequence of dietary habits. Anyone who wants to reduce their dose.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Generally applicable to all population groups although may be most appropriate to critical groups (e.g. people with a high rate of wild food or home grown vegetable consumption). In the early phase, vulnerable groups such as children and pregnant women may need special attention.
Contamination pathway	-
Exposure pathway pre intervention	Ingestion
Time of application	Any time after deposition, including early phase. For as long as selected foodstuffs have enhanced activity concentrations. In the early phase, more likely to be advice to avoid certain foods completely.
Constraints	
Legal constraints	-
Social constraints	For socially isolated/independent rural populations e.g. the Saami, a key issue may be trust (or lack of) in the institutions/experts advising dietary restrictions.
Environmental constraints	N/A
Effectiveness	
Management option effectiveness	Compliance with the recommendation of avoidance of certain foodstuffs would be 100% effective. Washing has shown to remove between 10 % and >90 % of a range of radionuclides (including Ru, I, Sr, Cs, Am, Pu) from vegetables and fruits. Strawberries are an exception. Peeling is a very effective way of reducing the activity levels of insoluble radionuclides such as plutonium and americium (removing between 10 and 100 % of the activity) in root vegetables and is also effective for radiocaesium (up to 80 % but as little as 2 %) and radiostrontium (50-90 %).

Management option effectiveness (continued)	Blanching or boiling (following peeling) of vegetables or fruit in salted water can remove more than half of the radioactivity to the cooking liquor (which must then be discarded), the greatest amounts associated with radionuclides with a higher solubility. Radiostrontium activity concentrations will increase if the meat is roasted with the bone attached. De-boning of meat would almost completely remove ^{89}Sr and ^{90}Sr. Boiling meat is very effective in removing radiocaesium (approx 68%) into the cooking liquid (which must then be discarded); it is recommended that small pieces of meat are boiled in large quantities of water (salted water further increases the efficiency (by about 10%)). Slightly less effectiveness is seen for ^{106}Ru and ^{131}I and radiostrontium. Soaking in brine solution is one of the most effective ways of removing radiocaesium from meat and fish (see 35 Salting of meat). Filleting and washing fish, and washing and shelling mussels and shrimps, are very effective in reducing levels of ^{226}Ra (c. 80% reduction). Whilst there are no data for the effectiveness of food processing measures for some of the target radionuclides listed it is likely that some of the measures will be effective (e.g. washing or boiling). **Many procedures are only effective if cooking or preserving liquids are discarded.**
Factors influencing effectiveness of procedure	Foodstuffs and methods of preparation. Willingness of affected population to accept this type of intervention, and the extent to which advice is used (possible language and literacy issues). This may depend on the extent to which the food has a cultural and economic significance in the population.
Feasibility	
Required specific equipment	Normal cooking utensils.
Required ancillary equipment	None
Required utilities and infrastructure	Appropriate lines of communication lines.
Required consumables	Dependent on communication method.
Required skills	Communication skills.
Required safety precautions	N/A
Other limitations	N/A
Waste	
Amount and type	N/A
Possible transport, treatment and storage routes	N/A
Factors influencing waste issues	N/A
Doses	
Incremental dose	N/A
Intervention costs	
Equipment	N/A
Consumables	Printing and distributing leaflets.
Operator time	Time used for providing advice – depends on the communication method (personal contact, internet, telephone, etc.).
Factors influencing costs	
Compensation costs	Compensation may be considered in special cases, such as populations for whom wild or home produced foods have a cultural or economic significance. For example, in Norway, reindeer herders are given compensation to enable alternative foods to be purchased if their reindeer meat is above intervention limits (level of compensation is dependant upon level of contamination).

Compensation costs (continued)	Possible liability issues in the case of unforeseen health effects.
Waste cost	N/A
Assumptions	
Communication needs	Dialogue and dissemination of information about the management option (its rationale and possible alternatives) within affected communities. The method of communication is likely to change with time after the accident, and will need revision according to available information.
Side-effect evaluation	
Ethical considerations	When the population has trust in the institutions/experts advising dietary restrictions, the management option is likely to have more positive than negative social consequences (e.g. trust, personal control and informed choice).
Environmental impact	Possible ecological effect from increase in game population if hunting/fishing declines, or cessation of large-scale fungi/berry collection. Could be positive (e.g. conservation of habitats and increased nutrient availability resulting from increased decomposition) or negative (e.g. change in ecological equilibrium, lack of animal foodstuffs due to increased competition).
Agricultural impact	Possible increased utilisation of agricultural grasslands or crops by 'uncontrolled' game species.
Social impact	Changed perception of natural resources because of feeling that they are damaged/polluted. Loss of traditional activities e.g. gathering wild food, however, advice could maintain this as opposed to the alternative (food restrictions). Possible negative effects on food producers or collectors if the public avoids specialist or wild foodstuffs from contaminated areas. Potential loss of home produced and or wild foodstuffs may have most negative impact on poorer population groups.
Other side effects	
FARMING Network stakeholder opinion	Not considered by the FARMING Network.
Practical experience	Used in western Europe (especially Scandinavia) and the fSU after the Chernobyl accident. Proven to be a cheap and effective management option, if people are willing to follow the advice.

Key references	Brynildsen LI, *et al*. (1996). Countermeasures for radiocaesium in animal products in Norway after the Chernobyl accident – techniques, effectiveness and costs. *Health Physics*, 70, 665-672. Strand P, Selnaes TD, Boe E, Harbitz O and Andersson-Sorlie A (1992). Chernobyl fallout: internal doses to the Norwegian population and the effect of dietary advice. *Health Physics*, 63, 4, 385-392. Petäjä E, Rantavaara A, Paakkola O and Puolanne E (1992). Reduction of radioactive caesium in meat and fish by soaking. *Journal of Environmental Radioactivity*, 16, 273-285. IAEA Technical Report Series (1994). Handbook of parameter values for the prediction of radionuclide transfer in temperate environments, No. 364. IAEA, Vienna. Bryne AR, Dermelj M and Vakselj T (1979). Silver accumulation by fungi. *Chemosphere*, 10, 815-821. Tønnessen A, Skuterud L, Panova J, Travnikova IG, Strand P and Balonov MI (1996). Personal Use of Countermeasures Seen in a Coping Perspective. Could the Development of Expedient Countermeasures as a Repertoire in the Population, Optimise Coping and Promote Positive Outcome Expectancies, When Exposed to a Contamination Threat? *Radiation Protection Dosimetry*, 68, 261-266. Beresford NA, Voigt G, Wright SM, Howard BJ, Barnett CL, Prister B, Balonov M, Ratnikov A, Travnikova I, Gillett AG, Mehli H, Skuterud L, Lepicard S, Semiochkina N, Perepeliantnikova L, Goncharova N and Arkhipov AN (200). Self-help countermeasure strategies for populations living within contaminated areas of Belarus, Russia and the Ukraine. *Journal of Environmental Radioactivity*, 56, 215-239. See also 18 Processing of crops for subsequent consumption and 35 Salting of meat.
Comments	Can be combined with local provision of monitoring equipment.
Document History	**STRATEGY originator:** Oughton D (UMB) and Hunt J (ULANC). **STRATEGY contributors:** **STRATEGY peer reviewer(s)**: Manchester Metropolitan University (Mythen G); HPA-RPD (Morrey M). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Mutadis (Wallaert V).

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41 Food labelling	
Objective	To allow informed choice of foodstuffs with low levels of contamination.
Other benefits	Potentially beneficial in terms of increased information and understanding by the public.
Management option description	Provision of information on activity concentrations, and also possibly on the source of produce, and any remedial treatment. Labelling of food or provision of information at retail outlet. Requires an associated system of analysis/monitoring and provision of information explaining information provided in the labelling.
Target	Consumers.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Localised to large.
Contamination pathway	-
Exposure pathway pre intervention	Ingestion.
Time of application	Medium to long term.
Constraints	
Legal constraints	Would require legislation changes (for example, as seen from the demands of consumer groups and retail companies regarding genetically modified foods). Accredited methods for food labelling would need to be adhered to and may differ between counties.
Social constraints	Retailers' resistance to management option.
Environmental constraints	May lead to waste food products.
Effectiveness	
Management option effectiveness	Potentially highly effective in providing information and increasing informed choice.
Factors influencing effectiveness of procedure	Difficult to do for anything other than gamma emitting radionuclides for fresh produce such as milk which has a short time between production and delivery to the consumer. Public's perception and understanding of risks – without good explanation of labelling the public may avoid anything labelled, regardless of what the label says.
Feasibility	
Required specific equipment	Analytical / monitoring equipment.
Required ancillary equipment	N/A
Required utilities and infrastructure	Monitoring of foodstuffs for radionuclide content. Provision of information explaining labelling. Retailers may need to separate food with different contamination levels.
Required consumables	Labels.
Required skills	Radionuclide measurement, including low-level. Labelling already practiced for some foodstuffs; similar consumer demand for labelling of GMOs, organic foods, etc.
Required safety precautions	
Other limitations	Possible black market in foodstuffs with higher levels of radionuclides even if under the Council Food Intervention Limits (CFIL).
Waste	

Amount and type	N/A
Possible transport, treatment and storage routes	N/A
Factors influencing waste issues	N/A
Dose	
Incremental dose	May be higher in low income proportion of public if more highly contaminated produce is cheaper.
Intervention costs	
Equipment	
Consumables	Printing and distributing, labels, leaflets etc.
Operator time	
Factors influencing costs	Radionuclide, food production techniques (i.e. homogeneity of food batches).
Compensation costs	**Producers and retailers:** for potential reduction in profit margins.
Waste cost	N/A
Assumptions	
Communication needs	Potentially highly contentious and more likely to be a measure instigated by public demand, rather than as a result of authorities' decision. Likely to meet resistance from some production or retail companies, good stakeholder dialogue procedures will be essential. Dissemination of information about the management option, its rationale and possible alternatives i.e. explanation of the risks associated with differing levels of contamination, uncertainty and variance of levels.
Side-effect evaluation	
Ethical considerations	Information increases ability for individual control and informed consent to exposure. Conversely, pressure of having to make daily decisions regarding the radioactive content of food may be unfair. Risk of inequitable distribution of dose if costs of "clean" foods increase and 'contaminated' decreases. If prices rise of non-contaminated or non-treated foods, low income populations will have less choice in avoidance of contaminated products.
Environmental impact	
Agricultural impact	Consumer reaction may provoke agricultural changes (but unlikely to be worse than if no labelling).
Social impact	Public confidence may decrease as consumers may lose trust in food products with quoted contamination levels. It may also increase, perceived as the crisis is being managed.
Other side effects	May have economic and side-effects for producers in contaminated areas. Consumer awareness is growing and increasingly important in the allocation of market shares (e.g. growth in the demand for organic produce).
FARMING Network stakeholder opinion	Not considered by FARMING Network. Labelling was discussed amongst Finnish stakeholders; based on (their perceptions of) the high cost, negative side effects and minimal benefit for radiation protection it was not considered to be a viable option.
Practical experience	
Key references	
Comments	
Document History	**STRATEGY originator:** Oughton D (UMB) and Hunt J (ULANC). **STRATEGY contributors:** - **STRATEGY peer reviewer(s):** Manchester Metropolitan University (Mythen G); HPA-RPD (Morrey M).

	EURANOS originator: n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Mutadis (Wallaert V).

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42 Local provision of monitoring equipment

Objective	To provide the public with personal access to equipment or facilities giving information on radiation levels in foodstuffs or surroundings. Screening of home-grown or self-gathered foodstuffs for radioactivity content. Identifying areas of significant contamination in and around homes and places of work.
Other benefits	Reassurance of affected populations. Enhancing technical knowledge and skills among affected populations.
Management option description	Provision of counting equipment or local measurement stations so that the general public can check habitats or foodstuffs for radionuclide content (particularly home grown or self-gathered). Facilities could include loan or donation of Geiger counters or access to independent monitoring services. Other services may include whole body monitoring or general advice on radiation risks.
Target	Home-grown and/or self-gathered foodstuffs.
Targeted radionuclides	**Known applicability:** ^{60}Co, ^{75}Se, ^{99}Mo/^{99m}Tc, ^{131}I, ^{134}Cs, ^{137}Cs, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{127}Sb, ^{132}Te, ^{140}Ba, ^{140}La, ^{144}Ce. **Probable applicability:** - **Not applicable:** Radionuclides with no effective photon emissions (i.e. beta and alpha emitters e.g. ^{90}Sr) and radionuclides with low photon energies (e.g. ^{141}Ce, ^{235}U, ^{238}Pu, ^{239}Pu, and ^{241}Am).
Scale of application	Small/medium scale. Areas where food is home produced/self-gathered. Homes and gardens.
Contamination pathway	Plant – Human; Animal – Human.
Exposure pathway pre intervention	Mainly ingestion.
Time of application	Early to long term. However, in early phase appropriate monitoring equipment is unlikely to be available. Consumption of wild foodstuffs is likely to be restricted in the early phase, but monitoring of essential and perishable foodstuffs such as water or milk may be necessary.
Constraints	
Legal constraints	Quality control of measurement (calibrated detectors, accreditation of analytical methods used as well as logging of samples and recording of results). Freedom of information necessary.
Social constraints	Resistance by affected populations to use equipment and to consume foodstuffs with low levels of contamination.
Environmental constraints	None
Effectiveness	
Management option effectiveness	Potentially high for dose reduction (can reduce ingestion to below intervention limits). Time taken to distribute calibrated equipment and provide training may preclude the use of this management option for those radionuclides on the target list with comparatively short half-lives.
Factors influencing effectiveness of procedure	Quality of, and access to, monitoring equipment. Quality of training to affected populations. Best used in conjunction with information provision. Need for trust in those providing equipment, information, monitoring results and interpretation of results.
Factors influencing effectiveness of	Acceptability and compliance of consumers to a) non-consumption of

procedure (continued)	contaminated foodstuffs, and b) continued consumption of foodstuffs with low levels of contamination. May depend upon e.g. availability of alternative foodstuffs, consumers' willingness to reject foodstuffs. If the monitoring equipment is used by the general public calibrations may be missing or used erroneously which may give incorrect results thus leading to a lack of public confidence.
Feasibility	
Required specific equipment	Appropriate monitoring equipment (e.g. NaI detectors for foodstuffs). Radiochemical laboratories and equipment for beta and alpha measurement.
Required ancillary equipment	Data recording equipment.
Required utilities and infrastructure	Transport, distribution networks. Co-ordination of counting equipment/monitoring services.
Required consumables	
Required skills	Knowledge of radioanalytical and radiochemical methods; teaching for education and training of public (e.g. in use of counting equipment).
Required safety precautions	N/A
Other limitations	N/A
Waste	
Amount and type	Rejected foodstuffs will require disposal.
Possible transport, treatment and storage routes	Local disposal may be necessary.
Factors influencing waste issues	Acceptability of disposal methods likely to be dependent on levels of overall contamination in the region (populations are unlikely to be willing to accept wastes from other areas – see appropriate waste disposal sheets). Legal requirements for disposal will have to be met.
Doses	
Incremental dose	Potentially higher doses to those providing monitoring services due to working in more highly contaminated areas.
Intervention Costs	
Equipment	Depends on monitoring type.
Consumables	Chemicals - depends on monitoring type. Sample containers - depends monitoring type. Materials used to provide training and information.
Operator time	That associated with training, support and results recording and reporting. Laboratory analysts – amount depends upon sample type, number of samples and the analysis required.
Factors influencing costs	Scale of programme; efficiency of administration.
Compensation costs	Compensation or other financial assistance where rejected foodstuffs are not easily substitutable is likely to be necessary if this measure is to be effective.
Waste cost	Variable.
Assumptions	
Communication needs	Affected populations would have to be educated or trained in the use of monitoring equipment and how to interpret the results. Continued support may be necessary. Possible media interest in unusual levels of contamination.
Side-effect evaluation	
Ethical considerations	Self help and empowerment for the public.

	Improves personal control and ability to make informed choices, due to better public understanding of radiation risks and increased knowledge on levels in foodstuffs. Communicates authorities' trust in the public. Possible negative effects on lower income populations and inequitable distribution of dose, if the management option results in a black market for cheap "contaminated foodstuffs".
Environmental impact	No direct environmental impact.
Agricultural impact	Rejection of some foodstuffs may disrupt local practices.
Social impact	Disruption to people's image of the home-grown food as "natural". Disruption of traditional food provision. Potential for contaminated foodstuffs to enter black market. Increased public confidence.
Other side effects	Nutritional effects. Secondary effects e.g. erosion, loss of soil fertility, changes in biodiversity, creation of wildlife habitats could occur.
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	Tested with good results in fSU after Chernobyl (see Hériard Dubreuil et al.).
Key references	Hériard Dubreuil GF, Lochard J, Girard P, Guyonnet JF, Le Cardinal G, Lepicard S, Livolsi P, Monroy M, Ollagon H, Pena-Vega A, Pupin V, Rigby J, Rolevitch I and Schneider T (1999). Chernobyl post-accident management: The ETHOS project. *Health Physics*, 77, 361-372.
Comments	The management option should be carried out in conjunction with provision of 40 Dietary advice. The availability of local measurements was emphasised and appreciated in all Finnish FARMING seminars. Could also be used to monitor external doses if appropriate equipment was supplied (e.g. dose rate monitors) and suitable training provided.
Document History	**STRATEGY originator:** Oughton D (UMB) and Hunt J (ULANC). **STRATEGY contributors:** **STRATEGY peer reviewer(s):** Manchester Metropolitan University (Mythen G); HPA-RPD (Morrey M). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Wallaert V (Mutadis).

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43 No active implementation of management options (do nothing)	
Objective	The minimisation or avoidance of social and economic costs of management option implementation.
Other benefits	Protection of an important or minority social or cultural industry. Job security.
Management option description	A decision to not implement management options to reduce radionuclide levels in the environment or foodstuffs, depends on the conditions that the direct or side-effect costs of the management option outweigh any benefit from dose reduction, and/or that intervention limits are not exceeded. Intervention limits may need to be monitored and reasons for 'doing nothing' explained and/or approved by affected populations. In the early phase, would imply monitoring only.
Target	All management options.
Targeted radionuclides	**Known applicability:** All **Probable applicability:** - **Not applicable:** -
Scale of application	Generally applicable.
Contamination pathway	All.
Exposure pathway pre intervention	All.
Time of application	Early, medium, late (depending on availability of information).
Constraints	
Legal constraints	Dose or radionuclide concentrations in foodstuffs should be below intervention limits. Non-intervention can be supported by the justification or ALARA principle. Can be supported by nature or cultural heritage protection.
Social constraints	Public and stakeholder consent. There may be a demand for "something to be done" or for some form of compensation.
Environmental constraints	-
Effectiveness	
Management option effectiveness	Zero for dose reduction; can be effective for prevention of social/economic costs.
Factors influencing effectiveness of procedure	Good monitoring data, reliable estimates of costs of management options not undertaken and benefits foregone, quality and quantity of communication channels. Compliance of public.
Feasibility	
Required specific equipment	-
Required ancillary equipment	-
Required utilities and infrastructure	-
Required consumables	-
Required skills	-
Required safety precautions	-
Other limitations	-
Waste	
Amount and type	-
Possible transport, treatment and storage	-

routes	
Factors influencing waste issues	-
Doses	
Incremental dose	-
Intervention Costs	
Equipment	-
Consumables	-
Operator time	-
Factors influencing costs	-
Compensation costs	Food producers for loss of income.
Waste cost	-
Assumptions	-
Communication needs	Dialogue with public, consumers and stakeholders.
Side-effect evaluation	
Ethical considerations	Could maintain an inequitable distribution of doses among consumers and inhabitants. Loss of trust in authorities, particularly if the decision was subsequently overturned. If carried out in the early phase, may be seen as contrary to a precautionary approach.
Environmental impact	Possible effects from untreated areas as a source for transport to other areas (e.g. run-off or wind re-suspension).
Agricultural impact	Breakdown in agricultural industry.
Social impact	Fear and worries of workers and inhabitants. Consumer trust in food may be reduced leading to knock-on effects for producers, food-industries, tourism etc.
Other side effects	Multiple, both positive and negative, depending on case and handling by authorities.
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	Used with varying success after Chernobyl and other accidents. In France and the UK authorities' initial response was that there would be no effect and no need for any precautionary action. Particularly in the UK, the subsequent realisation that management options would have to be implemented led to a serious undermining of public trust in authorities.
Key references	Gould R (1990). Fire in the Rain: The Democratic Consequences of Chernobyl. The John Hopkins University Press: Baltimore. Oughton D, Bay I, Forsberg E-M and Kaiser M (2002). Value judgements and trade-offs in management of nuclear accidents: using an ethical matrix in practical decision-making. Presented at "VALDOR" 2001: Stockholm.
Comments	Good communication imperative. Self-help benefits may still accrue, indeed self-help may be more likely if there is no government action.
Document History	**STRATEGY originator:** Oughton D (UMB) and Hunt J (ULANC). **STRATEGY contributors:** **STRATEGY peer reviewer(s):** Manchester Metropolitan University (Mythen G); HPA-RPD (Morrey M). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating

	additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Wallert V (Mutadis).

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44 Processing and / or storage prior to consumption

Objective	To process and/or store foodstuffs until the activity concentrations have declined to what is considered to be acceptable levels.
Other benefits	Provides allotment holders and kitchen gardeners with the choice to consume home-grown produce. This reduces the amount of food requiring disposal.
Management option description	Processing and/or storing home-grown produce or gathered free foods, may achieve reductions in activity concentrations to below intervention levels. Storage allows decay of short-lived radionuclides especially ^{131}I. Methods for processing and storing may include blanching, marinating, deep freezing, drying and making jams, chutneys and preserves.
Target	Food products that can be processed and/or stored such as milk, meat, eggs, fruit, berries, vegetables, nuts, fish and honey.
Targeted radionuclides	Processing: radiocaesium (based on available data) Storage: ^{134}Cs, ^{89}Sr, ^{131}I, ^{192}Ir, ^{99}Mo/^{99m}Tc, ^{169}Yb (short lived radionuclides)
Scale of application	Small to medium scale.
Contamination pathway	Soil to plant and plant to animal
Exposure pathway pre intervention	Ingestion
Time of application	Any time after deposition, or for as long as selected foodstuffs have enhanced activity concentrations.
Constraints	
Legal constraints	The supply and sale of commercially produced foods intended for human consumption is subject to Council Food Intervention Levels (CFILs). Whether these apply to domestically produced food or foods from the wild will depend on national legislation.
Social constraints	Foodstuffs that may have been radioactively contaminated may not be acceptable to growers, when foodstuffs can be obtained from other sources.
Environmental constraints	None
Effectiveness	
Management option effectiveness	Blanching can remove activity incorporated within the food e.g. 50% of radiocaesium contamination is removed during blanching or boiling. Meat and fish can be marinated in NaCl brine with reductions of up to 80% and 50% respectively for radiocaesium. Storage of products can be very effective, achieving reductions of up to 100% for contamination with short-lived radionuclides.
Factors influencing effectiveness of procedure	Mode of contamination (direct deposition, root uptake, ingestion etc.) Interval between deposition and time of collection for processing. Half life of radionuclides involved. Storage characteristics of the particular foodstuff. Whether boiling and blanching, or marinating fluids have been discarded or re-used in another part of the cooking process. Willingness of producers to carry out procedures. Honey in the hive up to the point of deposition, would be suitable for consumption, although subject to contamination as soon as the bees fly out onto contaminated plants. The nectar is unlikely to be contaminated immediately, although uptake via groundwater maybe a problem later on. Direct deposition on to the flowers maybe transferred to the hive via contact with the bees.
Feasibility	

Required specific equipment	Typical kitchen utensils, including freezer and storage containers.
Required ancillary equipment	None.
Required utilities and infrastructure	None.
Required consumables	Marinating solution (if appropriate)
Required skills	Knowledge of appropriate storage times for different foods and half life of radionuclide(s) will be required.
Required safety precautions	None.
Other limitations	Contamination of kitchen utensils?
Waste	
Amount and type	Boiling and blanching solutions, marinated fluids. Depends on foodstuffs being dealt with and preparation carried out prior to storage.
Possible transport, treatment and storage routes	Liquids may be disposed of via the drain and solids to landfill. However, Local Authorities might have to organise special collections for the waste. Vegetable waste may be kept for composting.
Factors influencing waste issues	Dependent on type of foodstuff and type of processing carried out. The high moisture content and readily putrescible nature of some food residues mean that waste treatment cannot be delayed.
Doses	
Incremental dose	Trivial external exposure to householder from stored foodstuffs.
Intervention Costs	
Equipment	Kitchen utensils, freezer and cupboards would be already available. For reassurance purposes, the DPFF subgroup considered it important for the householder to have access to monitoring equipment to check contamination levels in foodstuffs following processing/storage, prior to consumption (see 42 Local provision of monitoring equipment).
Consumables	If marinating solution is brine, salt would be readily available.
Operator time	N/A
Factors influencing costs	N/A
Compensation costs	N/A
Waste cost	Dependent on nature and amount of waste arising and subsequent disposal route selected.
Assumptions	That the end product would be acceptable to growers' families
Communication needs	Possible cost of labelling
Side-effect evaluation	
Ethical considerations	Informed consent. Distribution of costs and benefits, for example, the possible inequity due to cost of option. Loss of profit if produce normally sold to public.
Environmental impact	None.
Agricultural impact	N/A
Social impact	Possible loss of confidence in products if normally sold.
Other side effects	Contamination of kitchen utensils.
FARMING Network stakeholder opinion	Only considered by the UK node of the FARMING Network. Preliminary opinion from the group is that this option would be acceptable. It was felt that provided the public was given advice on this option from trustworthy sources, domestic producers could make up their own mind. Furthermore, consumers that are 100% self-sufficient would be less likely to want to dispose of food they have grown and more in favour of processing/storage options.
Practical experience	In Greece following Chernobyl accident, milk contaminated with radioiodine was converted by householders to feta cheese, for

	storage prior to consumption.
Key references	Green N and Wilkins BT (1995). *Effects of processing on the radionuclide content of foods: Derivation of parameter values for use in radiological assessments*. Chilton, NRPB–M587. Prosser SL, Brown J, Smith JG and Jones AL (1999). *Differences in activity concentrations and doses between domestic and commercial food production in England and Wales: Implication for nuclear emergency response*. Chilton, NRPB – R310. IAEA Technical Report 363 (1994) Guidelines for agricultural countermeasures following an accidental release of radionuclides. Vienna, IAEA. NKS-16 (2000). A guide to countermeasures for implementation in the event of a nuclear accident affecting Nordic food producing areas.
Comments	Consider this option in conjunction with others including 40 Dietary advice and 42 Local provision of monitoring equipment.
Document history	Mercer JA and Nisbet AF (2005). *Domestic food production and the gathering of free foods. UK Recovery Handbook for Radiation Incidents, Version 1, 2005*. Chilton, HPA-RPD-002.

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45 Raising of intervention limits	
Objective	Raising intervention limits to allow sale or use of foodstuffs.
Other benefits	Protection of minorities, i.e. allows traditional (e.g. Sami reindeer herders) and small scale local production (e.g. specialist cheeses) to be maintained. In the case of small scale producers this may protect them from competition by larger commercial producers who may have more opportunity to produce less contaminated foods.
Management option description	Raising intervention limits in foodstuffs either because of the need to protect a particular producer/group or due to revision of dose-risk estimates. Usually most relevant for specialist or self-gathered or traditional foodstuffs. Likely to be controversial, so a good communication strategy will be essential.
Target	Producers.
Targeted radionuclides	**Known applicability:** ^{60}Co, ^{75}Se, ^{89}Sr, ^{90}Sr, ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{131}I, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{242}Cf **Probable applicability:** - **Not applicable:** The lack of existing Council Food Intervention Limits (CFILs) for the following radionuclides with half-lives of less than *circa* 10 d is likely to exclude this measure (as is the short half-life in itself): ^{99}Mo/^{99m}Tc, ^{127}Sb, ^{132}Te, ^{140}Ba, ^{140}La
Scale of application	Localised or large (national).
Contamination pathway	-
Exposure pathway pre intervention	Ingestion.
Time of application	Medium to long term (not relevant for the early phase as information likely to be inadequate).
Constraints	
Legal constraints	Permitted levels in foodstuffs, especially for international markets. Note, CFIL values would be in force for at most 3 months after an accident. They would subsequently have to be re-agreed by Member States or they could be adjusted to the particular accidental situation.
Social constraints	Public/producers resistance to management option.
Environmental constraints	-
Effectiveness	
Management option effectiveness	Will lead to increased doses.
Factors influencing effectiveness of procedure	Public's/producers' perception and understanding of risks - likely to be closely linked to good communication and dialogue.
Feasibility	
Required specific equipment	-
Required ancillary equipment	-
Required utilities and infrastructure	-
Required consumables	Those associated with communication.
Required skills	Those associated with communication.
Required safety precautions	-
Other limitations	-
Waste	
Amount and type	N/A
Possible transport, treatment and storage routes	N/A

Factors influencing waste issues	N/A
Doses	
Incremental dose	Increased, particularly in groups reliant on "specialised" foodstuff.
Intervention Costs	
Equipment	-
Consumables	-
Operator time	-
Factors influencing costs	-
Compensation costs	**Food producers:** for reduced market value of foodstuffs.
Waste cost	-
Assumptions	-
Communication needs	Dissemination of information about the management option its rationale and possible alternatives, i.e. explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels, and reasons for increase. Potentially highly contentious and is likely to meet resistance from consumers, so good stakeholder dialogue procedures will be essential. Would require stakeholder dialogue and consent of producers.
Side-effect evaluation	
Ethical considerations	Information to consumers. For natural/gathered foodstuffs, increased choice and control. Inequitable distribution of dose; if prices rise in non-contaminated foods, low income populations will have less choice in the avoidance of contaminated products. Potential risk of management option being used as an alternative to dose reducing intervention.
Environmental impact	Possibly positive by maintaining traditional practices.
Agricultural impact	Maintains on-going agricultural practices.
Social impact	Public confidence may decrease as consumers may lose trust in food products. It may also increase, if perceived as the crisis is being managed. Regional and cultural history (particularly that relating to food contamination) will be decisive in determining acceptability.
Other side effects	
FARMING Network stakeholder opinion	Not considered by FARMING Network.
Practical experience	Carried out in Scandinavia after Chernobyl (reindeer meat and freshwater fish). Good public acceptance in Norway (see Mehli *et al.,* 2000) although some confusion over different limits within Europe reported from other countries (Gould, 1992). Intervention limits gradually reduced with time in former Soviet Union countries following the Chernobyl accident.
Key references	Mehli H, Skuterud L, Mosdøl A and Tønnessen A (2000). The impact of Chernobyl fallout on the Southern Saami reindeer herders in Norway in 1996. *Health Physics*, 79: 682-690. Oughton D, Bay I, Forsberg E-M and Kaiser M (2002). Value judgements and trade-offs in management of nuclear accidents: using an ethical matrix in practical decision-making. Presented at "VALDOR" 2001: Stockholm.
Comments	Unlikely to be accepted without stakeholder consultation (producers, consumers, public).
Document History	**STRATEGY originator:** Oughton D (UMB) and Hunt J (ULANC). **STRATEGY contributors:** - **STRATEGY peer reviewer(s):** Manchester Metropolitan University

	(Mythen G); HPA-RPD (Morrey M). **EURANOS originator**: n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Wallaert V (Mutadis).

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46 Restrictions on gathering wildfoods	
Objective	Dose reduction by reducing consumption of contaminated wild food.
Other benefits	
Management option description	Restriction on hunting, fishing and gathering of wild food products such as mushrooms, berries and honey to reduce radionuclide intake from these foodstuffs. In early-phase this may avoid intake of surface contamination for all radionuclides; in the long-term the management option is predominantly aimed at reducing radiocaesium ingestion. Precautionary if carried out as an early phase management option.
Target	People who gather and/or consume wild foods.
Targeted radionuclides	**Known applicability:** All (especially radiocaesium in long-term). **Probable applicability:** - **Not applicable:** -
Scale of application	Large scale.
Contamination pathway	
Exposure pathway pre intervention	Ingestion
Time of application	Early to long term.
Constraints	
Legal constraints	Legislation banning collection would be required
Social constraints	Public or stakeholder resistance to the management option. Management option is likely to be met with strong resistance from local populations for whom collection of wild food has a cultural and economic significance.
Environmental constraints	N/A
Effectiveness	
Management option effectiveness	Effectiveness will be 100% if restrictions are complied with. However, contribution to total reduced dose will depend upon consumption habits in the area(s) of interest.
Factors influencing effectiveness of procedure	**Long-term (Radiocaesium)** Type of mushrooms consumed in the contaminated region (e.g. mycorrhizal fungi accumulate more radiocaesium than saprophytic). Type of game consumed in the contaminated region (Cs transfer to wild boar meat contributes more to total dose than an equal quantity of moose meat). Type of berries and or freshwater fish consumed. The willingness of affected populations to observe restrictions which will change over long time periods. Availability of alternative sources of food.
Feasibility	
Required specific equipment	N/A
Required ancillary equipment	N/A
Required utilities and infrastructure	"Policing" to ensure compliance.
Required consumables	Those associated with communication (e.g. leaflets and signage).
Required skills	None
Required safety precautions	N/A
Other limitations	
Waste	
Amount and type	N/A
Possible transport, treatment and storage	N/A

routes	
Factors influencing waste issues	N/A
Doses	
Incremental dose	Trivial external exposure to authorities erecting signs and information boards
Intervention Costs	
Equipment	
Consumables	Items required for the production of leaflets and signs.
Operator time	That associated with policing the management option. That associated with the erection of signs in areas known to be used by gatherers. That associated with distribution of leaflets circulated to gatherers.
Factors influencing costs	Methods used to ensure compliance. Degree of policing and monitoring required.
Compensation costs	There may be commercial enterprises affected by the bans – collection of some wild foodstuffs is conducted at a commercial scale in many countries.
Waste cost	N/A
Assumptions	
Communication needs	Public and stakeholder dialogue and dissemination of information about the management option (its rationale and possible alternatives) within affected communities, as part of a wider communication and information strategy. Need for update of information as data becomes available. Media interest is likely to be high compared to some other management options.
Side-effect evaluation	
Ethical considerations	Precautionary if carried out as an early phase management option. Negative for liberty and autonomy.
Environmental impact	Possible positive ecological effects e.g. increase in game population if hunting/fishing declines, or greater numbers/diversity if cessation of large-scale fungi/berry collections, conservation of habitats and increased nutrient availability resulting from increased decomposition. Possible negative ecological effects and animal welfare issues include change in ecological equilibrium, lack of animal foodstuffs due to increased competition for game.
Agricultural impact	Possible increased utilisation of agricultural grasslands or crops by ‘uncontrolled’ game species.
Social impact	Stigma associated to restricted area. Disruption to people’s image of countryside as “natural”. Negative social and psychological impacts caused by, for example, the loss of traditional activities and loss of cheap food sources. Possible increase in public confidence that the problem of contamination is being effectively managed. The willingness of affected populations to observe restrictions will change over long time periods.
Other side effects	Replacement foods may be required.
FARMING Network stakeholder opinion	Not considered by farming network.
Practical experience	Used following the Chernobyl and Mayak accidents.

Key references	Howard BJ, Wright SM and Barnett CL (eds.). (1999). Spatial analysis of vulnerable ecosystems in Europe: Spatial and dynamic prediction of radiocaesium fluxes into European foods (SAVE). Summary and Final report, Contract FI4PCT950015, European Commission. Beresford NA, Voigt G, Wright SM, Howard BJ, Barnett CL, Prister B, Balonov M, Ratnikov A, Travnikova I, Gillett AG, Mehli H, Skuterud L, Lepicard S, Semiochkina N, Perepeliantnikova L, Goncharova N and Arkhipov AN (2001). Self-help countermeasure strategies for populations living within contaminated areas of Belarus, Russia and the Ukraine, *Journal of Environmental Radioactivity,* 56, 215-239. Rafferty B and Synnott H (1998). Countermeasures applied to forest ecosystems and their secondary effects: a review of literature. Serie Documenti 6/1998. Agenzia National per la Protezione dell'Ambiente (ANPA), Roma. ISBN 88-448-0296-1. Bryne AR, Dermelj M and Vakselj T (1979). Silver accumulation by fungi. *Chemosphere*, 10, 815-821.
Comments	See also 40 Dietary advice and 28 Change of hunting season. Howard *et al.* (1999) give values of wild food consumption rates in Europe.
Document History	**STRATEGY originator:** Liland A (NRPA) **STRATEGY contributors:** CEH (Beresford NA, Barnett CL and Howard BJ), HPA-RPD (Nisbet AF). **STRATEGY peer reviewer(s):** Manchester Metropolitan University (Mythen G); HPA-RPD (Morrey M). **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability. **EURANOS peer reviewer(s):** Wallaert V (Mutadis).

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47 Biological treatment (digestion) of crops

Objective	To reduce the mass of solids derived from contaminated crops requiring disposal.
Other benefits	Digested crops can be used as a fertiliser and biogas generated used as an energy source.
Description	Biological treatment of crops is very effective at reducing the volume of material for disposal. Typically the volume is reduced by 40 to 60 %, but it can be as high as 80 % depending on type of anaerobic digester and crop. Anaerobic digestion (AD) is the fermentation of organic matter, such as green crop residues, to produce a methane-rich gas, which can be used for heating or electricity generation. Material is retained in an enclosed reactor at temperatures of 35-55^{o}C for a period of 10-30 days. Around 50% of the organic matter is degraded during this process. The remainder forms a sludge/slurry (digestate) that can be used directly as a fertiliser or separated to produce a solid fertiliser (cake) which may be disposed of via landfill or incineration and a liquid fertiliser (liquor) which may be put back into the digestion system.
Target	Contaminated crops.
Targeted radionuclides	**Probable applicability:** ^{60}Co, ^{89}Sr, ^{90}Sr ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf. **Not applicable:** High soil:plant concentration ratio (>1) may cause high plant uptake: ^{75}Se, ^{99}Mo/^{99m}Tc. Short half-life of ^{127}Sb, ^{131}I, ^{132}Te, ^{140}La likely to mean this management option is not applicable.
Scale of application	Small scale – crops need to be macerated prior to digestion and the equipment for this is not generally available.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to late phase.
Constraints:	
Legal constraints	Relate to management of waste arising from digestion of crops. Relevant EC legislation: EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). EC Nitrate Directive 91/676/EEC
Social constraints	Relate to disposal option selected for waste e.g. willingness of farmers to accept sludge from biological treatment of crops. Resistance if the resulting sludge is applied to previously uncontaminated areas. Perception of causing additional contamination of the soil when slurry spread on farmland. There may be local opposition to the use of particular landfill sites e.g. if contaminated sludge is disposed of in previously uncontaminated areas.
Environmental constraints	None for digestion of crops. Relate to subsequent fate of slurry, which should not be spread on land with a high risk of runoff or leaching, and high nutrient status.
Communication constraints	Farmers/operators require information on the biological treatment of crops.

Effectiveness:	
Effectiveness	N/A.
Factors influencing effectiveness of procedure	Availability of maceration equipment. Sewage treatment and on-farm anaerobic digestion plants are designed for sewage and animal waste treatment respectively and will not always have the required equipment. Macerated crops should be mixed with sewage, animal wastes or slurried with water to increase the digestion process. Partitioning of radionuclides between sludge and effluent. Capacity to treat contaminated crops depends on radiological impact of effluent. Acceptability of disposal routes for digestate. Willingness of privately owned landfill sites and local populations to accept the wastes.
Feasibility:	
Required specific equipment	Anaerobic digestion facility.
Required ancillary equipment	Maceration equipment. Vehicles for transport. Equipment for spreading slurry, solid fertiliser and liquid effluent following digestion.
Required utilities and infrastructure	Sewage treatment works for treatment and disposal of liquid effluent if it can not be applied to the land or put back into the digestion system. Agricultural land or landfill and incinerators for digestate and cake disposal if spreading on land is not possible.
Required consumables	Fuel for transport. Animal waste or water to increase digestion process.
Required skills	At anaerobic digestion facilities the necessary skills will be available. The farmer will have experience of spreading wastes to land.
Required safety precautions	None.
Other limitations	None.
Waste:	
Amount and type	Depends on the anaerobic digestion facility used. Typically the volume of material is reduced by 40 to 60 %, but it can be as high as 80%. The sludge/slurry produced can be separated into solid fertiliser and liquid effluent fractions. Anaerobic digestion produces biogas which is typically made up of 65% methane and 35% carbon dioxide. The conversion of solids to biogas varies by reactor type. Conversion can range from 30 to 80%.
Possible transport, treatment and storage routes	Biogas is normally used for process heating and electricity generation. Digested products can be stored on farm or transported to other farms to be used as fertilisers. For the liquor the preferred options would be for it to be applied to land or put back into the digestion system. Digestate and cake could be sent to landfill or incineration.
Factors influencing waste issues	Biological treatment method used. Disposal option chosen for sludge and effluent. Level of radioactivity in the waste products.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of the digestion of crops. There are separate datasheets for 54 Landfill and 53 Incineration as alternative disposal options for the digestate and cake. If liquor is not applied to land it may be put back into the digestion system.)*	**Anaerobic Digestion Facility Operative:** • inadvertent ingestion of digestate during anaerobic digestion of crops, • external exposure, inhalation and inadvertent ingestion of cake when loading it onto wagons.

Incremental dose (continued) *(Dose pathways in italics are indirectly incurred as a result of the digestion of crops. There are separate datasheets for 54 Landfill and 53 Incineration as alternative disposal options for the digestate and cake. If liquor is not applied to land it may be put back into the digestion system.)*	**Drivers (External Exposure):** • external exposure to driver while transporting crops to anaerobic digester, • *external exposure to driver while transporting digestion products (digestate, liquor, cake) to place of disposal (e.g. farmland).* ***Farmer:*** • *external exposure, inhalation and inadvertent ingestion while loading spreader/sprayer with digestate, cake or liquor,* • *external exposure while spreading/spraying digestate, cake or liquor,* • *external exposure, inadvertent ingestion and inhalation of digestate, cake or liquor while ploughing.* ***Public:*** • *ingestion by public of food grown on land spread with digestate, liquor or cake.*
Intervention Costs:	
Equipment	Anaerobic digestion facility already available. Maceration equipment limited availability. Vehicles for transport.
Consumables	Fuel for transport (depending on distance).
Operator tim	Operators' time for macerating crops. Operators' time at anaerobic digestion facilities for handling additional material.
Factors influencing costs	Amount of crops to be digested and disposal routes of digestion products. Volume of liquid effluent to be treated.
Compensation costs	To anaerobic digestion facilities for handling contaminated crops and decontamination of equipment. To transport companies for decontamination of vehicles.
Waste cost	Treatment and disposal of sludge/slurry and effluent.
Assumptions	None.
Communication needs	Dialogue with the operators and regulators needs to be established well in advance.
Side-effect evaluation:	
Ethical considerations	Additional dose to anaerobic digester operators and populations living close to sewage treatment works. Consent of workers. Environmental risk.
Environmental impact	Nitrogen oxides, sulphur oxides and particulates are released to atmosphere as a result of combustion of biogas. These emissions can be offset against the reduced need for energy generation elsewhere. Digestate or cake and liquor are used as soil conditioner and liquid fertiliser. They contain the nutrients of the initial waste so landspreading may be limited. Incineration of digestate can release acids, heavy metals and other noxious gases. Fly ash is generated as a result of incomplete combustion, but is normally prevented from release by use of filters or other gas cleaning systems. Ash is typically disposed of to landfill. Landfill of digestate and ash can result in contamination of ground and surface waters. This should be avoided using a properly maintained landfill site.
Agricultural impact	Application of digestate or cake provides additional nutrients for crop-uptake and could lead to reduced requirements for fertiliser. The cake also provides organic matter that improves the soil quality.

Social impact	Contamination of soil may restrict subsequent uses (e.g. organic farming) where sludge is spread on clean land.
Other side effects	BOD removal is usually between 70 and 80%. Reduced greenhouse gas emissions. Deactivation of plant and animal pathogens. Greatly reduces waste odours.
FARMING Network stakeholder opinion	-
Practical experience	Anaerobic digestion is a current practice.
Key references	IEA Bioenergy (1996). Biogas from municipal solid waste. Published by Ministry of Energy/Danish Energy Agency, Copenhagen and Netherlands Agency for Energy and the Environment, Utrecht. IEA Bioenergy (2001). Biogas and more: Systems and markets overview of anaerobic digestion. Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.
Comments	Anaerobic digesters are commonly found at sewage treatment works.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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48 Biological treatment (digestion) of milk	
Objective	To reduce the mass of solids derived from contaminated milk requiring disposal.
Other benefits	Reduction in BOD of treated milk. Digested milk can be used as a fertiliser and biogas generated used as an energy source.
Description	Milk may be processed through aerobic (activated sludge or fixed-film systems) and anaerobic digestion (AD) facilities present in sewage treatment works (STW) and dairy effluent plants (DEP). In aerobic systems the provision of oxygen and bacteria accelerates processes that would naturally occur in oxygenated rivers. In anaerobic systems material is retained in an enclosed reactor at temperatures of 35-55°C for a period of 10-30 days. These biological treatments accelerate a series of natural processes and significantly reduce the mass of solids for disposal and the biological oxygen demand of the effluent. Sludge and cake produced can be used as fertiliser and biogas for heating and electricity generation.
Target	Contaminated milk.
Targeted radionuclides	**Probable applicability:** ^{60}Co, ^{89}Sr, ^{90}Sr, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{131}I, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf. **Not applicable:** High soil:plant concentration ratio (>1) may cause high plant uptake: ^{75}Se. Short half-life of ^{127}Sb likely to mean this management option is not applicable. Potential high doses received (> 300µSv) if management option is carried out when activities in crops are at or above CFIL: ^{95}Nb, ^{226}Ra. Management option not applicable to ^{99}Mo/^{99m}Tc due to soil:plant concentration ratio and potential high doses and to ^{132}Te, ^{140}La due to half-lives and potential high doses.
Scale of application	Small.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A
Time of application	Early to late.
Constraints:	
Legal constraints	The treatment of milk at STW's and DEP's will be subject to the Urban Waste Water Directive 91/271/EEC and EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). Other relevant EC legislation includes: EC Framework Directive on Waste Sewage Sludge Directive 86/278/EEC EC Nitrate Directive 91/676/EEC EC Landfill Directive 1999/31/EC
Social constraints	Relate to disposal option selected for waste e.g. willingness of farmers to accept sludge from biological treatment of milk. Resistance if the resulting sludge is applied to previously uncontaminated areas. Perception of causing additional contamination of the soil when slurry spread on farmland. There may be local opposition to the use of particular landfill sites e.g. if contaminated sludge is disposed of in previously uncontaminated areas.
Environmental constraints	None for digestion of milk. Relate to subsequent fate of

	sludge, which should not be spread on land with a high risk of runoff or leaching, and high nutrient status.
Communication constraints	Farmers/operators require information on the biological treatment of milk.
Effectiveness:	
Effectiveness	N/A
Factors influencing effectiveness of procedure	Dairy wastes at sewage treatment works (aerobic) cause problems due to the inadequate size of the plant, insufficient balancing (maximum holding capacity of one days average flow), and are not designed for the high BOD of dairy waste. Water companies usually insist that the fat content should not exceed 150 mg/l, pH should be between 6 and 9 and BOD between 300 and 600 mg/l. The optimum dry matter content for anaerobic digestion is 6-8%. To reduce raw milk's dry matter content to 6-8% it has to be diluted with water to produce a 40% milk/60% water mixture. Long residence time of milk in anaerobic reactor. Capacity to treat contaminated milk depends on radiological impact of effluent. Partitioning of radionuclides between effluent and sludge. Willingness of STWs or DEPs to treat contaminated milk. Acceptability of disposal routes for sludge. Willingness of privately owned landfill sites and local populations to accept the wastes.
Feasibility:	
Required specific equipment	Biological treatment facility.
Required ancillary equipment	Vehicles for transport. Equipment for spreading sludge and cake.
Required utilities and infrastructure	Agricultural land, landfill and incinerators for sludge and cake disposal. Adequate storage space is required at the farm for sludge and cake prior to landspreading.
Required consumables	Fuel for transport.
Required skills	The necessary skills should be available at commercial facilities. Special attention must be given to the quantities of milk treated because of its potential to 'poison' the process because too much milk stops the digestion process. The farmer will have experience of spreading wastes to land.
Required safety precautions	None.
Other limitations	Capacity of biological treatment facilities for milk which has an extremely high BOD. Generally, for milk to be treated at aerobic plants it has to be pre-treated at an anaerobic plant.
Waste:	
Amount and type	*Anaerobic* Depends on the anaerobic digestion facility used. Typically the volume of material is reduced by 40 to 60%, but it can be as high as 80%. The sludge can be treated further to produce a solid cake and liquid. Anaerobic digestion produces biogas which is typically made up of 65% methane and 35% carbon dioxide. The conversion of solids to biogas varies by reactor type. Conversion can range from 30 to 80%.
Amount and type (continued)	*Aerobic* Sludge is produced and the amounts depend on the micro-organisms present, BOD of milk, treatment method used etc. Excess sludge represents 1 to 5% of the volume of waste treated.

Possible transport, treatment and storage routes	*Anaerobic* Biogas is normally used for process heating and electricity generation. Sludge and sludge cake can be used in agriculture as fertilisers. The cake can also be stored on farm until required. Sludge and cake can also be sent to landfill or incineration for disposal. Any liquid generated during cake production is usually returned to the beginning of the treatment process. *Aerobic* Sludge can be used in agriculture as fertilisers. If the sludge is produced at a STW it needs to be anaerobically treated in accordance with the 'Safe Sludge Matrix' before it can be spread on agricultural land. Sludge and cake can also be sent to landfill or incineration for disposal. The effluent produced during aerobic digestion is normally discharged to a watercourse.
Factors influencing waste issues	Biological treatment method used. Disposal option chosen for sludge. Level of radioactivity in the waste products. Radiological impact of effluent discharged to watercourses.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of the digestion of milk.* *They represent the exposure to the end products of biological treatment, i.e. sludge, cake and liquid effluent. There are datasheets outlining the incremental dose pathways from the alternative disposal of sludge and cake to 54 Landfill or 53 Incineration.)*	**Anaerobic Digester Operative (STW):** • inadvertent ingestion of sludge during milk treatment, • external, inhalation and inadvertent ingestion exposure loading cake. **Aerobic Digester Operative (DEP):** • external exposure and inadvertent ingestion of milk during milk treatment. **Drivers (External Exposure):** • transporting milk to treatment plant, • *transporting sludge and cake to place of disposal (e.g. farmland).* ***Farmer Applying Sludge or Cake to Land:*** • *external exposure, inadvertent ingestion and inhalation of sludge and cake while loading spreader,* • *external exposure while spreading,* • *external exposure, inhalation and inadvertent ingestion of dirt while ploughing in sludge or cake.* ***Public:*** • *ingestion of food grown on land spread with sludge or cake,* • *ingestion of drinking water and freshwater fish extracted from rivers to which effluent is discharged.*
Intervention Costs:	
Equipment	Biological treatment facilities. Vehicles for transport. Equipment for spreading sludge and cake.
Consumables	Fuel for transport (depending on distance).
Operator time	Additional work incurred by operators at biological treatment facilities and operators involved with disposal of wastes.
Factors influencing costs	Volume of milk to be treated and disposal routes of digestion products. Volume of liquid effluent to be treated.
Compensation costs	To biological treatment facilities for handling contaminated milk and decontamination of equipment. To transport

	companies for decontamination of vehicles. To incineration and landfill operators for decontamination of equipment.
Waste cost	Treatment and disposal of sludge and effluent.
Assumptions	None.
Communication needs	Dialogue with the operators and regulators needs to be established well in advance.
Side-effect evaluation:	
Ethical considerations	Additional dose to digester operators and populations living close to biological treatment facilities. Consent of workers. Environmental risk.
Environmental impact	Nitrogen oxides, sulphur oxides and particulates are released to atmosphere as a result of combustion of biogas. These emissions can be offset against the reduced need for energy generation elsewhere. Effluent after aerobic treatment is discharged to watercourses with minimal environmental impact. Sludge and cake are used as soil conditioner and liquid fertiliser. They contain the nutrients of the initial waste so landspreading may be limited. Incineration of sludge can release acids, heavy metals and other noxious gases. Fly ash is generated as a result of incomplete combustion, but is normally prevented from release by use of filters or other gas cleaning systems. Ash is typically disposed of to landfill. Landfill of sludge and ash can result in contamination of ground and surface waters. This should be avoided using a properly maintained landfill site.
Agricultural impact	Application of sludge or cake provides additional nutrients for crop-uptake and could lead to reduced requirements for fertiliser. The cake also provides organic matter that improves the soil quality.
Social impact	Contamination of soil may restrict subsequent uses (e.g. organic farming) where sludge is spread on clean land.
Other side effects	*Aerobic* • BOD removal in excess of 95%. • Pathogens are negligible in milk sludges. • Sludge odours are strong so quick disposal required. *Anaerobic* • BOD removal is usually between 80 and 95% at DEPs. • Reduced greenhouse gas emissions. • Deactivation of plant and animal pathogens. Greatly reduces waste odours.
FARMING Network stakeholder opinion	-
Practical experience	Biological treatment is a current practice at all sewage treatment works and dairy effluent plants. Disposal of raw milk to STWs has been carried out on a small-scale. STW are ubiquitous whereas DEPs are only found in milk producing area. DEPs treat large volumes of dilute milk processing wastes.
Key references	Nisbet AF, Marchant JK, Woodman RFM, Wilkins BT and Mercer JA (2002). Management options for food production systems affected by a nuclear accident: (7) Biological treatment of contaminated milk. NRPB-W38. Marshall KR and Harper WJ (1984). The Treatment of Wastes from the Dairy Industry. In Surveys in Industrial Wastewater Treatment. Barnes D, Forster CF and Hurdey S . (eds). Pitman Publishing, London, 296-376.

	Wheatley AD (2000). Food and Wastewater. In Food Industry and the Environment in the European Union. Practical Issues and Cost Implications. 2nd Edition. Dalzell J M (ed.). Aspen Publishers Inc. Maryland.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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49 Burial of carcasses	
Objective	To dispose of animal carcasses following slaughter.
Other benefits	No treatment of carcasses needed prior to burial, therefore, no risk of additional contamination of for example rendering plants, incinerators etc.
Description	After slaughter animal carcasses may be disposed of in purpose built burial pits, on-farm or at mass burial sites.
Target	Meat and milk producing livestock.
Targeted radionuclides	**Probable applicability:** ^{75}Se, ^{95}Nb, ^{95}Zr, ^{99}Mo/^{99m}Tc, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf. **Not applicable:** A high soil mobility (k_d) of between 0 and 30 may cause rapid movement into ground: ^{89}Sr, ^{90}Sr, ^{131}I, ^{235}U. Short half-lives of ^{127}Sb, ^{132}Te, ^{140}La likely to mean this management option is not applicable. Potential high doses received (> 300μSv) if management option is carried out when activities in carcasses are at or above CFIL: ^{60}Co, ^{110m}Ag.
Scale of application	Medium to large.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A
Time of application	Early to late phase.
Constraints:	
Legal constraints	Under normal circumstances the burial of animals is prohibited by the Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972. Other relevant EC legislation includes the *EC Groundwater Directive 80/68/EEC*.
Social constraints	Acceptability of changes to landscapes and of other environmental effects, to relevant populations. Local opposition to the selection of burial sites e.g. where contaminated carcasses are disposed of in previously uncontaminated areas. Aesthetic consequences of landscape/amenity changes.
Environmental constraints	Availability and capacity of suitable burial sites. Animal carcasses must be disposed of without endangering human health or harming the environment.
Communication constraints	Dialogue with land users. Media interest is likely to be high. Likely requirement to monitor area around burial pit and publish results.
Effectiveness:	
Effectiveness	N/A
Factors influencing effectiveness of procedure	Engineering of burial pit, suitability and availability of land for burial pit i.e. away from water sources and not on land with high water table. On-Farm burial site: relies on the dispersal and dilution of animal leachate (fluids from carcasses) in the ground to protect water, so number of disposal sites are limited. Normally 8 tonnes of carcasses can be buried. This is equivalent to 16 adult cattle, 40 pigs or 100 sheep. More may be allowed in a crisis. Mass burial site: Sewage treatment works (STW) must have the capacity to treat the volumes of animal leachate produced. Time to construct mass burial sites. Transportation of carcasses to burial site.

Factors influencing effectiveness of procedure (continued)	Acceptability of this disposal option to farmers and the public. There is potential for a black market in slaughtered meat. Willingness of private landowners and local populations to accept carcasses for burial. Maintenance of correct burial pit procedures (e.g. clay lining) including burial of non-carcass material (e.g. sheep dip, paint diesel manure).
Feasibility:	
Required specific equipment	Excavators for digging pits. JCB's, bulldozers or tractors with bucket loaders for moving carcasses. Lamps to allow night working. For mass burial site: clay liner 1m thick, geoclay liner and geocomposite liner to prevent seepage. Vents to collect and burn off gasses produced by decomposition. Sumps/wells and pumps to collect and remove any animal leachate produced. Ideally on-site treatment facilities to pre-treat leachate and reduce biological strength (COD) before removal to sewage treatment works (either inland or coastal). Fencing to contain the site and prevent dumping of non-carcass material.
Required ancillary equipment	Transportation of carcasses to burial site and animal leachate to sewage treatment works.
Required utilities and infrastructure	Animal leachate has to be removed by tanker for treatment and disposal at sewage treatment works and on site gas control measures.
Required consumables	Fuel for transportation of carcasses to burial pit and animal leachate to sewage treatment works.
Required skills	Engineers and construction workers to build burial pit.
Required safety precautions	Risk assessment to be carried out before purpose- built burial pit constructed. Protective clothing and equipment for engineers, construction workers and sewage plant operators.
Other limitations	Mass burial sites can only be kept open when being filled rapidly and soil capped. When there is only a small daily supply there is potential for carcasses to be left exposed to carnivorous animals with the possible transmission of pathogens. All purpose-built burial pits should ensure that carcasses remain permanently buried in such a way that carnivorous animals can not gain access to them.
Waste:	
Amount and type	Animal leachate e.g. body fluids from carcasses are released (about 0.1 m^3 per adult sheep and 1.0 m^3 per adult cow) within the first year, and gas.
Possible transport, treatment and storage routes	Animal leachate has to be removed by tanker for treatment and disposal at sewage treatment works and on site treatment of gas.
Factors influencing waste issues	Volume of leachate to be treated and the radionuclide concentration of the leachate.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of burial. The leachate generated during burial will be disposed of at a Sewage Treatment Works (STW): the relevant dose pathways for this disposal route are given in the 54 Landfill datasheet.)*	**Burial Site Operative:** • external exposure to carcasses while burying, • inhalation and inadvertent ingestion of dirt while burying the carcasses. **Drivers (External Exposure):** • transporting carcasses to burial sites, • *transporting animal leachate to STW's.*
Intervention Costs:	

Equipment	Civil engineering equipment required to dig pit (e.g. bulldozers, JCBs), clay, geoclay liner and geocomposite liner to line mass-burial pit, appropriate equipment to vent gas and collect animal leachate.
Consumables	Fuel for transporting carcasses to burial pit and animal leachate to sewage treatment works.
Operator time	Time to construct burial pit and transport carcasses and animal leachate. Time required to monitor groundwater after burial. Operator at sewage treatment works.
Factors influencing costs	Numbers of animals requiring burial. Size of pit required. Volume of animal leachate to be treated.
Compensation costs	To transport and machinery hire companies for cleaning and decontamination of vehicles. To sewage treatment works for handling contaminated animal leachate and for decontamination of equipment.
Waste cost	Treatment and disposal of animal leachate.
Assumptions	None.
Communication needs	Dissemination of information about carcass burial to the general public.
Side-effect evaluation:	
Ethical considerations	Negative side-effects on populations living close to burial sites. Possible environmental and aesthetic consequences. Loss of amenity/change in public perception of land used for burial. Liability for potential negative effects from disposal site (e.g., leakage).
Environmental impact	Minimal risk of contamination of surface and groundwater from leachate from correctly designed and managed purpose built burial pits. However animal leachate may contain very high concentrations of ammonium (2000 mg l^{-1}), COD (100,000 mg l^{-1}) and potassium (3000 mg l^{-1}) as well as sheep dip chemicals, barbiturates and disinfectants. Animal leachate can contain pathogens such as Escherichia coli 0157, Campylobacter, Salmonella, Leptospira and protozoa Cryptosporidium and Giardia and BSE prions from cattle born before 01/08/96. In the early stages of decomposition carcasses will release carbon dioxide and other gases such as methane, carbon monoxide and hydrogen sulphide.
Agricultural impact	Potential risk of land becoming blighted.
Social impact	Changed relationship to the countryside and potential loss of amenity/social value resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Disruption to farming and other related activities e.g. tourism. Policing the carcass burial and averting growth of a black market. Contamination of the soil may restrict subsequent uses (e.g. organic farming). Potential for dispute regarding selection of burial pit sites. Stigma associated with areas surrounding designated burial pits.
Other side effects	There is a potential risk from carcasses awaiting disposal to contaminate private and public water supplies. The extent of risk will depend on the state of decomposition of the carcasses and type of ground. Disposal of potentially hazardous non-carcass wastes to on-farm burial sites.
FARMING Network stakeholder opinion	-
Practical experience	Mass burial occurred in the UK to deal with Foot and Mouth infected animal carcasses where multiple pits each capable of holding 10,000-60,000 carcasses were constructed.

Key references	Department of Health (2001). Foot and Mouth Disease. Measures to Minimise Risk to Public Health from Slaughter and Disposal of Animals–Further Guidance. 24th April 2001. Environment Agency (2001). The Environmental Impact of the Foot and Mouth Disease Outbreak: An Interim Assessment. December 2001. Food Standards Agency (2002). Foot and Mouth disease. Press release - website viewed February 2002. MAFF (2001). Guidance Note on the Disposal of Animal By-Products and Catering Waste. January 2001. Trevelyan GM, Tas MV, Varley EM and Hickman GAW (2001). The disposal of carcasses during the 2001 Foot and Mouth disease outbreak in the UK. Defra, FMD Joint Co-ordination Centre, Page Street, London, SW1P 4Q, UK.
Comments	Burial of carcasses may be appropriate if the quantity of material or distance and access to premises in which disposal is otherwise permitted, does not justify transporting it.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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50 Burning of carcasses

Objective	To dispose of animal carcasses following slaughter.
Other benefits	Limits the movement of contaminated carcasses.
Description	After slaughter, animal carcasses may be completely destroyed to ash, at sites suitable for burning.
Target	Meat or milk producing livestock.
Targeted radionuclides	**Probable applicability:** ^{60}Co, ^{89}Sr, ^{90}Sr, ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{127}Sb, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf. **Not applicable:** Boiling temperature is below temperature of option and volatilisation may occur: ^{131}I. High soil:plant concentration ratio (>1) may cause high plant uptake: ^{75}Se, $^{99}Mo/^{99m}Tc$. Short half-lives of ^{132}Te, ^{140}La likely to mean this management option is not applicable. Potential high doses received (> 300μSv) if management option is carried out when activities in carcasses are at or above CFIL: ^{110m}Ag.
Scale of application	Medium to large.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to late phase.
Constraints:	
Legal constraints	The burning of animal carcasses is likely to be subject to specific water and air legislation in each Member State. Relevant EC legislation includes: Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972. EC Groundwater Directive 80/68/EEC.
Social constraints	Acceptability of changes to landscapes and of other environmental effects e.g. radionuclides released during burning, to relevant populations. Local opposition to the selection of burning sites. Aesthetic consequences of landscape/amenity changes.
Environmental constraints	Availability of suitable sites for burning large quantities of carcasses. Animal carcasses must be disposed of without endangering human health or harming the environment.
Communication constraints	Dialogue with land users. Media interest is likely to be high. Likely requirement to monitor air/water quality in area around burning site and publish results.
Effectiveness:	
Effectiveness	N/A.
Factors influencing effectiveness of procedure	Availability of suitable sites for burning. Availability of burning materials. Quantity of carcasses. Transportation of carcasses to site for burning. Poorly constructed pyre can burn for several weeks. Acceptability of implementing carcass burning to farmers and the public. There is potential for a black market in slaughtered meat. Willingness of private landowners and local populations to accept carcasses for burning.
Feasibility:	
Required specific equipment	Excavators for digging trenches. JCB's, forklift trucks and tractors with bucket loaders for moving fire ingredients and carcasses. Lamps to allow night working.

Required ancillary equipment	Vehicles for the transportation of carcasses to site for burning and to the ash disposal site.
Required utilities and infrastructure	Burning site with good road network.
Required consumables	Fuel to aid combustion and for transportation.
Required skills	Continued supervision of burning.
Required safety precautions	Respiratory equipment. Protective clothing and equipment.
Other limitations	Availability of labour to build pyres. Pyres are open to having illegal material (tyres, rubber and plastics) burned on them.
Waste:	
Amount and type	Ash. Approximately 350 kg is produced per tonne of animal.
Possible transport, treatment and storage routes	The ash produced may be disposed of via burial *in situ* or transported to a fully instrumented landfill site. In some situations the ash may have to be disposed of at an authorised incinerator prior to landfill disposal.
Factors influencing waste issues	Radionuclide concentration of waste product. Local opposition to disposal of ash via burial *in situ.*
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of burning carcasses. If burial of ash in situ is not possible the ash may be disposed of via 53 Incineration or to 54 Landfill. There are separate datasheets for these disposal routes.)*	**Pyre site operatives:** • external exposure from carcasses when loading on pyre, • external exposure and inhalation of contaminated material emitted by pyre, • external exposure and inadvertent ingestion of ash when collecting ash for transportation to incinerator or landfill site. **Driver:** • external exposure while transporting animal carcasses to pyre site, • external exposure while transporting ash to incinerator or landfill. ***Farmer when ploughing in:*** • *external exposure from land when ploughing in ash,* • *inadvertent ingestion of ash while ploughing in (as ash is wetted).* ***Public:*** • *inhalation of contaminated material deposited by the pyre,* • *external exposure from contaminated material deposited by the pyre,* • *ingestion of foodstuffs grown on land which has had ash ploughed into it.*
Intervention Costs:	
Equipment	Hire of machinery and equipment.
Consumables	To destroy 250 carcasses the following are required; 250 railway sleepers, 250 bales of straw, 6,250 kg of kindling wood, 50,750 kg of coal, 1 gallon of diesel oil per metre length of pyre.

Operator time	Time to prepare pyres varies with the machinery and workforce available. Pyres burn continuously for 2 to 3 days. Transportation from farm to burial site. To monitor air and water pollution in surrounding area during and following burning.
Factors influencing costs	Numbers of livestock. Distance between farm and burning site. Availability of burning materials.
Compensation costs	To transport and machinery hire companies for cleaning and decontamination of vehicles.
Waste cost	Cost of burial or landfill.
Assumptions	None.
Communication costs	Dissemination of information about carcass burning to the general public.
Side-effect evaluation:	
Ethical considerations	Highly disruptive effect on farmers. Additional dose to populations living close to burning sites.
Environmental impact	Short term air quality and odour issues. Atmospheric emissions from pyres include: • gases: CO, CO2, NOx, SO2, etc., • mineral dust: fly ash (PM10), • heavy metals: Pb, Cu, Hg, Cd, etc., • organic molecules: dioxins, furans, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), • radionuclides. All of these are damaging to human and animal health and the environment, and can enter the foodchain downwind. Critical air quality pollutant downwind of centre of pyre is SO_2. Amounts will be reduced if coal with low S content (< 2%) is used. It is recommended that populations downwind of pyre should be: • 2km from small pyres (250 cattle equivalents over 3 days), • 3km from large pyres (1000 cattle equivalents over 3 days), • 4km from very large pyres (1000 cattle equivalents per day for 20 days). Ash will contain radionuclides, heavy metals and hydrocarbons. Leachate from ash can produce ammonia, phosphorous and potassium. Therefore there is a risk of surface and ground water pollution from ash associated contaminants, and to groundwater from fuels used.
Agricultural impact	Ash has high concentrations of micro and macronutrients that will fertilise the soil.
Social impact	Disruption to farming and other related activities e.g. tourism. Policing the carcass burning and averting growth of a black market in slaughtered animals. Potential for dispute regarding burning sites (and) selection of areas for ash disposal. Stigma associated with areas surrounding designated burning sites.
Other side effects	There is a potential risk from carcasses awaiting burning to contaminate private and public water supplies. The extent of risk will depend on the state of decomposition of the carcasses and type of ground.
FARMING Network stakeholder opinion	-

Practical experience	Over 950 pyres were built in England and Wales during the FMD outbreak to control the spread of the disease. A limit of 1000 cattle per pyre was introduced during the outbreak though the Department of Health recommends smaller ones to reduce the amounts of air pollutants.
Key references	Environment Agency (2001). The environmental impact of the foot and mouth disease outbreak: An interim assessment. December 2001. Environment Agency, Bristol, UK. Environment Agency Wales (2001). Report to the National Assembly for Wales. Preliminary Assessment of Carcass Disposal sites at Mynydd Eppynt (Sennybridge Training Area, SEN. T. A). Internet version published 06/04/01. MAFF (2001). Guidance Note on the Disposal of Animal By-Products and Catering Waste. January 2001. Trevelyan GM, Tas MV, Varley EM and Hickman GAW (2001). The Disposal of Carcasses during the 2001 Foot and Mouth Disease Outbreak in the UK. Defra, FMD Joint Co-ordination Centre, Page Street, London SW1P 4Q, UK
Comments	Burning of carcasses maybe appropriate if the quantity of material or distance and access to premises in which disposal is otherwise permitted does not justify transporting it.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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51 Composting

Objective	To reduce mass and volume of contaminated biomass requiring disposal.
Other benefits	Final compost useful as a fertiliser or soil conditioner.
Description	Composting may be considered where it is impractical to plough contaminated crops back into the soil and/or when contaminated grass needs to be disposed of. Composting achieves a mass reduction of 50% and a volume reduction of 50-90%. It may be carried out at commercial facilities or *in situ* on the farm. Ideally, contaminated crops are mixed with woody material to provide bulk and aeration in the feedstock. The feedstock is degraded aerobically by a succession of micro-organisms, to produce stable humus.
Target	Contaminated crops and grass.
Targeted radionuclides	**Probable applicability:** ^{60}Co, ^{75}Se, ^{89}Sr, ^{90}Sr, ^{95}Nb, ^{95}Zr, ^{99}Mo/^{99m}Tc, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf **Not applicable:** Short half-lives of ^{127}Sb, ^{131}I, ^{132}Te, ^{140}La likely to mean this management option is not applicable.
Scale of application	Large-scale on farm. Capacity could be limited at commercial composting facilities within an affected area. Centralised sites have a larger capacity, but would involve the transportation of contaminated biomass into uncontaminated areas.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to late. For contaminated crops it is best carried out in the early phase to reduce the amount of biomass to be composted.
Constraints:	
Legal constraints	Composting on agricultural land may require an authorisation. Relevant EC legislation is listed below: EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC) Integrated Pollution Prevention and Control Directive 96/61/EC Nitrate Directive 91/676/EEC (if compost is landspread)
Social constraints	Willingness of farmer to carry out composting if this is not usual practice. Possible perception of causing additional contamination of the soil when compost spread on farmland. In particular, there is likely to be resistance if compost is applied to previously uncontaminated areas. Acceptability to food industry/consumers of residual levels of contamination in food produced on land where compost is spread.
Environmental constraints	Spreading of compost should not be conducted near water courses. Consideration needs to be given to underlying geology, particularly aquifers.
Communication constraints	Need for dialogue regarding selection of areas for composting. Need for dialogue between land owners/farmers, environmentalists and public. Farmers/operators require information on how to carry out the waste management option, including its objective.

Effectiveness:	
Effectiveness	N/A.
Factors influencing effectiveness of procedure	Climatic conditions affect speed and efficiency with which material is broken down. Availability of green (woody) waste for dilution. Quantity of precipitation. Willingness of farmers or commercial composters to carry out composting of contaminated biomass. Acceptability to farmers and the public of returning contaminated compost to land. Status of the land.
Feasibility:	
Required specific equipment	Commercial composting facilities. On farms, composting can be carried out directly on agricultural land.
Required ancillary equipment	Dedicated front end loaders or other material handling vehicles may be required. Windrow turners and screens may also be required. Temporary compost heaps such as those that a farmer might set up on open ground would benefit from temporary covering e.g. Dutch barn.
Required utilities and infrastructure	Area of hard-standing (e.g. concrete) on farm. Storage for compost.
Required consumables	Green (woody) waste to dilute feedstock. This should be readily available at centralised and community facilities. Fuel for transporting compost to commercial site. Fuel for operating equipment on site.
Required skills	At commercial composting facilities the necessary skills will be available. Many farmers will be able to carry out composting, but some may need instruction.
Required safety precautions	Consider protective clothing. Respiratory protection is recommended whenever materials are handled or moved. Aerosolisation of micro-organisms (bioaerosols) and small fragments of vegetation can be problematic if inhaled or in contact with eyes.
Other limitations	None.
Waste:	
Amount and type	Any compost that might not be considered suitable as a soil conditioner. As a rule of thumb, 1 m^3 of leachate may be generated for every 20 m^2 of composting area, depending on the nature of the wastes being composted (Environment Agency, 2001). This weight of material would produce in the region of 30 litres of leachate per tonne of material. Aerial emissions.
Possible transport, treatment and storage routes	Landfill or incineration of unusable compost. Leachate should be returned to the compost or if necessary disposed of to a sewage treatment works.
Factors influencing waste issues	The application of the compost to arable land is dependent on the time of year and state of land (i.e. do not apply when frozen, waterlogged, or to land on a steep slope). Dependant on whether carried out at composting facility or on farms, if carried out on open ground on farms leachate will not be collected.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of composting.* *Any unused compost may have to be disposed of to 54 Landfill or 53 Incineration. There are separate datasheets for these disposal options*	**Composting Facility Operative or Farmer:** • external exposure during daily inspection, • inadvertent ingestion while turning compost, • ihalation of dust while turning compost. **Drivers (External Exposure):**

giving the relevant dose pathways that should be considered. Any leachate generated during composting would be sent to a Sewage Treatment Works (STW): the relevant dose pathways for this disposal route are given in the 54 Landfill datasheet.)	• transporting crops to composting facilities, • *transporting leachate to STW's.* ***Public:*** • *ingestion of food grown on land spread with compost.*
Intervention Costs:	
Equipment	Already available at commercial facilities. Transport for crops/grass if destined for commercial facilities.
Consumables	Fuel for transport (depending on distance). Fuel for operating equipment on site.
Operator time	Time to establish a composting system on farm. Time to inspect and turn compost. Time to transport crops/grass to commercial facility.
Factors influencing costs	Volumes of crops and grass to be composted. Whether composting carried out *in situ* or at commercial facilities.
Compensation costs	Possible decontamination of equipment at commercial composting facilities.
Waste cost	Landfill charges and landfill tax. Leachate treatment.
Assumptions	None.
Communication needs	Provision of information to farmers on rationale of this waste treatment option. Provision of information to operators on correct application of the procedure on farm so as to avoid pollution.
Side-effect evaluation:	
Ethical considerations	*In situ* disposal option. Self-help for farmer if carried out on individual farms. Informed consent issues in relation to consumers of food produced in areas where compost applied. If carried out at composting facility, there may be a requirement for radiation protection training, consent of workers.
Environmental impact	Large volumes of carbon dioxide and water vapour are released. Trace gases such as ammonia and hydrogen sulphide may be produced if excess nitrogen or sulphide are present in the feedstock. These gases would cause odour problems at the composting site. Large quantities of leachate are produced, typically 30 litres of leachate per tonne of waste. If carried out on open ground the leachate might result in some contamination of land and groundwater. There may also be a release of bioaerosols. Inappropriate application of compost to land may cause pollution of watercourses.
Agricultural impact	Application of compost provides additional nutrients for crop-uptake and could lead to reduced requirements for fertiliser. In the long term it could improve soil structure, increase water retention and aeration and allow easier cultivation.
Social impact	The waste management option will need policing. Contamination of soil may restrict subsequent uses (e.g. organic farming) where compost is spread on clean land. Stigma associated with areas and perceived contamination of food products (crops, dairy, meat) where the compost has been applied.
Other side effects	None.
FARMING Network stakeholder opinion	-

Practical experience	Composting is a current practice.
Key references	Slater RA, Frederickson J and Gilbert EJ (2001). The state of composting 1999: Results of the Composting Association's survey of UK composting facilities and collection systems in 1999. The Composting Association, Wellingborough. Shaw S, Green N, Hammond DJB and Woodman RFM (2001). Management options for food production systems affected by a nuclear accident. 1. Radionuclide behaviour during composting NRPB-R328. Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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52 Disposal of contaminated milk to sea

Objective	To dispose of contaminated milk.
Other benefits	None.
Description	Contaminated milk may in principle, be discharged to sea via outfalls of coolant water or liquid effluent at nuclear installations or via long sea outfalls at coastal sewage treatment works.
Target	Contaminated milk.
Targeted radionuclides	**Probable applicability:** ^{89}Sr, ^{90}Sr, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{169}Yb, ^{235}U. **Not applicable:** Short half-life of ^{127}Sb likely to mean this management option is not applicable. High concentration ratio in marine foods (>1000) may cause high uptake in fish crustaceans and molluscs: ^{60}Co, ^{75}Se, ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{131}I, ^{141}Ce, ^{144}Ce, ^{192}Ir, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf. Short half-life of ^{132}Te as well as high concentration ratio in marine foods likely to mean this management option is not applicable. High concentration ratio in marine foods and potential high doses received (> 300μSv) if management option is carried out when activities in milk are at or above CFIL will make this management option not applicable for ^{99}Mo/^{99m}Tc. Management option not applicable to ^{140}La due to all of these reasons
Scale of application	Large scale application as long as practical arrangements are possible at power stations or sewage works.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to late phase. Seasonal.
Constraints:	
Legal constraints	The Oslo-Paris (OSPAR) Convention protects the marine environment within Europe. However, the requirements of the convention would not apply in the event of an emergency. The Euratom Treaty Article 37 (EEC, 1957) requires each member state to provide data on planned disposal of radioactive waste. The Commission decides within 6 months if the plan will cause radioactive contamination of water, soil or airspace to another member state. However, milk containing radionuclides may not be classed as radioactive waste. Milk discharged to sea via long sea outfalls at coastal sewage treatment works will be subject to regulations that implement the *Urban Waste Water Directive 91/271/EEC*. The regulations ensure certain standards of wastewater treatment are attained and limit the BOD concentration of all significant discharges of wastewaters to 25 mg O_2 l^{-1}.
Social constraints	Discharge of radioactive wastes to sea is currently highly contentious and unlikely to be publicly acceptable. However, in emergency conditions, or conditions of high levels of widespread contamination, it may be more acceptable.
Environmental constraints	Limits on total BOD discharged by long sea outfalls. These vary according to the degree of mixing of water body receiving contaminated milk.
Communication constraints	Need for widespread dialogue to ascertain the acceptability of discharge to sea both nationally and internationally. Public consultation can be a lengthy process that might not

	be achievable on the timescales required for disposing of large volumes of milk. Requirement to monitor water quality in surrounding water body.
Effectiveness:	
Effectiveness	N/A.
Factors influencing effectiveness of procedure	Ability to transport waste milk to discharge points and offload it easily. Limits on total BOD discharged by long sea outfalls that vary according to the degree of mixing of the receiving water body.
Factors influencing effectiveness of procedure (continued)	Acceptability of the implementation of the waste management option to operators, haulage companies and the public. Compliance/resistance to the waste management option.
Feasibility:	
Required specific equipment	Large capacity vehicles with specialised equipment and couplings for transport. A 13,000 litre tanker would hold milk from around 10 average size dairy farms. An average size dairy farm has a herd of 80 cows, each producing 16 $l\ d^{-1}$.
Required ancillary equipment	At some nuclear installations pumps will be required to offload milk from tankers into holding pits.
Required utilities and infrastructure	Coolant water and liquid effluent outfalls at nuclear installations or long sea outfalls at sewage treatment works.
Required consumables	Fuel for transporting milk to outfalls.
Required skills	The vehicle drivers and operators at the power stations and sewage works should have the necessary skills. Little additional training would be needed.
Required safety precautions	Not necessary at the levels of contamination for which this method would be considered. However, the discharge of milk to sea is a non-standard practice that will require station managers to carry out a full risk assessment. Potential hazards need to be identified and controlled. A constant stream of tankers arriving at a nuclear or sewage treatment plant may require traffic management and parking.
Other limitations	Contingency plans for dealing with protestors at the gates need to be made.
Waste:	
Amount and type	N/A.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of disposing milk to sea. Milk discharged directly to sea via coastal STWs is not subject to any treatment. Therefore production of by-products normally generated by treatment of milk at STWs is avoided together with doses to STW operatives.)*	**Drivers (External Exposure):** transporting milk to nuclear sites and coastal sewage treatment works ***Public:*** *ingestion of marine foodstuffs due to milk being discharged to the sea.*
Intervention Costs:	
Equipment	One (13,000 l) tanker per 30 average size farms, with milk collected from 10 farms each journey for 3 journeys per

	day. Pumps. Approximately £2000 to buy or use plant hire companies.
Consumables	Fuel for transport (depending on distance).
Operator time	Modellers' time will be required to demonstrate the effects of discharge of milk on BOD on a site specific basis. Tanker drivers 10 hour shifts. Operators at power stations and sewage works as necessary.
Factors influencing costs	Distance from farms to sea outfalls.
Compensation costs	To power stations and sewage works for use of facilities. To milk transporters for decontamination of tankers and equipment. To plant hire companies for decontamination of equipment.
Waste cost	N/A.
Assumptions	None.
Communication needs	Dialogue with the operators and regulators need to be established well in advance. This will involve considerable time and effort. Potential need to facilitate widespread debate regarding the ethics and practice of disposal at sea.
Side-effect evaluation:	
Ethical considerations	Additional dose to tanker drivers, marine life and consumers of marine produce. Aesthetic/ecological effects from sea disposal.
Environmental impact	Effects of discharge on the dissolved oxygen content of the seawater should be small, but must have been demonstrated in advance on a site specific basis. In the worst case, dissolved oxygen content should return to ambient levels within about 17 days if 40 million litres are discharged over a 6 week period.
Agricultural impact	None.
Social impact	Potential for dispute regarding selection of this waste disposal option. Stigma associated with areas or fish produce where milk has been disposed of to sea. Disruptions to people's image/perception of the 'seaside' e.g. milk flowing onto the beach from outflow pipes, with potential impacts on tourism etc.
Other side effects	None.
FARMING Network stakeholder opinion	-
Practical experience	Milk discharged to drains following Windscale fire.
Key references	EEC (1957). The Treaty establishing the European Atomic Energy Community (Euratom). Rome, 25th March 1957. Wilkins BT, Woodman RFM, Nisbet AF and Mansfield PA (2001). Management options for food production systems affected by a nuclear accident. 5. Disposal of waste milk to sea. NRPB–R323.
Comments	Disposal of milk to sea will require pre-planning e.g. doing site specific modelling to check environmental impact, liaison with nuclear or sewage plant operators. It would be helpful to get arrangements established well in advance of an accident. The suitability of power stations and sewage works will be highly variable.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have

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53 Incineration

Objective	To reduce volume of contaminated food products prior to disposal and to produce a stable end product.
Other benefits	None.
Description	Incineration is the controlled burning of waste at high temperatures, typically around 900°C. Organic components present in waste are released as exhaust gases, and mineral matter is left as a residual ash. The volume of the ash is about an order of magnitude less than the original waste; the corresponding reduction in terms of mass is about a factor of 3. The ash is typically disposed of to landfill.
Target	Contaminated cereals, vegetables, fruit, fish, rendered meat, eggs, milk powder, honey, mushrooms, berries, grass.
Targeted radionuclides	**Probable applicability:** ^{60}Co, ^{95}Nb, ^{95}Zr, ^{99}Mo/^{99m}Tc, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf **Not applicable:** Boiling temperature is below temperature of option and volatilisation may occur: ^{75}Se, ^{134}Cs, ^{137}Cs. A high soil mobility (k_d) of between 0 and 30 may cause rapid movement into ground: ^{89}Sr, ^{90}Sr. Short half-lives of ^{127}Sb, ^{140}La likely to mean this management option is not applicable. Management option not applicable to ^{131}I due to all of these reasons and to ^{132}Te due to boiling temperature and half-life.
Scale of application	Medium to large.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to late.
Constraints:	
Legal constraints	Possible need for radiation protection training of workers. Relevant EC legislation is given below: Waste Incineration Directive 2000/76/EC Animal Waste Directive 90/667/EC Integrated Pollution Prevention and Control Directive 96/61/EC
Social constraints	Unlikely to be acceptable to the public if the crops/carcasses have to be incinerated outside the affected area. Local opposition to incinerators due to negative perception of health effects, particularly dioxins. Opposition to disposal of radioactively contaminated material by incineration very likely. Local opposition to building new incinerators. However 2000/76/EC allows public to comment before decision is made.
Environmental constraints	Availability and capacity of suitable incinerators. Animal carcasses and crops must be incinerated and the ash disposed of without endangering human health or harming the environment.
Communication constraints	Operators require information on the incineration of contaminated material. Likely requirement to monitor air/water quality in area neighbouring the incinerator and publish results.
Effectiveness:	
Effectiveness	N/A.

Factors influencing effectiveness of procedure	Energy value, moisture content and combustibles content of the material affects the success of this procedure. Vegetables have a high moisture content and low energy value compared with cereals. Vegetables should therefore be mixed with other wastes, which will be available at municipal waste incinerators. To produce a feedstock that will sustain combustion the feedstock should have the following characteristics: Energy value: minimum 6 MJ kg^{-1} Moisture content: maximum 35% Combustibles content: minimum 30% In addition, the operating temperature of incinerator, combustion conditions and physio-chemical form of the radionuclides and the waste also affect this procedure. The temperature of a municipal waste incinerator furnace must be maintained above 900°C. Nuclides which volatilise at temperatures below the operating temperatures of the furnace would be found in the exhaust gases (i.e. iodine volatilises at 184°C, caesium at 671°C and selenium at 685°C). It would therefore be expected that some fraction of these elements activity would be released in the exhaust gases. Elements that volatilise at temperatures higher than 900°C will be retained in the ash. The majority of carcass incineration plants burn less than one tonne per hour and are not large enough to accommodate a whole bovine carcass. During the Foot and Mouth (FMD) crisis all facilities capable of taking whole bovine carcasses were fully committed to the disposal of either BSE infected cattle, Specified Risk Material (SRM) or cattle destroyed under the Over Thirty Months Scheme (OTMS). Compliance/resistance to incineration. There is potential for a black market in slaughtered meat/condemned crops.
Feasibility:	
Required specific equipment	Commercial incinerators, on-farm incinerators and mobile air-curtain incinerators capable of disposing of crops and/or mammalian carcasses.
Required ancillary equipment	Vehicles for transporting crops/carcasses to incineration site and ash to landfill site.
Required utilities and infrastructure	Disposal route for ash. If ash can't immediately be sent to landfill it must be safely stored.
Required consumables	Fuel for transporting crops/carcasses to incineration site and to run incinerator. Mobile air-curtain incinerators only work effectively when fed with dry seasoned timber.
Required skills	Trained personnel will be available at incineration facilities.
Required safety precautions	Respiratory equipment. Protective clothing and equipment.
Other limitations	Foodstuffs need to be mixed with other materials to produce feedstock that will sustain combustion. Typical incinerator feedstock should have the following characteristics: • energy value: minimum 6 MJ kg^{-1}, • moisture content: maximum 35%, • combustibles content: minimum 30%. The majority of carcass incineration plants burn less than one tonne per hour and are not large enough to accommodate a whole bovine carcass. The majority of small on-farm incinerators burn less than 50 kg per hour and can not accommodate large animals.

Waste:	
Amount and type	Ash. The volume of ash produced is usually 10% of the original material and the mass is reduced to 25-30% of the original material. Fly ash may also be produced due to incomplete combustion of material and released if no filter or cleaning system is fitted to incinerator. This is unlikely to happen at incineration plants authorised to dispose of carcasses and crops because cleaning systems will be in place. The ash is likely to have a higher activity concentration than the original material. This is due to the volume of original material being greatly reduced and the majority of radionuclides being retained in the ash, with some activity being released in the flue gases.
Possible transport, treatment and storage routes	Ash from commercial incinerators must be disposed of to landfill. Ash from air-curtain and on-farm incinerators can be buried on site providing there is no possibility of ground and surface water contamination. Otherwise it must be collected, stored and sent to landfill.
Factors influencing waste issues	Radionuclide concentration of waste product. Quantity of ash produced and space available for landfill. If landfilling is not possible then the ash should be safely stored.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of incineration.* *There is a separate datasheet for 54 Landfill as a disposal option for the residual ash.)*	**Incineration Plant Operative:** • external, inhalation, inadvertent ingestion and facial skin exposure to fly ash while cleaning the incinerator. **Drivers (External exposure):** • transporting residual ash to landfill site. **Farmer Ploughing Land:** • external, inhalation and inadvertent ingestion of material deposited by incinerator stack while ploughing. **Public:** • external and inhalation exposure from material deposited by incinerator stack, • *ingestion of food grown on land where material from incinerator stack is deposited.*
Intervention Costs:	
Equipment	Incineration facility.
Consumables	Fuel for transporting food products to incineration plant and to run incinerator.
Operator time	Time to transport food products. Incineration plant operatives for processing additional material.
Factors influencing costs	Volumes of food products and requirements for pre-treatment. Distance between farm and incinerator. Calorific value of material (costs increase with calorific value).
Compensation costs	To farmer for decontamination of on-farm incinerator. To transport companies for cleaning and decontamination of vehicles. To incinerator companies for cleaning and decontamination of plant and equipment.
Waste cost	Transportation of ash to disposal site. Cost of landfill - charges/tax if appropriate.
Assumptions	Fly ash and gases are collected by filtering system and not released into the atmosphere.
Communication needs	Dissemination of information about incineration of

	contaminated produce to farmers and the public.
Side-effect evaluation:	
Ethical considerations	Additional dose to incinerator operators and populations living close to incineration plants. Consent of incinerator workers. Environmental risk.
Environmental impact	Atmospheric emissions from incineration include: • gases: CO, CO_2, NO_x, SO_2, etc., • mineral dust: fly ash (PM10), • heavy metals: Pb, Cu, Hg, Cd, etc., • organic molecules: dioxins, furans, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). All of these are damaging to human and animal health and the environment. However the amounts discharged have been significantly reduced (and continue to be) due to advances in incinerator and flue gas treatment technologies. Radionuclides released during incineration may be taken up into the foodchain by animals grazing on grass near by. Possible risk of pollution to soil, surface waters and ground waters from ash associated contaminants.
Agricultural impact	Ash has high concentrations of micro and macronutrients that will fertilise the soil.
Social impact	Selection of incinerators.
Other side effects	None.
FARMING Network stakeholder opinion	-
Practical experience	Some BSE infected cattle, Specified Risk Material (SRM) and Over Thirty Month Scheme (OTMS) cattle were incinerated during the FMD crisis in the UK, although due to the high costs and the limited capacity of incineration most were disposed of by alternative methods. Incineration is frequently used as a disposal route for household waste, as landfill space becomes less available.
Key references	Bontoux L (1999). The Incineration of Waste in Europe: Issues and Perspectives, IPTS, March 1999. Environment Agency (2001). Waste Incineration, November 2001. Website last viewed 6 May 2004. Stanners D and Bourdeau P (eds.) (1995). Europe's Environment: The Dobris Assessment - An overview. European Environment Agency, Copenhagen. Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.
Comments	A valuable option when landfill space is scarce.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation

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54 Landfill	
Objective	To dispose of contaminated food products before or after volume reduction techniques.
Other benefits	None.
Description	Organic material can be disposed of to fully engineered landfill sites. These have clay or membrane liners and collection systems designed to contain leachates and landfill gas.
Target	Contaminated cereals, vegetables, fruit, compost, fish, rendered meat, eggs, milk powder, honey, mushrooms, berries, incinerator ash, topsoil.
Targeted radionuclides	**Probable applicability:** ^{60}Co, ^{75}Se, ^{95}Nb, ^{95}Zr, ^{99}Mo/^{99m}Tc, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf **Not applicable:** A high soil mobility (k_d) of between 0 and 30 may cause rapid movement into ground: ^{89}Sr, ^{90}Sr. ^{235}U. Short half-lives of ^{127}Sb, ^{132}Te, ^{140}La likely to mean this management option is not applicable. Management option not applicable to ^{131}I due to both of these reasons.
Scale of application	Large.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to late phase.
Constraints:	
Legal constraints	Limits on radioactive wastes that can be disposed of to landfill. Limits on amounts of organic wastes that can be disposed of to landfill. Training/consent of workers for handling radioactive wastes. Relevant EC legislation is listed below: EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC) EC Landfill Directive 1999/31/EC. EC Groundwater Directive (80/68/EEC)
Social constraints	Local opposition to use of particular landfill sites e.g. where contaminated crops are disposed of in previously uncontaminated areas.
Environmental constraints	None provided landfill site is fully engineered.
Communication constraints	Likely requirement to monitor area around landfill site and publish results.
Effectiveness:	
Effectiveness	N/A.
Factors influencing effectiveness of procedure	Large quantities of putrescible wastes can cause instability and uneven settlement in a landfill. These effects mean that it is necessary to restrict the proportion of foodstuffs entering a landfill. The maximum proportion of putrescible wastes which could practicably be disposed of to landfill is estimated to be 50% by weight of the inventory. The contaminated organic waste should only be disposed of to a fully engineered sanitary landfill licensed to accept putrescible waste.

Factors influencing effectiveness of procedure (continued)	Willingness of privately owned landfill sites and local populations to accept the wastes. Maintenance of correct landfill procedures.
Feasibility:	
Required specific equipment	Landfill site.
Required ancillary equipment	Vehicles for transport of food products, compost, soil and ash to landfill.
Required utilities and infrastructure	Appropriate transport network.
Required consumables	Fuel for transport of food products, compost, soil and ash to landfill.
Required skills	At landfill sites the necessary skills will be available.
Required safety precautions	Consider respiratory protection if very dry conditions.
Other limitations	Putrescible waste must be thoroughly mixed with inert wastes to provide a suitable medium to allow continuation of normal landfill operations e.g. waste spreading and compaction. Future management of landfills may further restrict quantities of putrescible wastes admitted.
Waste:	
Amount and type	Leachate, landfill gas (methane and carbon dioxide).
Possible transport, treatment and storage routes	Leachate treatment may involve on-site pre-treatment including aeration, biodegradation or reed bed filtration. The treated leachate can be discharged to a sewer or directly tankered away for further treatment at a sewage treatment works (STW). It can also be discharged to waterways provided the relevant discharge authorisations are held. Landfill gas is usually managed either by a pumping system with passive venting or flaring or by a pumping system with a condensation system to remove moisture and permit use of gas for heating or electricity generation
Factors influencing waste issues	Quantity and timing of leachate production dependent on rate of ingress of water to landfill and rate of waste decomposition. Factors influencing gas production include organic composition of waste, pH, waste density, moisture content, nutrient distribution and temperature.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of landfill. They represent doses from the treatment of leachate at a Sewage Treatment Works and disposal of resulting sludge and cake to farmland.)*	**Landfill Site Operative:** • external exposure, inhalation of dust and inadvertent ingestion of dirt while landfilling contaminated material. ***Sewage Treatment Works Operative:*** • *external exposure and inadvertent ingestion of leachate and sludge during treatment,* • *external, inhalation and inadvertent ingestion exposure loading cake onto wagons.* **Drivers (External Exposure):** • transporting leachate to STW's, • *transporting sludge and cake to place of disposal (e.g. farmland).* ***Farmer Applying Sludge or Cake to Land:*** • *external exposure, inadvertent ingestion and inhalation of sludge or cake while loading spreader,* • *external exposure while spreading sludge or cake,* • *external exposure, inhalation and inadvertent ingestion while ploughing sludge or cake.*

Incremental dose (continued) *(Dose pathways in italics are indirectly incurred as a result of landfill. They represent doses from the treatment of leachate at a Sewage Treatment Works and disposal of resulting sludge and cake to farmland.)*	***Public:*** • *ingestion of food grown on land spread with sludge or cake* *Ingestion of drinking water and freshwater fish extracted from rivers to which STW's effluent is discharged*
Intervention Costs:	
Equipment	Landfill site – costs for disposing of waste to landfill (including landfill tax). Suitable vehicle for transport.
Consumables	Fuel for transport (depending on distance).
Operator time	Additional work by landfill operator as required. Additional journeys made by lorry driver.
Factors influencing costs	Volume of material to be disposed of. Distance to landfill site. Future increases in landfill tax.
Compensation costs	To landfill facility for handling contaminated material and decontamination of equipment. To transport companies for decontamination of vehicles. To STW's for handling contaminated leachate and for decontamination of equipment.
Waste cost	Included in landfill costs. Treatment of leachate at STW's.
Assumptions	None.
Communication needs	Dialogue and dissemination of information about this waste disposal option (its rationale and possible alternatives) within affected communities.
Side-effect evaluation:	
Ethical considerations	Additional dose to site operators and populations living close to disposal sites. Consent of landfill workers. Environmental risk.
Environmental impact	The leachate may have a high BOD or contain significant quantities of ammoniacal-nitrogen. In a fully engineered site, this will be collected and disposed of via an appropriate route, so environmental impact should be minimised. Both methane and carbon dioxide are greenhouse gases that contribute to global climate change. A high proportion of food wastes in a landfill would provide conditions for maximum gas production. Unless landfill gas is used for electricity generation, landfilling of organic wastes will not result in energy or nutrient recovery.
Agricultural impact	None.
Social impact	Potential for dispute regarding waste disposal sites and selection of areas for disposal. Stigma associated with areas surrounding designated landfill sites.
Other side effects	None.
FARMING Network stakeholder opinion	-
Practical experience	Landfill is a current practice.
Key references	Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS

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55 Landspreading of milk and/or slurry	
Objective	To dispose of contaminated milk and/or slurry.
Other benefits	Additional source of nutrients to soil.
Description	Some agricultural land is potentially suitable for the spreading of milk, either in conjunction with slurry or diluted with water. The spreading of slurry is a normal agricultural practice. In the event of an accident, contaminated milk and slurry would be landspread *in situ*.
Target	Contaminated milk and/or contaminated slurry.
Targeted radionuclides	**Probable applicability:** ^{60}Co, ^{89}Sr, ^{90}Sr ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf. **Not applicable:** High soil:plant concentration ratio (>1) may cause high plant uptake: ^{75}Se, ^{99}Mo/^{99m}Tc. Short half-life of ^{127}Sb, ^{131}I, ^{132}Te, ^{140}Ba, ^{140}La likely to mean this management option is not applicable.
Scale of application	Large scale application on most farms that stock dairy herds. Application may be more restricted on farms stocking alpine sheep and goats.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to medium term. Landspreading milk is highly seasonal, because of the danger of pollution when fields are waterlogged or frozen. Under such circumstances it is possible to store the milk in slurry tanks, if space is available: spreading may then be carried out at a later date.
Constraints:	
Legal constraints	Constraints under some environmental schemes. Relevant EC legislation is listed below: EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC) EC Nitrate Directive 91/676/EEC EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC) and EC Landfill Directive 1999/31/EC. Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972 EC Groundwater Directive 80/68/EEC
Social constraints	Variable depending on usual practice. Willingness of farmer to carry out landspreading if this is not usual practice. Possible perception of causing additional contamination of the soil if milk/slurry is spread on farmland. Acceptability to food industry/consumers of residual levels of contamination in food produced on land where spreading is practised.
Environmental constraints	Milk should not be spread on land with a high risk of runoff or near to any watercourses, and should be diluted with the same volume of water or slurry. The amount of diluted milk spread at any one time should not exceed 50 m^3 ha^{-1} y^{-1} and at least three weeks should be left between each application to reduce surface sealing. On bare land the soil should be lightly cultivated after spreading to quickly mix the waste.

Communication constraints	Need for dialogue regarding selection of areas for treatment. Need for dialogue between land owners/ farmers, environmentalists and public.
Effectiveness:	
Effectiveness	N/A.
Factors influencing effectiveness of procedure	Land available for landspreading. Soil type. Storage space in slurry tank. Environmental conditions on farm. Radionuclide content of the milk or slurry. Degree to which landspreading diverges from common practice will affect willingness of farmers to implement this option. Status of the land.
Feasibility:	
Required specific equipment	Slurry transport and distribution systems (usually available on farms).
Required ancillary equipment	Slurry storage tanks (usually available on farm).
Required utilities and infrastructure	None.
Required consumables	Fuel.
Required skills	Farmers would possess the necessary skills as landspreading is an existing practice.
Required safety precautions	Not necessary at the levels of contamination that this method would be used.
Other limitations	Capacity of slurry storage tanks. Due to potential risk of contaminating water courses, the quantity of nitrogen being applied to land should be monitored.
Waste:	
Amount and type	N/A.
Possible transport, treatment and storage routes	If some or all of the milk can not be landspread alternative disposal routes will have to be established
Factors influencing waste issues	N/A.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of landspreading.)*	**Farmer applying milk/slurry to land:** • external exposure and inadvertent ingestion of milk while loading spreader, • external exposure while spreading milk/slurry mix, • external exposure, inhalation of dust and inadvertent ingestion of dirt while ploughing. ***Public:*** • *ingestion of food grown on land spread with milk*/slurry mix.
Intervention Costs:	
Equipment	Available on farm.
Consumables	Fuel (ca. 7 l ha^{-1}).
Operator time	22 min ha^{-1} when spreading milk at a rate of 20,000 l ha^{-1}.
Factors influencing costs	Volume of milk to be spread.
Compensation costs	To farmer if storage and distribution equipment permanently contaminated. Otherwise to farmer for decontaminating equipment.
Waste cost	N/A.
Assumptions	None.
Communication costs	Provision of information to operators on correct application of procedure so as to avoid pollution.

Side-effect evaluation:	
Ethical considerations	*In situ* disposal option. Self-help for farmer. Highly dependent on the area and status of land used for spreading. Run-off may cause transfer of radionuclides to other, non-contaminated areas.
Environmental impact	Inappropriate disposal of milk to land could lead to pollution of water courses.
Agricultural impact	Additional nutrients provided for crop-uptake which could lead to reduced requirements for fertiliser.
Social impact	Stigma associated with food products where the waste management option has been applied. Landspreading of contaminated milk may restrict subsequent use of the land (e.g. organic farming).
Other side effects	None.
FARMING Network stakeholder opinion	-
Practical experience	Landspreading of milk is carried out on a small scale when farmers are over quota or there is evidence of microbiological contamination. It has not, however, been carried out on a large-scale in the past.
Key references	Marchant JK and Nisbet AF (2002). Management options for food production systems affected by a nuclear accident. 6. Landspreading as a waste disposal option for contaminated milk. NRPB–W11.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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56 Ploughing in of a standing crop

Objective	To dispose of a contaminated crop *in situ*.
Other benefits	Provides a source of organic matter and nutrients to the soil.
Description	This is the direct incorporation of crops at any stage of development up to maturity. Crops are destroyed and do not enter the foodchain. Subsequent ploughing dilutes activity e.g. the activity concentration of radiocaesium or radiostrontium in the soil following incorporation of a mature cereal crop would be at least 10^3 times less than that in the original crop. Desiccation of the standing crop by applying herbicides prior to ploughing in reduces the volume of material that has to be incorporated into the soil.
Target	Contaminated crops.
Targeted radionuclides	**Probable applicability:** ^{89}Sr, ^{90}Sr ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{127}Sb, ^{131}I, ^{132}Te, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{235}U. **Not applicable:** High soil:plant concentration ratio (>1) may cause high plant uptake: ^{75}Se, ^{99}Mo/^{99m}Tc. Short half-life of ^{140}La likely to mean this management option is not applicable. Potential high doses received (> 300μSv) if management option is carried out when activities in crops are at or above CFIL: ^{60}Co, ^{110m}Ag, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf.
Scale of application	Large.
Contamination pathway	N/A.
Exposure pathway pre-intervention	Soil-plant transfer.
Time of application	Early to medium phase, although to reduce the amount of biomass to be incorporated ploughing in is best carried out in the early phase.
Constraints:	
Legal constraints	There may be some legal restrictions under environmental schemes. Also, herbicides would not be permitted under organic farming systems. Relevant EC legislation is listed below: EC Nitrate Directive 91/676/EEC
Social constraints	Acceptability of incorporating contamination into the soil, rather than removing crops and disposing elsewhere.
Environmental constraints	Ploughing in should not be carried out on excessively wet or dry soils because it may damage the soil structure. Therefore ploughing in may not be possible at certain times of the year. Ploughing in may not be possible on shallow soils.
Communication constraints	Need for dialogue regarding selection of areas for treatment.
Effectiveness:	
Effectiveness	A standard mouldboard plough can achieve 90-95% incorporation of standing stripped straw on a range of soils from medium loams to heavy clays. Similar efficiencies would be expected for other crops. Ploughing in destroys crops and removes them from the foodchain, thereby removing doses from ingestion.

Factors influencing effectiveness of procedure	Chopping the material into shorter lengths and spreading it using a combine reduces the bulk of material to be ploughed in. Bulky residues such as vegetable stalks are usually incorporated using a rotary cultivator. Desiccation of standing crop using herbicides reduces the volume of biomass to be ploughed in. Acceptability of the implementation of the waste management option to farmers and the public.
Feasibility:	
Required specific equipment	Tractor and tractor-driven mouldboard plough (widely available).
Required ancillary equipment	Disc or skim coulters, trash boards, forage harvester, rotary cultivator.
Required utilities and infrastructure	None.
Required consumables	Fuel, desiccants such as glyphosate or diquat.
Required skills	Farmers and agricultural workers would have the required skills, but must be instructed carefully about the objectives.
Required safety precautions	Consider respiratory protection if very dry conditions and protective clothing.
Other limitations	The availability of alternative food supplies should be considered before a crop is ploughed in. Dose limits for farmers/agricultural workers.
Waste:	
Amount and type	None.
Possible transport, treatment and storage routes	N/A.
Factors influencing waste issues	N/A.
Doses:	
Incremental dose	Farmer using forage harvester or rotary cultivator: • external exposure from desiccating crops, • external exposure, inadvertent ingestion and inhalation using forage harvester or rotary cultivator, • external exposure, inhalation and inadvertent ingestion of material during ploughing.
Intervention Costs:	
Equipment	Tractor and mouldboard plough already available. Forage harvester and rotovators. Field crop sprayer for application of desiccants, already available.
Consumables	Fuel (ca. 15 l ha^{-1}). Glyphosate (ca. 6 l ha^{-1}).
Operator time	One operator per plough. 4 h ha^{-1} mouldboard plough; 1h ha^{-1} forage harvester; 2h ha^{-1} rotovator; 0.3 h ha^{-1} field crop sprayer
Factors influencing costs	Work rates vary depending on crop type and stage of maturity, herbicide application, soil type and conditions, field size and shape, topography and operator experience.
Compensation costs	To farmer for loss of income from crop, for carrying out ploughing in and for loss of income for non-adherence to conservation schemes. Labour costs may be higher to compensate operators for exposure to radiation.
Waste cost	N/A.
Assumptions	None.

Communication needs	Dialogue regarding selection of areas considered suitable for application of this waste management option. Provision of information to operators on correct operation of procedure.
Side-effect evaluation:	
Ethical considerations	*In situ* treatment of contaminated crop and soil. Self-help for farmer. Free informed consent and compensation for operators. Depending on scenario (i.e. radionuclides are largely on the crop) there may be negative consequences to contaminating the soil beneath the crop.
Environmental impact	Incorporated organic matter provides a source of nitrogen for mineralisation. Unless a cover crop is planted immediately, leaching of nitrates may occur. Incorporation of rape straw may cause slug problems. Other possible impacts include soil erosion, loss of wildlife habitat and the application of additional herbicide.
Agricultural impact	Incomplete breakdown of incorporated crops may make subsequent cultivation difficult.
Social impact	Appropriate selection of priority areas for application of the waste management option. Disruption to farming practices on the farm. Stigma associated with food products where the waste management option has been applied. Disruption to the supply of crops with subsequent market shortages.
Other side effects	None.
FARMING Network stakeholder opinion	-
Practical experience	Ploughing in of crop residues is a standard practice on arable farms, particularly for cereal straw.
Key references	Watts CW, Cope RE and Dexter AR (1996). Harvesting and Ploughing in of crops at various stages of growth. Contract report, Silsoe Research Institute, Bedford, UK. Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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57 Processing and storage of milk products for disposal

Objective	To convert contaminated milk into a more stable end product for storage and subsequent disposal.
Other benefits	Storage offers the authorities more time to plan disposal options.
Description	Milk processing facilities may be used to produce milk products that are suitable for storage and subsequent disposal. This would give the authorities additional time in which to consider disposal options. The most effective and straightforward option is the processing of liquid milk into whole milk powder.
Target	Milk.
Targeted radionuclides	**Probable applicability:** ^{75}Se, ^{89}Sr, ^{90}Sr, ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{125}Sb, ^{131}I, ^{134}Cs, ^{137}Cs, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{235}U, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{252}Cf. **Not applicable:** Short half-life of ^{127}Sb likely to mean this management option is not applicable. Potential high doses received (> 300µSv) if management option is carried out when activities in milk are at or above CFIL: ^{60}Co, ^{99}Mo/^{99m}Tc, ^{110m}Ag, ^{140}Ba. Management option not applicable to ^{132}Te, ^{140}La due to both of these reasons.
Scale of application	Medium to large.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to medium phase.
Constraints:	
Legal constraints	Dairy workers may have to be trained in the handling of radioactive waste. EC legislation relevant to the control of milk processing plants is listed below: Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). Urban Waste Water Directive 91/271/EEC for the treatment of liquid wastes.
Social constraints	Resistance to allowing contaminated milk into dairies because retailers and consumers would not have the confidence that the plant could be put back to normal operation after treatment has taken place, without the risk of contaminating milk and milk products subsequently produced.
Environmental constraints	None.
Communication constraints	None.
Effectiveness:	
Effectiveness	N/A.
Factors influencing effectiveness of procedure	Availability and capacity of facilities for processing. Acceptability of implementing the waste management option to dairy operatives. Acceptability of siting of storage facilities and subsequent disposal routes.
Feasibility:	
Required specific equipment	Milk processing plant with freeze-drier.
Required ancillary equipment	Milk tankers.
Required utilities and infrastructure	Storage facilities for milk powder.

Required consumables	Fuel for tankers.
Required skills	Operatives at milk processing plants will have the required skills.
Required safety precautions	Consider respiratory protection.
Other limitations	There might be reluctance to move contaminated raw materials to a processing plant located outside a contaminated area. This might affect the availability of processing plants for this purpose.
Waste:	
Amount and type	Milk powder. Contaminated water from washing and rinsing of tankers. Water extracted in production of milk powder is uncontaminated and does not require special disposal.
Possible transport, treatment and storage routes	Milk powder can be disposed of to landfill. The stability of milk powder permits a period of storage (i.e. supervised warehouse) in advance of a suitable disposal route being found. Disposal of contaminated washings can be made to dairy effluent plants or sewage treatment works.
Factors influencing waste issues	Disposal of processing wastes would be subject to individual national regulations and may require licensing.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of processing of milk. There are datasheets outlining the incremental dose pathways from the disposal of milk powder to 54 Landfill.)*	**Dairy Operatives:** • external dose from milk during processing (dependant on the location of the control room from the machinery). **Drivers (External Exposure):** • transporting milk to milk processing plant, • transporting milk powder to storage facility. ***Milk Powder Storage Facility Operatives:*** • *external dose when overseeing loading and unloading of milk powder to storage.*
Intervention Costs:	
Equipment	Milk processing plant.
Consumables	Processing consumables, including for example electricity. Fuel for transport.
Operator time	Tanker drivers on 10 hour shifts. Operators at processing plants for additional work. Security guard.
Factors influencing costs	Transportation costs depend on distance. Length of storage time. Disposal route.
Compensation costs	To processing plants for accepting contaminated milk and for subsequent decontamination of equipment. To dairy operatives for handling contaminated milk.
Waste cost	Cost of storage of milk powder and disposal to landfill or other facility. Cost of disposal of rinsing waters to dairy effluent/sewage treatment plant if necessary.
Assumptions	None.
Communication needs	None.
Side-effect evaluation:	
Ethical considerations	Dairy workers will have to give informed consent to the treatment of contaminated milk.
Environmental impact	Minimal environmental impact when processing liquid milk into whole milk powder, provided the latter is disposed of properly.
Agricultural impact	None.

Social impact	Disruption to the supply of milk to the food industry and market shortages. Negative social and psychological impact that people's food/food supply is so contaminated that it requires disposal. Conversely, it may increase public confidence that contamination is being removed from the foodchain and the situation is being effectively managed.
Other side effects	None.
FARMING Network stakeholder opinion	-
Practical experience	Processing of milk to whole milk powder is a current practice.
Key references	Long S, Pollard D, Cunningham JD, Astasheva NP, Donskaya GA and Labetsky EV (1995). The effects of food processing and direct decontamination techniques on the radionuclide content of foodstuffs: a literature review. Part 1: milk and milk products. *Journal of Radioecology*, 3 (1), 15-30. Mercer J, Nisbet AF and Wilkins BT (2002). Management options for food production systems affected by a nuclear accident: 4 Emergency monitoring and processing of milk. NRPB-W15.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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58 Rendering	
Objective	To reduce volume of contaminated carcasses prior to disposal.
Other benefits	None.
Description	Animal carcasses may be sent to licensed rendering plants and reduced to tallow, meat and bonemeal (MBM), condensate (the condensed steam produced from boiling off the water from the rendering process) and blood. These products require subsequent disposal to landfill, incineration and wastewater treatment plant.
Target	Meat and milk producing livestock.
Targeted radionuclides	**Probable applicability:** ^{60}Co, ^{75}Se, ^{95}Nb, ^{95}Zr, ^{99}Mo/^{99m}Tc, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{169}Yb, ^{192}Ir, ^{226}Ra, ^{238}Pu, ^{239}Pu, ^{241}Am ^{252}Cf. **Not applicable:** A high soil mobility (k_d) of between 0 and 30 may cause rapid movement into ground: ^{89}Sr, ^{90}Sr, ^{131}I, ^{235}U. Short half-lives of ^{127}Sb, ^{132}Te, ^{140}La likely to mean this management option is not applicable.
Scale of application	Medium to large.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to late phase.
Constraints:	
Legal constraints	Rendering is likely to be subject to specific legislation in each member state. Relevant EC legislation is listed below: Integrated Pollution Prevention and Control Directive 96/61/EC. Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972. Over Thirty Month Scheme as specified in EC Regulation (Reg 716/96).
Social constraints	Public or stakeholder acceptability. Most rendering plants have local protest groups due to odours. Low acceptance of radioactively contaminated material to these groups.
Environmental constraints	Rendering should result in minimal environmental impact provided all control measures and best practice is fully implemented.
Communication constraints	Operators require information on rendering contaminated carcasses.
Effectiveness:	
Effectiveness	N/A.
Factors influencing effectiveness of procedure	The availability and capacity of rendering plants to cope with large numbers of livestock carcasses at any one time. The reduction of the carcasses to tallow, meat and bonemeal (MBM) is dependent on temperature, time, and pressure combinations at each facility. Acceptability of disposal/treatment procedures.
Feasibility:	
Required specific equipment	Rendering plants suitable for disposal of mammalian carcasses.

Required ancillary equipment	Transportation of carcasses from farm to rendering plant and waste products to landfill or incineration and waste water treatment plant.
Required utilities and infrastructure	Disposal route for waste products e.g. landfill, incineration, wastewater treatment.
Required consumables	Fuel for transportation of carcasses and waste products.
Required skills	Rendering operators should have the necessary skills.
Required safety precautions	Protective clothing.
Other limitations	Capacity of rendering plants.
Waste:	
Amount and type	The main products of rendering are: • MBM (Meat and Bone Meal) - dust like end product containing 60-65% protein, • tallow – solid hard fat, • greaves - same material as MBM but the final grinding stage has been omitted, • condensate - generated from the rendering process, • blood - blood meal. When a whole carcass is rendered the volume is reduced by 12%. Generally this is made up of 60% MBM and 40% tallow. Upon incineration this is reduced further. Between 100 and 150 kg ash is produced per tonne of carcass.
Possible transport, treatment and storage routes	Tallow and MBM may be incinerated and/or sent to licensed commercial landfill. Condensate has to be treated on site or at a wastewater treatment plant to produce clean water and sludge.
Factors influencing waste issues	Temperature, time and pressure of rendering plant. These conditions depend on the rendering process used and should ensure that any BSE infectivity is removed. Level of radioactivity in the waste products.
Doses:	
Incremental dose *(Dose pathways in italics are indirectly incurred as a result of rendering. Rendering products are disposed of to 54 Landfill or by 53 Incineration. There are separate datasheets for these disposal options giving the relevant dose pathways that should be considered. The condensate generated during rendering may be sent to a Sewage Treatment Works (STW): the relevant dose pathways for this disposal route are given in the 54 Landfill datasheet.)*	**Rendering Plant Operative:** • external exposure to carcasses, • external exposure to rendering products (MBM, tallow, greaves) store, • external exposure and inadvertent ingestion during treatment of condensate. **Drivers (External Exposure):** • transporting carcasses to rendering plants, • *transporting rendering products (MBM, tallow, greaves) to landfill or incineration,* • *transporting sludge from rendering plant to STW.*
Intervention Costs:	
Equipment	Rendering plant.
Consumables	Fuel for transportation of carcasses and disposal of waste products.
Operator time	Rendering plant operators for additional work. Additional time to transport carcasses.
Factors influencing costs	Number of carcasses to be treated and disposal routes of rendered products. Risk of contaminating rendering plant and vehicles used to transport carcasses.
Compensation costs	To rendering plant owners for decontamination of the plant and vehicles.

Waste cost	Transportation of waste products to disposal site/plant. Costs of incineration or landfill and treating condensate. Compensation to landfill, incinerator and waste water treatment owners for decontamination of the plant and vehicles if necessary.
Assumptions	All the infrastructure needed is readily available.
Communication needs	Information and training for operators.
Side-effect evaluation:	
Ethical considerations	Additional dose to operators and populations living close to rendering plants. Consent of plant operators.
Environmental impact	Minimal from rendering itself. Incinerating rendering wastes does not cause any particular air quality problems as standard flue gas cleaning systems minimise the formation of harmful by-products as well as meet the authorised emission levels. Minimal pollution risk to surface and groundwater arising from landfilling ash and rendering wastes.
Agricultural impact	None.
Social impact	Minimal.
Other side effects	None.
FARMING Network stakeholder opinion	-
Practical experience	Rendering was the preferred option for disposing of livestock during the FMD outbreak in the UK, although capacity was a limiting factor at the peak of the outbreak. Therefore, incineration, burial and burning disposal methods were also used. Rendering waste products were disposed of by incineration and landfill, depending on the rendering process used and age of cattle.
Key references	MAFF (2001). Guidance Note on the Disposal of Animal By-Products and Catering Waste. January 2001. SEGHERS better technology (2001). From Mad Cow Crisis to Clean Energy. Trevelyan GM, Tas MV, Varley EM and Hickman GAW (2001). The Disposal of Carcasses during the 2001 Foot and Mouth Disease Outbreak in the UK. Defra, FMD Joint Co-ordination Centre, Page Street, London, SW1P 4Q, UK
Comments	Rendering is the preferred method of whole carcass disposal as it has the least disposal hazards associated with it.
Document History	**STRATEGY originator:** Nisbet AF. **STRATEGY contributors:** HPA-RPD (Mercer JA, Hesketh, N), NRPA (Liland A, Thørring H, Bergen T), CEH (Beresford NA, Howard BJ), ULANC (Hunt J), UMB (Oughton D) **EURANOS originator:** n/a **EURANOS revisions:** The STRATEGY datasheets have all been revised to varying extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA-RPD (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI (Papacristodoulou C and Ioannides K) for adaptation to Mediterranean conditions; STUK (Rantavaara A and Rissanen K) for adaptation to northern European conditions; UMB (Oughton D and Bay I) for consideration of social, ethical and communication issues; and CEH and STUK for consideration of early-phase post accident applicability.

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4 PLANNING FOR RECOVERY IN ADVANCE OF AN INCIDENT

There is a broad diversity of climatic conditions, food production systems, culture, infrastructure and regulatory frameworks across Europe. Planning for recovery in advance of an incident will require customisation of this generic handbook at national, regional or local level. An essential component of the customisation process is the involvement of all stakeholders to better identify and include national/regional/local specificities. Practical recommendations for engaging with stakeholders in the management of contaminated areas are given in Appendix D.

The purpose of this chapter is to support the planning process by identifying the key topics that would need to be addressed and information that is needed to support the development of recovery strategies. Although much will depend on the nature of the emergency or incident (e.g. its magnitude and the extent of radioactive contamination), consideration of topics such as 'requirements for information' and 'outline arrangements' prior to the occurrence of an incident would benefit the speed of recovery response and may also ensure a more successful outcome. Table 4.1 provides a breakdown of topics covering data and information requirements that could usefully be gathered in advance of an incident. The development and sharing of localised databases on commercial and private food producers, dietary habits, suppliers of raw materials, contractors, waste disposal facilities and other information need to be considered. Although some of these databases may already exist in some form, the point of contact may not be widely known. Furthermore, it is important that the information is kept up to date and is maintained. Responsibility for this task for each database would need to be assigned. Communication between data collectors and users is important so that it is available in the correct format. Due to the wide ranging nature of the information presented in Table 4.1, it is not yet clear how these data would be assembled. Priorities would need to be assigned to help ensure the best use of available resources. Organisations at the local level would need to develop their own approach for preparing for a radiological emergency, according to their responsibilities and involvement. Table 4.2 gives a list of factors, in addition to the information requirements listed in Table 4.1 that might need to be considered when developing an outline of a recovery strategy in advance of an incident. The strategy should be focussed at the local level and as a co-ordinated activity between all relevant agencies and stakeholders. Dialogue between different stakeholders is important in order to gain a balanced view on various aspects of topics at the national, regional or local level. It enables a common language and a shared understanding of the challenges to be developed. Various approaches for co-developing regional Handbooks with stakeholders can be used, including scenario-based workshops, feedback sessions on the datasheets and Handbook and the establishment of subgroups for more detailed planning on specific topics (e.g. waste management).

Table 4.1 Data and information requirements that could usefully be gathered in advance of an incident

Topic	Category	Data and information requirements
Land use	Agricultural production - Milk	Availability of/access to databases providing information on the following: • Rapid identification of milk producers in an area • Rapid identification of milk purchasers within an area (geographical size of this area could be large if milk is transported for use in the manufacture of other foods) • Rapid identification of private dairies and on-farm consumers • Rapid identification of haulage companies that would provide drivers willing to enter a restricted area if milk tanker drivers refused to do so • Rapid identification of other milk producing livestock, including sheep and goats • Rapid identification of small holdings with domestic livestock e.g. goats and hens Availability of buildings for sheltering livestock during passage of the plume Availability of alternative animal feeds
	Agricultural production – Crops	Information on scale and importance of crop production in an area Information on harvest times for different produce
	Domestic production	Information on scale and importance of domestic production in an area Information on feeding regimes of domestic livestock Information on seasonality of production within the affected area Availability of/access to databases providing information on the following: • Rapid identification of areas with allotments and small holdings. Availability of maps? • Rapid identification of allotment holders and other types of domestic producer • Rapid identification of houses with private gardens
	Gathering of free/wild foods	Information on scale and importance of free/wild food collection in an area Availability of/access to databases allowing rapid identification of areas where gathering of free foods is common at different times of the year
	Hunting/fishing	Availability of/access to database of people with licenses for fishing and hunting in the area
Management options	Raw materials	List of raw materials required for implementation of options (fertilisers, lime, clay minerals, AFCF, Prussian blue) Construct database giving local, regional and national availability of raw materials including list of suppliers
	Equipment	List of equipment required for implementation of options and indication if this is 'specialist' machinery and likely to be in limited supply (e.g. deep ploughing, topsoil removal) Construct database giving local and regional availability of equipment including list of suppliers List of types of monitoring equipment available for particular purposes

Topic	Category	Data and information requirements
		Availability of/access to national database of suppliers of monitoring equipment, including arrangements for dispatching equipment
	Infrastructure	Availability of/access to database with local/regional information on road networks, sewage and water treatment facilities, licensed landfill and incineration facilities, composting sites, milk processing plants, slaughterhouses and rendering facilities List of locations where contaminated material, equipment etc may be stored
	Personnel	Availability of/access to database of available contractors and organisations that can be contacted for advice on techniques, equipment, staff protection, radiological protection advisory services etc. Establish whether skilled personnel are required to operate equipment and the numbers that would be available in a particular area/region Establish criteria for working in contaminated areas Prepare template for risk assessment Identify training requirements where shortage of skilled workers
	Impact of geography and weather on implementation	Availability/access to meteorological information, including weather forecasts for local area and region Availability/access to geographical information systems providing information on soil types, topography, nitrate sensitive area etc.
	Impact on the economy/environment	Consider the likely scale of the economic impact from implementing each of the management options, both direct and indirect effects Consider whether some options could have a negative impact on the local environment
	Acceptability	This is likely to be influenced by the type of radiological emergency/incident, its size, how the response is handled, the cause of the emergency etc. However, public and other stakeholder views on the acceptability at the local level of the types of management options available could be sought to reduce the number of options to be considered in the event of a radiological emergency. Establish whether there is a framework in place locally for stakeholder engagement and agree in advance how it would be used.
Dietary habits		Availability of/access to database of dietary habits in the local area/region to identify whether there are groups with unusual dietary habits that could make them more likely to be exposed to contaminated food.
Waste disposal or storage	General issues	Availability of/access to database giving: • Authorised limits for incinerators, landfill sites, composting facilities etc. in the area • Number, type and capacities of facilities Protection of workers at disposal sites Disposal of foodstuffs below action levels that cannot be marketed because of public perception
	Specific issues - milk	Availability of/access to database giving size of slurry stores for on farm storage in an area Prevalence of nitrate vulnerable zones in the area that would prevent landspreading of milk Availability of ground water vulnerability maps Access roads for large milk tankers to disposal sites (e.g. long-sea outfalls, sewage treatment works)

Topic	Category	Data and information requirements
	Specific issues – domestic produce	Consider advice to segregate fruit, vegetables and other garden waste from normal household refuse and arrange for special collection of contaminated putrescible waste e.g. eggs, milk and animal wastes
Legislation	Options	Environmental legislation may preclude implementation of some management options in the contaminated area. Establish whether there are designated areas, which can be one or more of the following: an area of special scientific interest, a special protection area, a special area of conservation, RAMSAR site or nature reserve
		Establish the prevalence of organic farms and legal requirements with regard to implementation of management options
		Establish whether sewage treatment works with long sea outfalls have been considered suitable for disposal of contaminated milk
	Workers and public	Establish dose limits for all those involved in recovery
		Establish criteria for transportation of radioactive wastes e.g. foodstuffs, soils
Training		Local authorities might wish to consider developing a competence framework and training programme for the recovery roles required
Contacts	For consumers	Helpdesk number or emergency email address in organisations that have a role in the event of a radiological emergency
		Lists of contacts with local information
		Lists of country/regional/local databases that provide useful background data and information on how to access them
		Lists of allotment societies and gardening clubs
	For farmers	Helpdesk number or emergency email address in organisations that have a role in the event of a radiological emergency.
		Lists of contacts with local information
		Eligibility and how to claim compensation
	For food manufacturers	List of contact details for distributors and suppliers
Communication	Provision of information to consumers	Pre-prepared leaflets about radioactivity and the foodchain and steps undertaken to maintain food safety. Also fact sheets, briefing packs, press releases
		Guidance to domestic producers about safety of produce
		Arrangements for communications via local/national TV and radio, national, websites - timeline
		Plan for engaging local people in decisions that will affect them. Consider using existing infrastructure: parish councils, community groups, schools
	Compensation	Pre-prepared information that can rapidly be circulated to affected farmers. Receipts, record keeping
		Pre-prepared information for others who may suffer financial losses due to the incident
	Provision of information to implementers of management options	Provision of information on the objectives of the recovery option to ensure that those implementing the option understand why it is being undertaken and how the objective can be achieved
		Leaflets to provide instruction on how to implement options correctly and effectively

Table 4.2 Factors and actions that might need to be considered when developing an outline recovery strategy for food in advance of an incident

Topic	Factors and actions to consider
Generic strategy	Ensure information requirements (see Table 4.1) are prioritised, actioned, achieved and maintained – it is important to have confidence that information is complete, reliable and up-to-date Establish mechanisms for accessing information Identify priorities for recovery based on the main type of agricultural production in the area. Note importance of milk in this respect Consider generation of putrescible waste food arisings and have shortlist of disposal routes available Develop a communication strategy with pre-prepared information for consumers, farmers, allotment holders, those engaged in fishing and hunting. Establish the audience, message and how it will be conveyed Consider the impact of seasonality on the recovery strategy Produce and maintain a risk register for things that could go wrong in the development of the strategy (e.g. non compliance, local population won't engage in dialogue). Identify drivers and barriers and establish which ones will make the biggest difference
Roles and responsibilities	Make sure the roles and responsibilities of those agencies that would undertake tasks in the recovery response are well known (i.e. through national guidance). Identify leading agencies and legal responsibilities. Establish how the roles and responsibilities change along the timeline Consider for each management option how available resources will be co-ordinated and moved to the affected area, e.g. the use of army, civil protection. This should be done at the national level to ensure consistency Explore the best role for the local government and local agencies
Role of stakeholders	Identify existing stakeholder groups in the area. Investigate whether these could/would be prepared to provide feedback on a recovery strategy for the area Consider processes that could be used to establish bespoke stakeholder panels where no relevant groups exist. Establish steps for each process considered
Recovery options	Identify practicable and acceptable recovery options for use at the local level based on information provided in the Food Handbook in advance. Try engaging with the stakeholders. Consider: • any constraints on use of an option • impact of season • generation of wastes and how it would be managed • Which options might be applicable according to type of emergency/incident scenario? Identify aspects for each recovery option that will require consideration in advance of a radiological emergency and those that will be of particular importance to be taken into account in the event of a radiological emergency Consider trials of the recovery options, to obtain a better understanding of the effectiveness and feasibility
Criteria for a successful strategy	Identify appropriate criteria to be used to determine the need for and scale of recovery countermeasures and to measure their success

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CONTENTS OF SECTION 5

5 CONSTRUCTING A MANAGEMENT STRATEGY

In the event of a radiological accident or incident, decision-makers will need to be in a position to construct a strategy for managing contaminated food production systems. For small-scale, single isotope releases the strategy may comprise of one or two management options that could be applied over the first few days or weeks following the accident. For wide scale, multi-nuclide releases a management strategy is likely to be more complex, comprising a series of management options that could be implemented over different phases of accident response and affecting several types of food production system. Some aspects can be considered in advance of an incident as part of contingency planning. A series of checklists are provided in Section 4 to highlight the type of information that can be gathered under non-crisis conditions to help manage the pre-release and early phases of an incident.

This Handbook provides information on 58 management options (Section 3) subdivided into the following categories:

- Options for the pre-deposition phase (n=6)
- Options for the early-late phase: general applicability (n=6); soils/crops/grassland (n=11); animal products (n=15); societal (n=8); disposal of waste foods (n=12)

The selection of individual options depends on a wide range of criteria (temporal and spatial distribution of the contamination, effectiveness, economic cost, radiological and environmental impact, waste disposal, legislative issues and societal and ethical aspects, for example) which are described in Section 2. For any one accident scenario only a subset of options will be applicable. However, as each accident will be different in terms of its radiological composition and impact on the foodchain it is not possible to devise a generic strategy. This section provides a series of tables to guide decision makers to the most appropriate subset of management options through elimination of inappropriate options. Two worked examples are given in Section 6 on how to select and combine management options to develop an overall management strategy.

5.1 Key steps in selecting and combining options

There are 8 key steps involved in selecting and combining options. These steps are summarised in Table 5.1 and described in more detail below.

Step 1: Identify one or more production systems that are likely to be/have been contaminated (i.e. cereals, free foods, leafy vegetables, woody fruit trees, milk, eggs, meat, reindeer).

Step 2: Refer to selection tables for specific production systems (Table 5.2 – Table 5.18). These selection tables provide a list of all of the applicable management options for the production system selected. Separate selection tables are given for continuing food production and the management of the wastes. The tables indicate whether the management options are suitable for implementation in the pre-deposition, early, medium or late phases. The tables also provide an indication of whether the management options are likely to be implemented using a system of knowledge of potential technical, logistical, economic or social constraints based on colour coding. The classification used in the selection tables is intended to be a guide and would certainly require customization at local or regional level by the relevant stakeholders.

Step 3: Refer to look-up tables (Table 5.19 – Table 5.24) showing applicability of management options, including those for waste disposal, for each radionuclide being considered. This allows various options listed in the selection tree to be eliminated on the basis of physical, chemical, biological or environmental behaviour of the radionuclide(s).

Step 4: Refer to look-up tables (Table 5.25 – Table 5.26) showing checklist of key constraints for each management option, including those for waste disposal.

Step 5: Refer to look-up table (Table 5.27) showing maximum activity concentrations in the target medium for which the option would be effective (i.e. in reducing concentrations to below the Council Food Intervention Level). This indicates whether an option would be effective on its own or whether it would need to be combined with others to achieve the desired reduction in activity concentration in the target medium. Much of the data presented relate to $^{134,137}Cs$, $^{89,90}Sr$ and ^{239}Pu.

Step 6: Refer to look-up tables (Table 5.28 – Table 5.29) showing which management options incur an incremental dose to those involved in their implementation either directly or through the management of any secondary wastes produced. This information will not necessarily eliminate options but serves to warn the decision maker that selection of a particular option will have implications for wastes and doses that will require further assessment.

Step 7: Refer to individual datasheets (Section 3) for all options remaining in the selection table and note the relevant constraints. It is likely that on a site specific basis, several more options will be eliminated from the selection tree as a result of additional constraints.

Step 8: Based on Steps 1-7, select and combine options for managing each phase of the accident, both for maintaining production and for disposing of wastes.

By following Steps 1-8 it should be possible to devise a strategy, based on a combination of management options that could be implemented over all accident phases from pre-deposition to the late phase. This step should be based on a participative approach with the stakeholders.

Table 5.1 Generic steps involved in selecting and combining options

Step	Action
1	Identify one or more production systems that are likely to be/have been contaminated
2	Refer to selection tables for specific production systems (Table 5.2 – Table 5.18). These selection tables provide a list of all of the applicable management options for the production system selected
3	Refer to look-up tables (Table 5.19 – Table 5.24) showing applicability of management options, including those for waste disposal, for each radionuclide being considered
4	Refer to look-up tables (Table 5.25 - Table 5.26) showing checklists of key constraints for each management option, including those for waste disposal
5	Refer to look-up table (Table 5.27) showing maximum activity concentrations in the target medium for which the option would be effective
6	Refer to look-up tables (Table 5.28 – Table 5.29) showing which management options incur an incremental dose to those involved in their implementation either directly or through the management of any secondary wastes produced
7	Refer to individual datasheets (Section 3) for all options remaining in the selection table and note the relevant constraints
8	Based on the outputs from Steps 1-7, select and combine options that should be considered as part of the recovery strategy

5.2 Selection tables

Selection tables are presented for the following production systems:

- cereals (Table 5.2 for continuing production; Table 5.3 for managing waste)
- leafy vegetables - commercially produced (Table 5.4 for continuing production; Table 5.5 for managing waste)
- woody fruit trees (Table 5.6 for continuing production; Table 5.7 for managing waste)
- milk (Table 5.8 for continuing production and Table 5.9 for managing waste)
- meat - beef and sheep (Table 5.10 for continuing production; Table 5.11 for managing waste)
- eggs (Table 5.12 for continuing production and Table 5.13 managing waste)
- vegetables, herbs, fruit and berries gathered in the wild or grown domestically (Table 5.14 for continuing production; Table 5.15 for managing waste)
- nuts and mushrooms gathered in the wild (Table 5.16 for continuing production; Table 5.17 for managing waste)
- reindeer (Table 5.18 for continuing production).

These selection tables provide:

- A list of most of the applicable management options for the production system selected. A few of the ‘societal’ options have been omitted from the tables due to high uncertainty about their applicability (e.g. food labeling, compensation scheme, do nothing, raising intervention levels). For each food production system illustrated, a distinction is made between management of the land for the purpose of continuing food production and the management of food waste arising as a result of restrictions on the entry of contaminated food from that production system into the food chain. Separate selection tables are given for continuing food production and the management of the wastes.

- An indication of whether the management options are suitable for implementation in the pre-deposition, early, medium or late phases.
- An indication of whether the management options are likely to be implemented based on knowledge of potential technical, logistical, economic or social constraints. The colour-coding distinguishes between: options that would usually be justified or recommended having few if any constraints; options that would also be recommended but would require further analysis to overcome potential constraints; options that would have to undergo a full analysis and consultation with stakeholders before implementation because of serious economic or social constraints and options that would only be justified in specific circumstances following full analysis and consultation due to major technical or logistical constraints. The classification used in the selection tables is intended to be a guide and requires customization at local or regional level by the relevant stakeholders.

The numbers in brackets in Tables 5.2 – 5.18 refer to the datasheet number.

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Table 5.2 Selection table of management options for cereals to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Dilution (7)	Red	Amber	Amber	Red	E-M
Feeding of animals with crops in excess of intervention levels (8)	Red	Dark red	Dark red	Dark red	E-M
Restrictions on the entry of food into the foodchain (11)	Red	Green	Green	Amber	E-M-L
Selection of alternative land use (12)	Red	Red	Red	Amber	L
Options for maintaining production					
Closure of air intake systems at food processing plants (1)	Green	Amber	Red	Red	P
Closure of irrigation systems (2)	Green	Amber	Red	Red	P
Covering of standing crops (3)	Amber	Amber	Red	Red	P
Protection of harvested crops from deposition (5)	Green	Amber	Red	Red	P
Application of lime to arable soils and grassland (13)	Red	Red	Green	Green	E-M-L
Application of K fertilisers to arable soils and grassland (14)	Red	Red	Green	Green	E-M-L
Deep ploughing (15)	Red	Red	Red	Red	E-M
Early removal of crops (16)	Red	Amber	Red	Red	P-E
Processing of crops for subsequent consumption (18)	Red	Dark red	Dark red	Dark red	E-M
Selection of edible crop that can be processed (20)	Red	Red	Dark red	Dark red	M-L
Shallow ploughing (21)	Red	Green	Green	Green	E-M-L
Skim and burial ploughing (22)	Red	Red	Amber	Amber	E-M
Topsoil removal (23)	Red	Amber	Amber	Red	E-M

Key

Green	Recommended with few constraints.
Amber	Recommended but requires further analysis to overcome some constraints.
Dark red	Economic or social constraints exist, requiring full analysis and consultation period.
Red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.3 Selection table of waste management options for contaminated cereals

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated cereals					
Biological treatment (digestion) of crops (47)					E-M-L
Composting (51)					E-M
Incineration (53)					E-M
Landfill (54)					E-M
Ploughing in of a standing crop (56)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.4 Selection table of management options for leafy vegetables (commercial) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Feeding of animals with crops in excess of intervention levels (8)	Red	Dark red	Dark red	Dark red	E-M
Restrictions on the entry of food into the foodchain (11)	Red	Green	Green	Amber	E-M-L
Selection of alternative land use (12)	Red	Red	Red	Amber	M-L
Options for maintaining production					
Closure of air intake systems at food processing plants (1)	Green	Amber	Red	Red	P
Closure of irrigation systems (2)	Green	Amber	Red	Red	P
Covering of standing crops (3)	Amber	Amber	Red	Red	P
Prevention of contamination of greenhouse crops (4)	Green	Amber	Red	Red	P
Protection of harvested crops from deposition (5)	Green	Amber	Red	Red	P
Application of lime to arable soils and grassland (13)	Red	Red	Green	Green	E-M-L
Application of K fertilisers to arable soils and grassland (14)	Red	Red	Green	Green	E-M-L
Deep ploughing (15)	Red	Red	Red	Red	E-M-L
Early removal of crops (16)	Red	Amber	Red	Red	P-E
Processing of crops for subsequent consumption (18)	Red	Dark red	Dark red	Dark red	E-M
Selection of edible crop that can be processed (20)	Red	Red	Dark red	Dark red	M-L
Shallow ploughing (21)	Red	Green	Green	Green	E-M-L
Skim and burial ploughing (22)	Red	Red	Amber	Amber	E-M-L
Topsoil removal (23)	Red	Amber	Amber	Red	E-M

Key

Green	Recommended with few constraints.
Amber	Recommended but requires further analysis to overcome some constraints.
Dark red	Economic or social constraints exist, requiring full analysis and consultation period.
Red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.5 Selection table of waste management options for contaminated leafy vegetables produced commercially

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated vegetables					
Biological treatment (digestion) of crops (47)					E-M-L
Composting (51)					E-M-L
Incineration (53)					E-M-L
Landfill (54)					E-M-L
Ploughing in of a standing crop (56)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.6 Selection table of management options for woody fruit trees to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Feeding of animals with crops in excess of intervention levels (8)					E-M
Restriction on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					L
Options for maintaining production					
Closure of air intake systems at food processing plants (1)					P
Closure of irrigation systems (2)					P
Protection of harvested crops from deposition (5)					P
Application of lime to arable soils and grassland (13)					E-M-L
Application of K fertilisers to arable soils and grassland (14)					E-M-L
Deep ploughing (15)					E-M
Pruning/defoliation of fruit trees and vines (19)					E
Selection of edible crop that can be processed (20)					M-L
Shallow ploughing (21)					E-M-L
Skim and burial ploughing (22)					M-L
Topsoil removal (23)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.7 Selection table of waste management options for contaminated woody fruit trees

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated fruit and fruit products					
Biological treatment (digestion) of crops (47)					E-M-L
Composting (51)					E-M
Incineration (53)					E-M-L
Landfill (54)					E-M-L
Ploughing in of a standing crop (56)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.8 Selection table of management options for milk to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Dilution (7)	Red	Amber	Amber	Red	E-M
Feeding animals with milk in excess of intervention levels (8)	Red	Dark red	Dark red	Dark red	E-M
Restriction on the entry of food into the foodchain (11)	Red	Green	Green	Green	E-M-L
Selection of alternative land use (12)	Red	Red	Red	Amber	L
Options for maintaining production					
Closure of air intake systems at processing plants (1)	Green	Amber	Red	Red	P
Short-term sheltering of dairy animals (6)	Green	Green	Red	Red	P
Addition of AFCF to concentrate ration (24)	Red	Red	Green	Green	E-M-L
Addition of calcium to concentrate ration (25)	Red	Red	Green	Green	E-M-L
Administration of AFCF boli to ruminants (26)	Red	Red	Amber	Amber	M-L
Administration of clay minerals to feed (27)	Red	Red	Amber	Amber	E-M-L
Clean feeding (29)	Red	Green	Green	Amber	E-M-L
Decontamination techniques for milk (30)	Red	Red	Dark red	Dark red	M-L
Distribution of saltlicks containing AFCF (31)	Red	Red	Amber	Amber	M-L
Processing of milk for subsequent human consumption (34)	Red	Red	Red	Red	E-M
Selective grazing regime (36)	Red	Red	Green	Green	E-M-L
Slaughtering of dairy livestock (37)	Red	Dark red	Dark red	Dark red	M-L
Suppression of lactation before slaughter (38)	Red	Dark red	Dark red	Dark red	M-L

Key

Green	Recommended with few constraints.
Amber	Recommended but requires further analysis to overcome some constraints.
Dark red	Economic or social constraints exist, requiring full analysis and consultation period.
Red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.9 Selection table of waste management options for contaminated milk

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated milk					
Biological treatment (digestion) of milk (48)	Red	Amber	Amber	Amber	E-M-L
Disposal of contaminated milk to sea (52)	Red	Dark red	Dark red	Dark red	E-M-L
Incineration (53)	Red	Amber	Amber	Amber	E-M-L
Landspreading of milk and/or slurry (55)	Red	Green	Green	Green	E-M-L
Processing and storage of milk products for disposal (57)	Red	Amber	Amber	Amber	E-M-L

Key

Green	Recommended with few constraints.
Amber	Recommended but requires further analysis to overcome some constraints.
Dark red	Economic or social constraints exist, requiring full analysis and consultation period.
Red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.10 Selection table of management options for meat (cow and sheep) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Restriction on the entry of food into the foodchain (11)	Red	Green	Green	Green	E-M-L
Selection of alternative land use (12)	Red	Red	Red	Amber	L
Options for maintaining production					
Closure of air intake system at processing factories (1)	Green	Amber	Red	Red	P
Short-term sheltering of (dairy) animals (6)	Green	Green	Red	Red	P
Addition of AFCF to concentrate ration (24)	Red	Red	Green	Green	E-M-L
Addition of calcium to concentrate ration (25)	Red	Red	Green	Green	E-M-L
Administration of AFCF boli to ruminants (26)	Red	Red	Amber	Amber	E-M-L
Administration of clay minerals to feed (27)	Red	Red	Amber	Amber	E-M-L
Clean feeding (29)	Red	Green	Green	Amber	E-M-L
Distribution of salt licks containing AFCF (31)	Red	Red	Amber	Amber	E-M-L
Live monitoring (32)	Red	Red	Green	Green	E-M-L
Manipulation of slaughter times (33)	Amber	Amber	Amber	Amber	P-E-M-L
Salting of meat (35)	Red	Red	Dark red	Dark red	L
Selective grazing regime (36)	Red	Red	Green	Green	E-M-L

Key

Green	Recommended with few constraints.
Amber	Recommended but requires further analysis to overcome some constraints.
Dark red	Economic or social constraints exist, requiring full analysis and consultation period.
Red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.11 Selection table of waste management options for managing contaminated meat (cow and sheep)

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated meat					
Burial of carcasses (49)	Red	Amber	Amber	Amber	E-M-L
Burning of carcasses (50)	Red	Dark red	Dark red	Dark red	E-M-L
Incineration (53)	Red	Amber	Amber	Amber	E-M-L
Landfill (54)	Red	Amber	Amber	Amber	E-M-L
Rendering (58)	Red	Green	Green	Green	E-M-L

Key

Green	Recommended with few constraints.
Amber	Recommended but requires further analysis to overcome some constraints.
Dark red	Economic or social constraints exist, requiring full analysis and consultation period.
Red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.12 Selection table of management options for eggs to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Restriction on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					L
Options for maintaining production					
Closure of air intake systems at processing plants (1)					P
Addition of AFCF to concentrate ration (24)					E-M-L
Addition of calcium to concentrate ration (25)					E-M-L
Administration of clay minerals to feed (27)					E-M-L
Clean feeding (29)					E-M-L
Selective grazing regime (36)					E-M-L

Key

(green)	Recommended with few constraints.
(amber)	Recommended but requires further analysis to overcome some constraints.
(dark red)	Economic or social constraints exist, requiring full analysis and consultation period.
(red)	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.13 Selection table of waste management options for eggs

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for contaminated domestic produce					
Incineration (53)	[red]	[amber]	[amber]	[amber]	E-M-L
Landfill (54)	[red]	[amber]	[amber]	[amber]	E-M-L

Key

[green]	Recommended with few constraints.
[amber]	Recommended but requires further analysis to overcome some constraints.
[dark red]	Economic or social constraints exist, requiring full analysis and consultation period.
[red]	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.14 Selection table of management options for vegetables, herbs, fruit and berries (domestic)

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for maintaining domestic production and gathering of wild foods					
Prevention of contamination of greenhouse crops (4)	green	amber	red	red	P
Protection of harvested crops from deposition (5)	green	amber	red	red	P
Topsoil removal (23)	red	amber	amber	red	E-M
Dietary advice (40)	red	green	green	green	P-E-M-L
Local provision of monitoring equipment (42)	red	amber	green	green	P-E-M-L
Processing and/or storage prior to consumption (44)	red	amber	green	green	E-M-L

Key

green	Recommended with few constraints.
amber	Recommended but requires further analysis to overcome some constraints.
dark red	Economic or social constraints exist, requiring full analysis and consultation period.
red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.15 Selection table of waste management options for vegetables, herbs, fruit and berries (domestic)

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for contaminated domestic produce					
Composting (51)	red	amber	amber	amber	E-M
Incineration (53)	red	amber	amber	amber	E-M-L
Landfill (54)	red	amber	amber	amber	E-M-L

Key

green	Recommended with few constraints.
amber	Recommended but requires further analysis to overcome some constraints.
dark red	Economic or social constraints exist, requiring full analysis and consultation period.
red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.16 Selection table of management options for nuts, mushrooms, fruit, berries and game (wild food)

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for maintaining domestic production and gathering of wild foods					
Protection of harvested crops from deposition (5)					P
Change of hunting season (28)					E-M-L
Dietary advice (40)					P-E-M-L
Local provision of monitoring equipment (42)					P-E-M-L
Processing and/or storage prior to consumption (44)					E-M-L
Restrictions on gathering wild foods (46)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.17 Selection table of waste management options for nuts, mushrooms fruit, berries and game (wild food)

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for contaminated domestic produce					
Composting (51)					E-M
Incineration (53)					E-M-L
Landfill (54)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 5.18 Selection table of management options for reindeer to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Restrictions on the entry of food into the foodchain (11)					E-M-L
Options for maintaining production					
Addition of AFCF to concentrate ration (24)					E-M-L
Addition of calcium to concentrate ration (25)					E-M-L
Administration of AFCF boli to ruminants (26)					E-M-L
Administration of clay minerals to feed (27)					E-M-L
Clean feeding (29)					E-M-L
Distribution of salt lick containing AFCF (31)					E-M-L
Live monitoring (32)					E-M-L
Manipulation of slaughter times (33)					E-M-L
Salting of meat (35)					E-M-L
Selective grazing (36)					E-M-L
Dietary advice (40)					P-E-M-L
Local provision of monitoring equipment (42)					E-M-L

Key

- Recommended with few constraints.
- Recommended but requires further analysis to overcome some constraints.
- Economic or social constraints exist, requiring full analysis and consultation period.
- Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

5.3 Applicability of management options for situations involving different radionuclides

Most of the information that is available on management options relates to radioactive isotopes of iodine, caesium and strontium due to the importance of their radiological impact in previous accidents. For many of the other radionuclides considered in the Handbook there are few data to indicate whether a particular management option is applicable or not. Nevertheless these radionuclides have certain characteristics in terms of their physical half-life, environmental transfer, mobility in soil, photon energy, chemical properties, and other characteristics that will give a guide as to whether an option should be considered.

This section provides look-up tables that indicate whether a management option is likely to be applicable or otherwise according to radionuclide. For agricultural production systems, including domestic production and free foods, information is presented in Table 5.19 and Table 5.22 for those radionuclides likely to be of significance in the foodchain. Table 5.19 contains information on management options for maintaining production and Table 5.22 focuses on disposal options. Complementary look-up tables are also provided (see Table 5.20 and Table 5.21 for options that maintain production, Table 5.23 and Table 5.24 for disposal options) for radionuclides not likely to have a significant impact on the foodchain. The information presented in all of these tables is based on data from Beresford et al. (2006). The numbers in brackets refer to the datasheet number.

In Table 5.19, Table 5.20 and Table 5.21 an option is considered to be applicable if:

- there is direct evidence that it was effective for a radionuclide (*known applicability*);
- the mechanism of action is such that it would be highly likely to be effective for a radionuclide (*probable applicability*);
- the option can be expected to be effective for a radionuclide on the basis that it is known to be effective for radionuclides with similar chemical, environmental, biological or physical characteristics (probably applicable).

The category of not applicable is attributed to an option if:

- there is direct evidence that it was not effective for the radionuclide;
- the chemical/environmental behaviour of the radionuclide is such that the option may result in increased mobility (e.g. ploughing options may increase the mobility of uranium because of potential redox changes; increases in soil pH as a consequence of liming may increase the mobility of a number of radionuclides);
- there is insufficient evidence on the option-radionuclide combination to make a judgement on effectiveness;
- the physical half-life of the radionuclide is sufficiently short compared to the implementation time of the option to preclude its use (e.g. large-scale, long-term changes of farming practices would be unwarranted to address high levels of ^{131}I, which has a half-life of 8.04 days.

- a radionuclide has very low environmental mobility and/or low biological transfer and the option was extremely radical (i.e. select alternative land use, select edible crop that can be processed, slaughtering of dairy livestock, suppression of lactation before slaughter). The small effect of an option for these radionuclides would not warrant the degree of disruption that may be caused.

The target radionuclides for each management option are given in the datasheets (Section 3). The applicability of a given option to particular radionuclides may change for the different phases of emergency and post accident response; this is also indicated in the datasheets.

In Table 5.22, Table 5.23 and Table 5.24 criteria were used to assess applicability of waste disposal options according to radionuclide. These are listed below.

- Volatilisation temperature of the radionuclide. This affects options which are carried out at higher than ambient temperatures.
- Soil-to-plant uptake of the radionuclide. This relates to options where the waste may come into contact with surface soil.
- Mobility of the radionuclide in soil. This relates to options where the waste may come into contact with soil at depth.
- Half-life of the radionuclide. This relates to options with relatively long implementation times.
- Uptake of the radionuclide by marine foods. This is only relevant to the disposal of milk to sea.
- Doses to the implementers of disposal options from each radionuclide. This affects all options.

These tables show that each disposal option may be unsuitable for some of the radionuclides of interest. However, in the event of an accident or incident a specific assessment should be carried out to confirm applicability.

The target radionuclides for each waste disposal option (i.e. ones for which there appear to be no constraints) are given in the datasheets (Section 3).

Table 5.19 Applicability of management options for radionuclides likely to be of significance in the foodchain

	Radionuclide											
Management options	^{60}Co	^{75}Se	^{89}Sr	^{90}Sr	^{103}Ru	^{106}Ru	^{131}I	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am
Radionuclide half-life	5.27 y	119.8 d	50.5 d	29.12 y	39.28 d	368.2 d	8.04 d	2.062 y	30 y	87.74 y	2.4 10^4 y	432.2 y
Addition of AFCF to concentrate ration (24)	a	a	a	a	a	a	a	✓	✓	a	a	a
Addition of calcium to concentrate ration (25)	b	b	✓	✓	b	b	b	b	b	b	b	b
Administration of AFCF boli to ruminants (26)	a	a	a	a	a	a	a	✓	✓	a	a	a
Administration of clay minerals to feed (27)	a	a	a	a	a	a	a	✓	✓	a	a	a
Application of lime to arable soils and grassland (13)	✓	c	✓	✓	✓	✓	d	c	c	✓	✓	✓
Application of K fertilisers to arable soils and grassland (14)	a	a	a	a	a	a	a	✓	✓	a	a	a
Change of hunting season (28)	✓	✓	✓	✓	✓	✓	✓	✓	✓	e	e	e
Clean feeding (29)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Closure of air intake systems at food processing plants (1)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Closure of irrigation systems (2)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Compensation scheme (39)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Covering of standing crops (3)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Decontamination techniques for milk (30)	e	e	✓	✓	e	e	d	✓	✓	e	e	e
Deep ploughing (15)	✓	✓	✓	✓	d	✓	d	✓	✓	✓	✓	✓
Dietary advice (40)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dilution (7)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Distribution of saltlicks containing AFCF (31)	a	a	a	a	a	a	a	✓	✓	a	a	a
Early removal of crops (16)	✓	✓	✓	✓	✓	✓	d	✓	✓	✓	✓	✓
Feeding of animals with crops/milk in excess of intervention levels (8)	f	f	✓	✓	✓	✓	✓	f	f	✓	✓	✓
Food labelling (41)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Land improvement (17)	✓	c	✓	✓	✓	✓	d	✓	✓	✓	✓	✓
Leaching of horticultural peat (9)	a	a	a	a	a	a	a	✓	✓	a	a	a
Live monitoring (32)	✓	✓	g	g	✓	✓	✓	✓	✓	g	g	g
Local provision of monitoring equipment (42)	✓	✓	g	g	✓	✓	✓	✓	✓	g	g	✓
Manipulation of slaughter times (33)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
No active implementation of management options (do nothing) (43)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Prevention of contamination of greenhouse crops (4)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 5.19 Applicability of management options for radionuclides likely to be of significance in the foodchain

	Radionuclide											
Management options	^{60}Co	^{75}Se	^{89}Sr	^{90}Sr	^{103}Ru	^{106}Ru	^{131}I	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am
Radionuclide half-life	5.27 y	119.8 d	50.5 d	29.12 y	39.28 d	368.2 d	8.04 d	2.062 y	30 y	87.74 y	2.4 10^4 y	432.2 y
Prevention of fire in forests, shrubland and other sensitive areas (10)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Processing and/or storage prior to consumption (44)	h	h	✓	h	h	h	✓	h	h	h	h	h
Processing of crops for subsequent consumption (18)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Processing of milk for subsequent human consumption (34)	✓	✓	✓	✓	✓	✓	✓	✓	✓	e	e	e
Protection of harvested crops from deposition (5)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pruning/defoliation of fruit trees and vines (19)	✓	e	✓	✓	e	e	d	✓	✓	e	e	e
Raising of intervention limits (45)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Restrictions on gathering wild foods (46)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Restriction on the entry of food into the foodchain (food ban) (11)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Salting of meat (35)	i	e	✓	✓	e	e	d	✓	✓	i	i	i
Selection of alternative land use (12)	✓	d	d	✓	d	j	d	✓	✓	j, k	j, k	j, k
Selection of edible crop that can be processed (20)	✓	d	d	✓	d	✓	d	✓	✓	k	k	k
Selective grazing regime (36)	✓	✓	✓	✓	j	j	d	✓	✓	j	j	j
Shallow ploughing (21)	✓	✓	✓	✓	d	✓	d	✓	✓	✓	✓	✓
Short-term sheltering of dairy animals (6)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Skim and burial ploughing (22)	✓	✓	✓	✓	d	✓	d	✓	✓	✓	✓	✓
Slaughtering of dairy livestock (37)	✓	✓	✓	✓	d, j	j	d	✓	✓	j	j	j
Suppression of lactation before slaughter (38)	✓	✓	✓	✓	d, j	j	d	✓	✓	j	j	j
Topsoil removal (23)	✓	✓	✓	✓	d	✓	d	✓	✓	✓	✓	✓

Key:

Half-life: h = hours, d = days, y = years

✓ Selected as target radionuclide (i.e. *known or probable applicability* see Section 5.3)

a Management option specific for Cs

b Management option specific for radionuclides in Group II of Periodic Table

c Management option (lime) increases mobility of some radionuclides in soil (pH effect)

d Comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option

e Insufficient information

Table 5.19 Applicability of management options for radionuclides likely to be of significance in the foodchain

	Radionuclide											
Management options	^{60}Co	^{75}Se	^{89}Sr	^{90}Sr	^{103}Ru	^{106}Ru	^{131}I	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am
Radionuclide half-life	5.27 y	119.8 d	50.5 d	29.12 y	39.28 d	368.2 d	8.04 d	2.062 y	30 y	87.74 y	2.4 10^4 y	432.2 y

f Radionuclide has high feed-to-meat or milk transfer, making management option inappropriate for production animals

g No/low effective photon emissions makes detection difficult

h Management option only effective for short-lived radionuclides

i Does not reduce radionuclide concentration in meat

j Radionuclide has low feed-to-meat or milk transfer, making radical management options inappropriate

k Low soil-to-plant transfer makes radical management option inappropriate

Table 5.20 Applicability of management options for radionuclides not likely to be of significance in the foodchain (^{95}Nb - ^{140}Ba)

	Radionuclide							
Management options	^{95}Nb	^{95}Zr	^{99}Mo/^{99m}Tc	^{110m}Ag	^{125}Sb	^{127}Sb	^{132}Te	^{140}Ba
Radionuclide half-life	35.15 d	63.98 d	66h/6.02h	249.9 d	2.77 y	3.85 d	78.2 h	12.74 d
Addition of AFCF to concentrate ration (24)	a	a	a	a	a	a	a	a
Addition of calcium to concentrate ration (25)	b	b	b	b	b	b	b	✓
Administration of AFCF boli to ruminants (26)	a	a	a	a	a	a	a	a
Administration of clay minerals to feed (27)	a	a	a	a	a	a	a	a
Application of lime to arable soils and grassland (13)	c,d	✓	c,d	c	c	c,d	c,d	d
Application of K fertilisers to arable soils and grassland (14)	a	a	a	a	a	a	a	a
Change of hunting season (28)	✓	✓	✓	✓	✓	✓	✓	✓
Clean feeding (29)	✓	✓	✓	✓	✓	✓	✓	✓
Closure of air intake systems at food processing plants (1)	✓	✓	✓	✓	✓	✓	✓	✓
Closure of irrigation systems (2)	✓	✓	✓	✓	✓	✓	✓	✓
Compensation scheme (39)	✓	✓	✓	✓	✓	✓	✓	✓
Covering of standing crops (3)	✓	✓	✓	✓	✓	✓	✓	✓
Decontamination techniques for milk (30)	e	e	d	e	e	d	d	d
Deep ploughing (15)	d	✓	d	✓	✓	d	d	d
Dietary advice (40)	✓	✓	✓	✓	✓	✓	✓	✓
Dilution (7)	✓	✓	✓	✓	✓	✓	✓	✓
Distribution of saltlicks containing AFCF (31)	a	a	a	a	a	a	a	a
Early removal of crops (16)	✓	✓	d	✓	✓	d	d	d
Feeding of animals with crops/milk in excess of intervention levels (8)	✓	✓	f	f	✓	✓	f	✓
Food labelling (41)	✓	✓	✓	✓	✓	✓	✓	✓
Land improvement (17)	c,d	✓	c,d	c	c	c,d	c,d	d
Leaching of horticultural peat (9)	a	a	a	a	a	a	a	a
Live monitoring (32)	✓	✓	✓	✓	✓	✓	✓	✓
Local provision of monitoring equipment (42)	✓	✓	✓	✓	✓	✓	✓	✓
Manipulation of slaughter times (33)	✓	✓	✓	✓	✓	✓	✓	✓
No active implementation of management options (do nothing) (43)	✓	✓	✓	✓	✓	✓	✓	✓
Prevention of contamination of greenhouse crops (4)	✓	✓	✓	✓	✓	✓	✓	✓

Table 5.20 Applicability of management options for radionuclides not likely to be of significance in the foodchain (^{95}Nb - ^{140}Ba)

	Radionuclide							
Management options	^{95}Nb	^{95}Zr	^{99}Mo/^{99m}Tc	^{110m}Ag	^{125}Sb	^{127}Sb	^{132}Te	^{140}Ba
Radionuclide half-life	35.15 d	63.98 d	66h/6.02h	249.9 d	2.77 y	3.85 d	78.2 h	12.74 d
Prevention of fire in forests, shrubland and other sensitive areas (10)	✓	✓	✓	✓	✓	✓	✓	✓
Processing and/or storage prior to consumption (44)	✓	✓	✓	✓	e	✓	✓	✓
Processing of crops for subsequent consumption (18)	✓	✓	✓	✓	✓	✓	✓	✓
Processing of milk for subsequent human consumption (34)	✓	✓	✓	✓	✓	✓	✓	✓
Pruning/defoliation of fruit trees and vines (19)	f	f	d	f	f	d	d	d
Protection of harvested crops from deposition (5)	✓	✓	✓	✓	✓	✓	✓	✓
Raising of intervention limits (45)	✓	✓	d	✓	✓	d	d	d
Restriction on the entry of food into the foodchain (food ban) (11)	✓	✓	✓	✓	✓	✓	✓	✓
Restrictions on gathering wild foods (46)	✓	✓	✓	✓	✓	✓	✓	✓
Salting of meat (35)	f	f	d	f	h	h	d	h
Selection of alternative land use (12)	d,i	d,i	d	✓	i	d,i	d,i	d,i
Selection of edible crop that can be processed (20)	d	d	d	✓	✓	d	d	d
Selective grazing regime (36)	i	i	d	✓	i	d,i	d,i	d, i
Shallow ploughing (21)	✓	✓	d	✓	✓	d	d	d
Short-term sheltering of dairy animals (6)	✓	✓	✓	✓	✓	✓	✓	✓
Skim and burial ploughing (22)	d	✓	d	✓	✓	d	d	d
Slaughtering of dairy livestock (37)	d, i	d, i	d	✓	i	d, i	d, i	d, i
Suppression of lactation before slaughter (38)	d, i	d, i	d	✓	i	d, i	d, i	d, i
Topsoil removal (23)	d	✓	d	✓	✓	d	d	d

Table 5.20 Applicability of management options for radionuclides not likely to be of significance in the foodchain (^{95}Nb - ^{140}Ba)

	Radionuclide							
Management options	^{95}Nb	^{95}Zr	^{99}Mo/^{99m}Tc	^{110m}Ag	^{125}Sb	^{127}Sb	^{132}Te	^{140}Ba
Radionuclide half-life	35.15 d	63.98 d	66h/6.02h	249.9 d	2.77 y	3.85 d	78.2 h	12.74 d

Key:

Half-life: h = hours, d = days, y = years
✓ Selected as target radionuclide (i.e. *known or probable applicability* see Section 5.3)
a Management option specific for Cs
b Management option specific for radionuclides in Group II of Periodic Table
c Management option (lime) increases mobility of some radionuclides in soil (pH effect)
d Comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option
e Management option only effective for short-lived radionuclides
f Insufficient information
g Radionuclide has high feed-to-meat or milk transfer, making management option inappropriate for production animals
h Does not reduce radionuclide concentration in meat
i Radionuclide has low feed-to-meat or milk transfer, making radical management options inappropriate

Table 5.21 Applicability of management options for radionuclides not likely to be of significance in the foodchain (^{140}La - ^{252}Cf)

	Radionuclide							
Management options	^{140}La	^{141}Ce	^{144}Ce	^{169}Yb	^{192}Ir	^{226}Ra	^{235}U	^{252}Cf
Radionuclide half-life	40.272 h	32.5 d	284.3 d	32.01 d	74.02 d	1600 y	7.038 10^{8} y	2.638 y
Addition of AFCF to concentrate ration (24)	a	a	a	a	a	a	a	a
Addition of calcium to concentrate ration (25)	b	b	b	b	b	✓	b	b
Administration of AFCF boli to ruminants (26)	a	a	a	a	a	a	a	a
Administration of clay minerals to feed (27)	a	a	a	a	a	a	a	a
Application of K fertilisers to arable soils and grassland (14)	a	a	a	a	a	a	a	a
Application of lime to arable soils and grassland (13)	c	✓	✓	✓	✓	✓	✓	✓
Change of hunting season (28)	✓	✓	✓	✓	✓	c	c	c
Clean feeding (29)	✓	✓	✓	✓	✓	✓	✓	✓
Closure of air intake systems at food processing plants (1)	✓	✓	✓	✓	✓	✓	✓	✓
Closure of irrigation systems (2)	✓	✓	✓	✓	✓	✓	✓	✓
Compensation scheme (39)	✓	✓	✓	✓	✓	✓	✓	✓
Covering of standing crops (3)	✓	✓	✓	✓	✓	✓	✓	✓
Decontamination techniques for milk (30)	c	c	c	c	c	c	c	c
Deep ploughing (15)	d	d	✓	d	✓	✓	e	✓
Dietary advice (40)	✓	✓	✓	✓	✓	✓	✓	✓
Dilution (7)	✓	✓	✓	✓	✓	✓	✓	✓
Distribution of saltlicks with AFCF (31)	a	a	a	a	a	a	a	a
Early removal of crops (16)	✓	✓	✓	✓	✓	✓	✓	✓
Feeding of animals with crops/milk in excess of intervention levels (8)	d	✓	✓	✓	f	✓	✓	✓
Food labelling (41)	✓	✓	✓	✓	✓	✓	✓	✓
Land improvement (17)	d	d	✓	d	✓	✓	✓	✓
Leaching of horticultural peat (9)	a	a	a	a	a	a	a	a
Live monitoring (32)	✓	✓	✓	✓	✓	✓	g	g
Local provision of monitoring equipment (42)	✓	✓	✓	✓	✓	✓	g	g
Manipulation of slaughter times (33)	✓	✓	✓	✓	✓	✓	✓	✓
No active implementation of management options (do nothing) (43)	✓	✓	✓	✓	✓	✓	✓	✓
Prevention of contamination of greenhouse crops (4)	✓	✓	✓	✓	✓	✓	✓	✓

Table 5.21 Applicability of management options for radionuclides not likely to be of significance in the foodchain (^{140}La - ^{252}Cf)

	Radionuclide							
Management options	^{140}La	^{141}Ce	^{144}Ce	^{169}Yb	^{192}Ir	^{226}Ra	^{235}U	^{252}Cf
Radionuclide half-life	40.272 h	32.5 d	284.3 d	32.01 d	74.02 d	1600 y	$7.038\ 10^{8}$ y	2.638 y
Prevention of fire in forests, shrubland and other sensitive areas (10)	✓	✓	✓	✓	✓	✓	✓	✓
Processing and/or storage prior to consumption (44)	✓	✓	✓	✓	✓	h	h	h
Processing of crops for subsequent consumption (18)	✓	✓	✓	✓	✓	✓	✓	✓
Processing of milk for subsequent human consumption (34)	✓	✓	✓	✓	✓	c	c	c
Protection of harvested crops from deposition (5)	✓	✓	✓	✓	✓	✓	✓	✓
Pruning/defoliation of fruit trees and vines (19)	c	c	c	c	c	✓	c	c
Raising of intervention levels (45)	d	✓	✓	✓	✓	✓	✓	✓
Restrictions on gathering wild foods (46)	✓	✓	✓	✓	✓	✓	✓	✓
Restriction on the entry of food into the foodchain (food ban) (11)	✓	✓	✓	✓	✓	✓	✓	✓
Salting of meat (35)	d, i	i	i	i	i	i	i	I
Selection of alternative land use (12)	d	d	j	d	d	✓	j, k	j, k
Selective grazing regime (36)	d, j	j	j	✓	✓	j	j	j
Selection of edible crop that can be processed (20)	d	d	✓	d	d	✓	k	k
Shallow ploughing (21)	d	✓	✓	✓	✓	✓	e	✓
Short-term sheltering of dairy animals (6)	✓	✓	✓	✓	✓	✓	✓	✓
Skim and burial ploughing (22)	d	d	✓	d	✓	✓	e	✓
Slaughtering of dairy livestock (37)	d, j	d, j	j	d, j	✓	j	j	j
Suppression of lactation before slaughter (38)	d, j	d, j	j	d, j	✓	j	j	j
Topsoil removal (23)	d	d	✓	d	✓	✓	✓	✓

Key:

Half-life: h = hours, d = days, y = years

✓ Selected as target radionuclide (i.e. *known or probable applicability* see Section 5.3)

a Management option specific for Cs

b Management option specific for radionuclides in Group II of Periodic Table

c Insufficient information

d Comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option

e Management option enhances mobility of radionuclide in soil

Table 5.21 Applicability of management options for radionuclides not likely to be of significance in the foodchain (^{140}La - ^{252}Cf)

	Radionuclide							
Management options	^{140}La	^{141}Ce	^{144}Ce	^{169}Yb	^{192}Ir	^{226}Ra	^{235}U	^{252}Cf
Radionuclide half-life	40.272 h	32.5 d	284.3 d	32.01 d	74.02 d	1600 y	7.038 10^{8} y	2.638 y

f Radionuclide has high feed-to-meat or milk transfer, making management option inappropriate for production animals

g Low/no photon energy of radionuclide makes detection difficult

h Management option only effective for short-lived radionuclides.

i Does not reduce radionuclide content in meat

j Radionuclide has low feed-to-meat or milk transfer, making radical management options inappropriate

k Low soil-to-plant transfer makes radical management option inappropriate

Table 5.22 Applicability of waste disposal options for radionuclides likely to be of significance in the foodchain

Management options	Radionuclide	^{60}Co	^{75}Se	^{89}Sr	^{90}Sr	^{103}Ru	^{106}Ru	^{131}I	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am
	Half-life	5.27 y	119.8 d	50.5 d	29.12 y	39.28 d	368.2 d	8.04 d	2.062 y	30 y	87.74 y	$2.4\ 10^{4}$ y	432.2 y
	Duration[1]												
Biological treatment (digestion) of crops[2] (47)	60 days	✓	a	✓	✓	✓	✓	b	✓	✓	✓	✓	✓
Biological treatment (digestion) of milk[2] (48)	30 days	✓	a	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Burial of carcasses[3] (49)	30 days	c	✓	d	d	✓	✓	d	✓	✓	✓	✓	✓
Burning of carcasses[1] (700 °C) (50)	1 day	✓	a	✓	✓	✓	✓	e	✓	✓	✓	✓	✓
Composting (51)	60 days	✓	✓	✓	✓	✓	✓	b	✓	✓	✓	✓	✓
Disposal of contaminated milk to sea (52)	30 days	f	f	✓	✓	f	f	✓	✓	✓	f	f	f
Incineration[3] (1100 °C)[4] (53)	60 days	✓	e	d	d	✓	✓	b, e	e	e	✓	✓	✓
Landfill[3] (54)	60 days	✓	✓	d	d	✓	✓	b, d	✓	✓	✓	✓	✓
Landspreading of milk and slurry[2] (55)	90 days	✓	a	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ploughing in of a standing crop[2] (56)	13 days	c	a	✓	✓	✓	✓	✓	✓	✓	c	c	c
Processing and storage of milk for disposal (57)	30 days	c	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rendering[3] (150 °C)[5] (58)	30 days	✓	✓	d	d	✓	✓	d	✓	✓	✓	✓	✓

Key:

Half-life: h = hours, d = days, y = years

✓ Selected as target radionuclide (i.e. *known or probable applicability* see Section 5.3)
1. Period of time waste disposal option is carried out for.
2. Nuclides placed or deposited onto surface layers of soil – only plant uptake is considered.
3. Nuclides are considered to be buried under clean soil – only mobility is considered.
4. Maximum temperature at which option is carried out. Operating temperature is typically between 850-1100°C but is usually 900°C.
5. Maximum temperature at which option is carried out, typically between 100-145°C.

a Not recommended due to the high potential plant uptake of the nuclide if it is available in the rooting zone, taken to be represented by a soil:plant concentrations ratio of > 1.
b Not recommended due to the short half-life of the nuclide, taken to be represented by the implementation time being greater than 5 decay half-lives.
c Not recommended as doses resulting from disposal could be similar to those resulting from consumption of the food.
d Not recommended due to the potential rapid movement of the radionuclide in the ground after burial, taken to be represented by a soil mobility (K_d) of between 0 and 30.
e Not recommended as boiling temperature is below temperature of option. Volatilisation may occur.
f Not recommended due to the potential for the radionuclide to concentrate in marine foods, taken to be represented by a concentration ratio in marine foods (fish, crustaceans and molluscs) of 1000 or more

Table 5.23 Applicability of waste disposal options for radionuclides not likely to be of significance in the foodchain (^{95}Nb - ^{140}Ba)

Management option	Radionuclide	^{95}Nb	^{95}Zr	^{99}Mo/^{99m}Tc	^{110m}Ag	^{125}Sb	^{127}Sb	^{132}Te	^{140}Ba
	Half-life	35.15 d	63.98 d	66 h/6.02 h	249.8 d	2.8 y	3.8 d	78.2 h	12.74 d
	Duration[1]								
Biological treatment (digestion) of crops[2] (47)	60 days	✓	✓	a, b	✓	✓	b	b	✓
Biological treatment (digestion) of milk[2] (48)	30 days	c	✓	a, c	✓	✓	b	b, c	✓
Burial of carcasses[3] (49)	30 days	✓	✓	✓	c	✓	b	b	✓
Burning of carcasses[2] (50)	1 day	✓	✓	a	c	✓	b	b	✓
Composting (51)	60 days	✓	✓	✓	✓	✓	b	b	✓
Disposal of contaminated milk to sea (52)	30 days	d	d	c, d	d	✓	b	b, d	✓
Incineration[3] (1100 ^{o}C)[4] (53)	60 days	✓	✓	✓	✓	✓	b	b, e	✓
Landfill[3] (54)	60 days	✓	✓	✓	✓	✓	b	b	✓
Landspreading of milk and slurry[2] (55)	90 days	✓	✓	a	✓	✓	b	b	b
Ploughing in of a standing crop[2] (56)	13 days	✓	✓	a, f	c	✓	✓	✓	✓
Processing and storage of milk for disposal (57)	30 days	✓	✓	c	c	✓	b	b, c	c
Rendering[3] (150 ^{o}C)[5] (58)	30 days	✓	✓	✓	✓	✓	b	b	✓

Key:

Half-life: h = hours, d = days, y = years

✓ Selected as target radionuclide (i.e. *known or probable applicability* see Section 5.3)

6. Period of time waste disposal option is carried out for.
7. Nuclides placed or deposited onto surface layers of soil – only plant uptake is considered.
8. Nuclides are considered to be buried under clean soil – only mobility is considered.
9. Maximum temperature at which option is carried out. Operating temperature is typically between 850-1100°C but is usually 900°C.
10. Maximum temperature at which option is carried out, typically between 100-145°C.

a Not recommended due to the high potential plant uptake of the nuclide if it is available in the rooting zone, taken to be represented by a soil:plant concentrations ratio of > 1.
b Not recommended due to the short half-life of the nuclide, taken to be represented by the implementation time being greater than 5 decay half-lives.
c Not recommended as doses resulting from disposal could be similar to those resulting from consumption of the food.
d Not recommended due to the potential for the radionuclide to concentrate in marine foods, taken to be represented by a concentration ratio in marine foods (fish, crustaceans and molluscs) of 1000 or more
e Not recommended as boiling temperature is below temperature of option. Volitisation may occur.
f Not recommended due to the potential rapid movement of the radionuclide in the ground after burial, taken to be represented by a soil mobility (K_d) of between 0 and 30.

Table 5.24 Applicability of waste disposal options for radionuclides not likely to be of significance in the foodchain (^{140}La - ^{252}Cf)

Management option	Radionuclide	^{140}La	^{141}Ce	^{144}Ce	^{169}Yb	^{192}Ir	^{226}Ra	^{235}U	^{238}Pu	^{252}Cf
	Half-life	40.272 h	32.5 d	284.3 d	32.01 d	74.02 d	1600 y	7.038 10^{8} y	87.74 y	2.7 y
	Duration[1]									
Biological treatment (digestion) of crops[2] (47)	60 days	b	✓	✓	✓	✓	✓	✓	✓	✓
Biological treatment (digestion) of milk[2] (48)	30 days	b, c	✓	✓	✓	✓	c	✓	✓	✓
Burial of carcasses[3] (49)	30 days	b	✓	✓	✓	✓	✓	f	✓	✓
Burning of carcasses[2] (50)	1 day	b	✓	✓	✓	✓	✓	✓	✓	✓
Composting (51)	60 days	b	✓	✓	✓	✓	✓	✓	✓	✓
Disposal of contaminated milk to sea (52)	30 days	b, d	d	d	✓	d	d	✓	d	d
Incineration[3] (1100 ^{0}C)[4] (53)	60 days	b	✓	✓	✓	✓	✓	✓	✓	✓
Landfill[3] (54)	60 days	b	✓	✓	✓	✓	✓	f	✓	✓
Landspreading of milk and slurry[2] (55)	90 days	b	✓	✓	✓	✓	✓	✓	✓	✓
Ploughing in of a standing crop[2] (56)	13 days	b	✓	✓	✓	✓	c	✓	c	c
Processing and storage of milk for disposal (57)	30 days	b, c	✓	✓	✓	✓	✓	✓	✓	✓
Rendering[3] (150 ^{0}C)[5] (58)	30 days	b	✓	✓	✓	✓	✓	f	✓	✓

Key:

Half-life: h = hours, d = days, y = years

✓ Selected as target radionuclide (i.e. *known or probable applicability* see Section 5.3)

1. Period of time waste disposal option is carried out for.
2. Nuclides placed or deposited onto surface layers of soil – only plant uptake is considered.
3. Nuclides are considered to be buried under clean soil – only mobility is considered.
4. Maximum temperature at which option is carried out. Operating temperature is typically between 850-1100°C but is usually 900°C.
5. Maximum temperature at which option is carried out, typically between 100-145°C.

a Not recommended due to the high potential plant uptake of the nuclide if it is available in the rooting zone, taken to be represented by a soil:plant concentrations ratio of > 1.
b Not recommended due to the short half-life of the nuclide, taken to be represented by the implementation time being greater than 5 decay half-lives.
c Not recommended as doses resulting from disposal could be similar to those resulting from consumption of the food.
d Not recommended due to the potential for the radionuclide to concentrate in marine foods, taken to be represented by a concentration ratio in marine foods (fish, crustaceans and molluscs) of 1000 or more
e Not recommended as boiling temperature is below temperature of option. Volitisation may occur.
f Not recommended due to the potential rapid movement of the radionuclide in the ground after burial, taken to be represented by a soil mobility (K_d) of between 0 and 30.

5.4 Checklist of key constraints for each management option

Management options invariably have constraints associated with their implementation. A detailed description of these constraints is provided in the datasheets for each option (Section 3). To assist in eliminating unsuitable options some of the key constraints for each option have been summarised in this section. Table 5.25 and Table 5.26 show the key constraints that should be considered when selecting management options for maintaining production, and disposing of wastes, respectively. These tables can be used in conjunction with the datasheets or beforehand to reduce the subset of options that require more in-depth analysis.

The numbers in brackets in Tables 5.25 and 5.26 refer to the datasheet number.

Table 5.25 Checklist of key constraints to consider when selecting management options for maintaining production

Pre-deposition phase	Key constraints
Closure of air intake systems at food processing plants (1)	Time between notification of release and deposition
Closure of irrigation systems (2)	Time between notification of release and deposition
Covering of standing crops (3)	Time between notification of release and deposition
	High winds
	Availability of covering materials and means to secure it
	Manpower if area large
	Difficulty in covering tall crops
Prevention of contamination of greenhouse crops (4)	Time between notification of release and deposition
Protection of harvested crops from deposition (5)	High winds
	Availability of covering materials and means to secure it
	Manpower if area large
	Difficulty in covering tall crops
Short-term sheltering of dairy animals (6)	Availability of suitable housing with water supply
	Distance between pastures and shelters
	Availability of stored feed
Early to late phase	
General applicability	
Dilution (7)	Acceptability by food industry and consumers
Feeding of animals with crops/milk in excess of intervention levels (8)	Acceptability by farmers, food industry and consumers
	Animal welfare issues concerning new diet
Leaching of horticultural peat (9)	Resistance by commercial growers
Prevention of fire in forests, shrubland and other sensitive areas (10)	Resistance by public due to restriction on leisure activities
Restriction on the entry of food into the foodchain (food ban) (11)	Fate of banned foodstuffs (waste disposal issues)
	Establishing a monitoring and surveillance programme
	Availability of appropriate monitoring equipment
Selection of alternative land use (12)	Restrictions imposed by environmental protection schemes
	Market for alternative products and know-how

Soils/crops/grassland	
Application of lime to arable soils and grassland (13)	Applicable if soil has low pH or low Ca status
	Restrictions imposed by environmental protection schemes
	May increase mobility of some radionuclides
	Carried out with ploughing so not for very wet, dry, frozen or steep areas
Application of K fertilisers to arable soils and grassland (14)	Applicable if soil has low K status
	Restrictions imposed by environmental protection schemes
	Carried out with ploughing so not for very wet, dry, frozen or steep areas
Deep ploughing (15)	Restrictions imposed by environmental protection schemes
	Not applicable if crop is present
	Not applicable if soil is very wet, sandy, frozen, stony, steep
	Availability of specialist equipment
Early removal of crops (16)	Not applicable after first rainfall
	Disposal of waste
Land improvement (17)	Restrictions imposed by environmental protection schemes
	Not applicable if soil is very wet, sandy, frozen, stony
Processing of crops for subsequent consumption (18)	Acceptability by food industry and consumers
	Availability of processing equipment
	Disposal of waste
Pruning/defoliation of fruit trees and vines (19)	Time lag between deposition and implementation, needs to be done a soon as possible
	Not applicable after first rainfall
	Large volumes of waste produced
Selection of edible crop that can be processed (20)	Acceptability by food industry and consumers
	Availability of processing equipment
Shallow ploughing (21)	Restrictions imposed by environmental protection schemes
	Not applicable if crop is present
	Not applicable if soil is very wet, sandy, frozen, stony, steep
Skim and burial ploughing (22)	Restrictions imposed by environmental protection schemes
	Not applicable if crop is present
	Not applicable if soil is very wet, sandy, frozen, stony, steep
	Availability of specialist equipment
Topsoil removal (23)	Restrictions imposed by environmental protection schemes
	Not applicable if crop is present
	Not applicable if soil is very wet, sandy, frozen, stony, steep
	Large volumes of waste produced
Livestock and animal products	
Addition of AFCF to concentrate ration (24)	Availability of AFCF
	Identification of feed manufacturing plants that can add AFCF to feed pellets
	Implications for ‘organic’ status of farms
	Acceptability by food industry, consumers and farmers
Addition of calcium to concentrate ration (25)	Availability of calcium supplements, or pelleted concentrates with enriched levels of calcium

Administration of AFCF boli to ruminants (26)	Availability of AFCF
	Identification of factory that can manufacture AFCF boli
	Implications for 'organic' status of farms
	Acceptability by food industry, consumers and farmers
Administration of clay minerals to feed (27)	Availability of clay minerals
	Identification of feed manufacturing plants that can add clay minerals to feed pellets
	Acceptability by food industry, consumers and farmers
Change of hunting season (28)	Resistance from hunters
	Must not coincide with breeding season
Clean feeding (29)	Availability of suitable housing with water, power supply and ventilation
	Availability of alternative clean feeds and straw for bedding
Decontamination techniques for milk (30)	Acceptability by food industry and consumers
	Disposal of waste
Distribution of saltlicks containing AFCF (31)	Only useful in salt-deficient areas
	Manufacturing plants willing to incorporate AFCF in saltlicks
	Acceptability by food industry, consumers and farmers
Live monitoring (32)	Limited to gamma emitting radionuclides
	Availability of portable lead-shielded NaI detectors, appropriately calibrated
	Availability of trained personnel
Manipulation of slaughter times (33)	If immediate slaughter, availability of abattoir or on-farm slaughtering equipment
	If immediate slaughter, ability to gather free-ranging animals quickly
	If prolonged slaughter, availability of additional feed and implications for animal welfare
Processing of milk for subsequent human consumption (34)	Acceptability by food industry and consumers
	Availability of processing equipment
	Disposal of waste
Salting of meat (35)	Acceptability by food industry and consumers
	Availability of processing equipment
	Disposal of waste
Selective grazing regime (36)	Availability of monitoring data identifying less contaminated pastures
	Availability of land providing less contaminated pasture and its proximity to farm
Slaughtering of dairy livestock (37)	Selection of priority area
	Availability of slaughtering equipment and licensed slaughter men
	Disposal route for livestock carcasses
Suppression of lactation before slaughter (38)	Use of synthetic oestrogens versus natural methods of drying off
	Acceptability to farmers
Societal	
Compensation scheme (39)	Establishing a system of administration and record keeping
Dietary advice (40)	Appropriate lines of communication to reach target population

Food labelling (41)	Availability of appropriate monitoring equipment
	Limited to gamma emitting radionuclides
Local provision of monitoring equipment (42)	Appropriate lines of communication to reach target population
	Availability of suitably calibrated equipment
	Availability of trained personnel to train affected populations and to interpret and explain results
No active implementation of management options (do nothing) (43)	Appropriate lines of communication to reach target population
	Availability of monitoring results to provide reassurance
Processing and/or storage prior to consumption (44)	Appropriate lines of communication to reach target population
Raising of intervention limits (45)	Public perception
Restrictions on gathering wild foods (46)	Appropriate lines of communication to reach target population

Table 5.26 Checklist of key constraints to consider when selecting management options for disposing of waste

Waste disposal	Key constraints
Biological treatment (digestion) of crops (47)	Capacity of biological treatment facility
	Availability of maceration equipment
Biological treatment (digestion) of milk (48)	Capacity of biological treatment facility
Burial of carcasses (49)	Availability and suitability of land for engineering a purpose built burial pit
Burning of carcasses (50)	Availability of suitable sites
	Acceptability to farmers and members of the public
Composting (51)	Suitability of land for composting in situ
	Availability of commercial facilities in the area
Disposal of contaminated milk to sea (52)	Identification of long sea outfalls with capacity to discharge milk
	Authorisation to discharge milk to sea
	Transportation and offloading at discharge points
Incineration (53)	Availability of commercial facilities in the area
Landfill (54)	Capacity of landfill sites for highly biodegradable material
Landspreading of milk and/or slurry (55)	Suitability of land for landspreading (not waterlogged, frozen, in nitrate sensitive area)
	Capacity of slurry tank to store milk at times when land not suitable for spreading
Ploughing in of a standing crop (56)	Restrictions imposed by environmental protection schemes
	Unsuitable if soil depth < 30cm
Processing and storage of milk products for disposal (57)	Availability of processing plant
	Availability of storage facility
Rendering (58)	Availability and capacity of rendering plants

5.5 Applicability of management options with respect to scale of contamination of food products

Predictions can be made about the applicability of management options according to the scale of contamination of food products. This is based on experimental work, particularly in the regions affected by the Chernobyl accident, where the effectiveness of various options has been measured often under field conditions. Information on effectiveness is provided in the datasheets. It is generally expressed as percentage reduction in activity concentration in the target medium (food product) following implementation of a management option.

This section provides a look-up table (Table 5.27) to determine the maximum activity concentration that can be present in a medium (e.g. soil, crop, animal product) above which the implementation of an option will result in the CFIL being exceeded (CEC, 1989). This gives an immediate idea about the applicability of options according to the scale of contamination of food products; for high levels of contamination it may be possible to eliminate some of the least effective options. Where datasheets have recorded ranges in effectiveness, it is generally the lower value that was used in the calculation of maximum activity concentration. Maximum activity concentrations were calculated using the following equation:

$$\text{Maximum activity concentration} = \frac{\text{CFIL}}{(1\text{- Effectiveness})}$$

The maximum activity concentration is expressed to two significant figures and the effectiveness is expressed as a percentage fraction. For some options there are several values, depending on radionuclide and food type. Not all management options considered in the Handbook are included in the look up table as not all are directed at reducing activity concentrations in food products; some for example are for reassurance purposes, while others encompass waste disposal routes.

The numbers in brackets in Table 5.27 refer to the datasheet number.

Table 5.27 - Maximum activity concentration present in a medium that can be reduced to below the CFIL following implementation of relevant management options.

Management option	Target radionuclide[a]	Target medium	Effectiveness[b] (%)	Food product	CFIL class[c]	Max. act. conc. (Bq kg^{-1} or Bq l^{-1})[d]	Comments
Soils/crops/grassland							
Application of lime to arable soils and grassland (13)	^{89}Sr, ^{90}Sr	Soil (mineral)	50	Crops, Meat	Other foods	1500	Only applicable when soil pH 5-7
				Milk	Dairy produce	250	
		Soil (organic)	83	Crops, Meat	Other foods	4500	
				Milk	Dairy produce	750	
Application of potassium fertilisers to arable soils and grassland (14)	^{134}Cs, ^{137}Cs	Soil	50	Crops, Meat	Other foods	2500	Effectiveness (50%) is pessimistic. May be up to 80%
				Milk	Dairy produce	2000	
Closure of air intake systems (1)	All	Foodstuffs for processing	~ 100	All	All	No limits	
Closure of irrigation systems (2)	All	Irrigated standing crops	Unknown	Crops	Other foods	No limits	
Covering of standing crops (3)	All	Standing crops	Up to 100	Crops	Other foods	No limits	
Deep ploughing (15)	^{89}Sr, ^{90}Sr	Soil	50	Crops, Meat	Other foods	1500	Observed data are for Cs and Sr. It would be reasonable to expect similar effectiveness for other radionuclides Maximum activity concentration depends on subsequent use of land
				Milk	Dairy produce	250	
	^{134}Cs, ^{137}Cs	Soil	50	Crops, Meat	Other foods	2500	
				Milk	Dairy produce	2000	
Dilution (7)	All	Grain/milk	Up to 100	Cereal	Other foods	No limits	
					Dairy products		
Land improvement (17)	^{134}Cs, ^{137}Cs	Mineral soils	50	Meat	Other foods	2500	
		Organic soils	67	Meat	Other foods	3750	
Leaching of horticultural peat (9)	^{134}Cs, ^{137}Cs	Horticultural peat	50	Greenhouse crops	Other foods	2500	Repeating the procedure can give total combined reduction of 80%
Processing of crops for subsequent consumption (18)	All	Crops	50	Crops	Other foods	2500	
Protection of harvested crops	All	Harvested crops	Up to 100	Crops	Other foods	No limits	

Table 5.27 - Maximum activity concentration present in a medium that can be reduced to below the CFIL following implementation of relevant management options.

Management option	Target radionuclide[a]	Target medium	Effectiveness[b] (%)	Food product	CFIL class[c]	Max. act. conc. (Bq kg^{-1} or Bq l^{-1})[d]	Comments
from deposition (5)							
Pruning/defoliation of fruit trees and vines (19)	^{134}Cs	Fruit trees, vines	50	Fruit	Other foods	2500	
	^{137}Cs			Wine	Liquid food	2000	
Restriction on the entry of food into the foodchain (food ban) (11)	All	Crops	100	Crops	All	No limits	
Selection of edible crop that can be processed (20)	^{134}Cs, ^{137}Cs	Olives (e.g.)	90	Olive oil	Other foods	12500	Limited data
Shallow ploughing (21)	^{89}Sr, ^{90}Sr	Soil	50	Crops, Meat	Other foods	1500	Observed data are for Cs and Sr. It would be reasonable to expect similar effectiveness for other radionuclides. Maximum activity concentration depends on subsequent use of land.
				Milk	Dairy produce	250	
	^{134}Cs, ^{137}Cs	Soil	50	Crops, Meat	Other foods	2500	
				Milk	Dairy produce	2000	
Skim & burial ploughing (22)	^{89}Sr, ^{90}Sr	Soil	90	Crops, Meat	Other foods	7500	Observed data are for Cs and Sr. It would be reasonable to expect similar effectiveness for other radionuclides Maximum activity concentration depends on subsequent use of land
				Milk	Dairy produce	1250	
	^{134}Cs, ^{137}Cs	Soil	90	Crops, Meat	Other foods	12500	
				Milk	Dairy produce	10000	
Topsoil removal (23)	^{89}Sr, ^{90}Sr	Soil	90	Crops, Meat	Other foods	7500	Observed data are for Cs and Sr. It would be reasonable to expect similar effectiveness for other radionuclides Maximum activity concentration depends on subsequent use of land
				Milk	Dairy produce	1250	
	^{134}Cs, ^{137}Cs	Soil	90	Crops, Meat	Other foods	12500	
				Milk	Dairy produce	10000	
Livestock/Animal products							

Table 5.27 - Maximum activity concentration present in a medium that can be reduced to below the CFIL following implementation of relevant management options.

Management option	Target radionuclide[a]	Target medium	Effectiveness[b] (%)	Food product	CFIL class[c]	Max. act. conc. (Bq kg^{-1} or Bq l^{-1})[d]	Comments
Addition of AFCF to concentrate ration (24)	^{134}Cs, ^{137}Cs	Beef cow	78	Beef	Other foods	5690	
		Dairy cow	80	Milk	Dairy produce	5000	
		Sheep/lamb	87	Sheep meat	Other foods	9380	
		Pigs	90	Pork	Other foods	12500	
Addition of calcium to concentrate ration (25)	^{89}Sr, ^{90}Sr	Dairy cow	50	Milk	Dairy produce	250	
	^{140}Ba, ^{226}Ra					2000	
Administration of AFCF boli to ruminants (26)	^{134}Cs, ^{137}Cs	Reindeer	80	Reindeer meat	Other foods	6250	
		Cows and goats	70	Cows' and goats' milk	Dairy produce	3330	
		Sheep	50	Sheep meat	Other foods	2500	
Administration of clay minerals to feed (27)	^{134}Cs, ^{137}Cs	Beef cow	50	Beef	Other foods	2500	
		Dairy cow		Milk	Dairy produce	2000	
Change of hunting season (28)	^{134}Cs, ^{137}Cs	Reindeer	85	Reindeer meat	Other foods	8330	
		Moose	65	Moose meat		3570	
Clean feeding (29)	All	Grazing livestock	Up to 100	Meat, fish	Other foods	No limits	
				Milk	Dairy produce	No limits	
Decontamination techniques for milk (30)	^{134}Cs, ^{137}Cs	Milk	90	Milk	Dairy produce	10000	
Distribution of saltlicks containing AFCF (31)	^{134}Cs, ^{137}Cs	Grazing livestock	50	Meat	Other foods	2500	
Manipulation of slaughter times (33)	^{134}Cs, ^{137}Cs	Sheep, reindeer	75	Meat	Other foods	5000	
Processing of milk for subsequent human consumption (34)	^{89}Sr, ^{90}Sr,	Milk	85	Butter	Other foods	5000	
	^{134}Cs, ^{137}Cs		50	Butter	Other foods	2500	
Salting of meat (35)	^{89}Sr, ^{90}Sr,	Meat	Around 50	Meat	Other foods	1500	
	^{134}Cs, ^{137}Cs					2500	
Selective grazing regime (36)	All	Grazing livestock	Up to 100	Meat	Other foods	No limits	
				Milk	Dairy produce		

Table 5.27 - Maximum activity concentration present in a medium that can be reduced to below the CFIL following implementation of relevant management options.

Management option	Target radionuclide[a]	Target medium	Effectiveness[b] (%)	Food product	CFIL class[c]	Max. act. conc. (Bq kg^{-1} or Bq l^{-1})[d]	Comments
Short-term sheltering of dairy animals (6)	All	Grazing dairy animals	Up to 100	Milk	Dairy produce	No limits	
Societal							
Processing and/or storage prior to consumption (44)	^{134}Cs, ^{137}Cs	Processed home-grown produce or gathered free foods	50	Meat, fish	Other foods	2500	Marinating meat in brine may be up to 80% effective for meat
Restrictions on gathering wild foods (46)	All (especially Cs)	Wild foods	Up to 100	Meat, fish	Other foods	No limits	

[a] Target radionuclides – the radionuclides for which the countermeasure is targeted.

[b] Effectiveness – amount, in percentage terms, by which the activity concentration in the foodstuff can be reduced by applying the countermeasure.

[c] CFIL class – the Council Food Intervention Level, recommended by the Council of the European Communities, which depends on the type of foodstuff and radionuclide. The values of CFILs may be subject to change.

[d] Maximum activity concentration – the limiting concentration of a radionuclide that can be present if the application of a countermeasure if capable of reducing the activity concentration to below the CFIL. The values of CFILs may be subject to change.

5.6 Management options incurring an incremental dose to implementers

Incremental dose is defined as an additional dose that is incurred as a result of carrying out an operation that is not part of the normal practice.

One important criterion to consider when assessing the practicability of a management option is the incremental dose received by the people implementing it. A number of factors influence the doses people receive as a consequence of implementing management options (see Section 2.3 and Hesketh et al., 2006). It is also important to note that some management options generate secondary/tertiary wastes that require disposal (e.g. 'topsoil removal', see Section 2.4). This may result in operatives at waste management facilities receiving incremental doses. In some cases members of the public might also receive an incremental dose depending on the final disposal site for the treated waste (e.g. application of contaminated sewage sludge to land following anaerobic digestion of waste milk). Table 5.28 gives a list of management options for agricultural, domestic and wild foods, showing whether they result in an incremental dose to implementers either directly or through the subsequent generation and management of secondary/tertiary wastes Table 5.29 gives a list of waste disposal options, showing whether they result in an incremental dose to implementers and members of the public. Doses to members of the public can be from the primary waste material (e.g. milk, crops) or from secondary waste such as leachates or by-products from the treatment process.

The numbers in brackets in Tables 5.28 and 5.29 refer to the datasheet number.

Table 5.28 Incremental doses incurred following implementation of management options

Management option	Incremental dose from management option	Waste produced	Incremental dose from waste management
Addition of AFCF to concentrate ration (24)	x	x	x
Addition of calcium to concentrate ration (25)	x	x	x
Administration of AFCF boil to ruminants (26)	x	x	x
Administration of clay minerals to feed (27)	x	x	x
Application of lime to arable soils and grassland (13)	✓	x	x
Application of K fertilisers to arable soils and grassland (14)	✓	x	x
Change of hunting season (28)	x	x	x
Clean feeding (29)	✓	✓	✓
Closure of air intake systems of food processing plants (1)	x	x	x
Closure of irrigation systems (2)	x	x	x
Compensation scheme (39)	x	x	x
Covering of standing crops (3)	x	x	x
Decontamination techniques for milk (30)	✓	✓	✓
Deep ploughing (15)	✓	x	x
Dietary advice (40)	x	x	x
Dilution (7)	✓	x	x
Distribution of saltlicks containing AFCF (31)	x	x	x
Early removal of crops (16)	✓	✓	✓
Feeding of animals with crops in excess of Intervention levels (8)	✓	x	x
Restriction on the entry of food into the foodchain (food ban) (11)	x	✓	✓
Food labelling (41)	x	x	x
Land improvement (17)	✓	x	x
Leaching of horticultural peat (9)	✓	✓	✓
Live monitoring (32)	✓	x	x
Local provision of monitoring equipment (42)	✓	x	x
Manipulation of slaughter time (33)	✓	x	x
No active implementation of management options (do nothing) (43)	x	x	x
Prevention of contamination of greenhouse crops (4)	x	x	x
Prevention of fire in forests, shrubland and other sensitive areas (10)	✓	✓	✓
Processing and/or storage prior to consumption (44)	✓	✓	✓
Processing of crops for subsequent consumption (18)	✓	✓	✓
Processing of milk for subsequent human consumption (34)	✓	✓	✓
Protection of harvested crops from deposition (5)	x	✓	✓
Pruning/defoliation of fruit trees and vines (19)	✓	✓	✓
Raising of intervention limits (45)	x	✓	✓
Restriction on the entry of food into the food chain (food ban) (11)	x	✓	✓
Restrictions on gathering of wildfoods (46)	x	X	X

Table 5.28 Incremental doses incurred following implementation of management options

Management option	Incremental dose from management option	Waste produced	Incremental dose from waste management
Salting of meat (35)	✓	✓	✓
Selection of alternative land use (12)	✓	X	X
Selection of edible crop that can be processed (20)	✓	✓	✓
Selective grazing regime (36)	✓	X	X
Shallow ploughing (21)	✓	X	X
Short-term sheltering of dairy animals (6)	x	X	X
Skim and burial ploughing (22)	✓	X	X
Slaughtering of dairy livestock (37)	✓	✓	✓
Suppression of lactation before slaughter (38)	x	X	X
Topsoil removal (23)	✓	✓	✓

Key:
✓ Yes
X No

Table 5.29 Incremental doses incurred following implementation of management options for waste disposal

Management option	Incremental dose to implementers	Incremental dose to members of the public – Primary waste	Incremental dose to members of the public – Secondary waste
Biological treatment (digestion) of crops (47)	✓	X	✓
Biological treatment (digestion) of milk (48)	✓	X	✓
Burial of carcasses (49)	✓	X	✓
Burning of carcasses (50)	✓	✓	✓
Composting (51)	✓	✓	✓
Disposal of contaminated milk to sea (52)	✓	✓	x
Incineration (53)	✓	X	x
Landfill (54)	✓	X	✓
Landspreading of milk/slurry (55)	✓	✓	x
Ploughing in of standing crop (56)	✓	✓	x
Processing and storage of milk products for disposal (57)	✓	X	x
Rendering (58)	✓	X	x

Key:
✓ Yes
X No

5.7 Applicability of management options based on stakeholder opinion

The technical feasibility of a management option does not itself determine whether it will be applicable. This is just a starting point. Many other non-technical factors such as legislation, radiological and environmental constraints, economic cost and societal concerns have to be taken into account (Section 2) by the wide range of individuals who could be affected by the implementation of a management option. Processes to engage stakeholders in the framing of these issues and in the identification and evaluation of particular options are essential. The FARMING network of stakeholder groups for example, was set up in 2000 to specifically provide a forum for discussion and debate on the applicability of management options for food production systems at the European level (Nisbet et al., 2005a; Nisbet et al., 2005b;). Feedback from the FARMING network on many of the management options has been included in the relevant datasheets (Section 3). It is important to realise however, that even if a group of stakeholders has reached a consensus on whether an option is acceptable or not, this does not necessarily mean that it is acceptable, nor that it would be acceptable under all circumstances. The process by which such judgements are reached always needs to be open for discussion. Furthermore, stakeholder opinion is not static. Opinion will evolve over time depending on context (location, scale, duration and land use), culture, political climate and public opinion. What is crucial, however, is the establishment of stakeholder panels and networks under non-crisis conditions to discuss the impact of/strategies for managing contamination of the foodchain. In this way, stakeholder opinion can be used to develop plans for use in the event of a radiological incident based on the acceptability of the various options. Following the event however, involvement of more local stakeholders may lead to revisions of the plans as views on applicability of options may differ on a spatial or temporal basis. Practical recommendations for engaging with stakeholders in the management of contaminated areas are given in Appendix D.

5.8 References

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CEC (1989). Council Regulation (Euratom) No 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feeding stuffs following a nuclear accident or any other case of radiological emergency. *Off J Eur Commun* L211/1.

Hesketh N, Harvey M and Cabianca T (2006). *Incremental doses to operatives and members of the public following the implementation of agricultural countermeasures and rural waste disposal management options – principles, illustrative methodology and supporting data*. Chilton, RPD-EA-4, 2006. Available at http://www.strategy-ec.org.uk.

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CONTENTS OF SECTION 6

6 WORKED EXAMPLES

Two worked examples have been developed to help users become familiar with the content of the Food Handbook and its structure. They take users, in a very general way, through the main decision steps and the types of issues that they would need to address in the development of a recovery strategy. It is important to note that **the worked examples provided are only illustrative and have been included solely to support training in the use of the Handbook**. They should therefore not be used as proposed solutions to the contamination scenarios selected.

6.1 Example 1: Windscale scenario

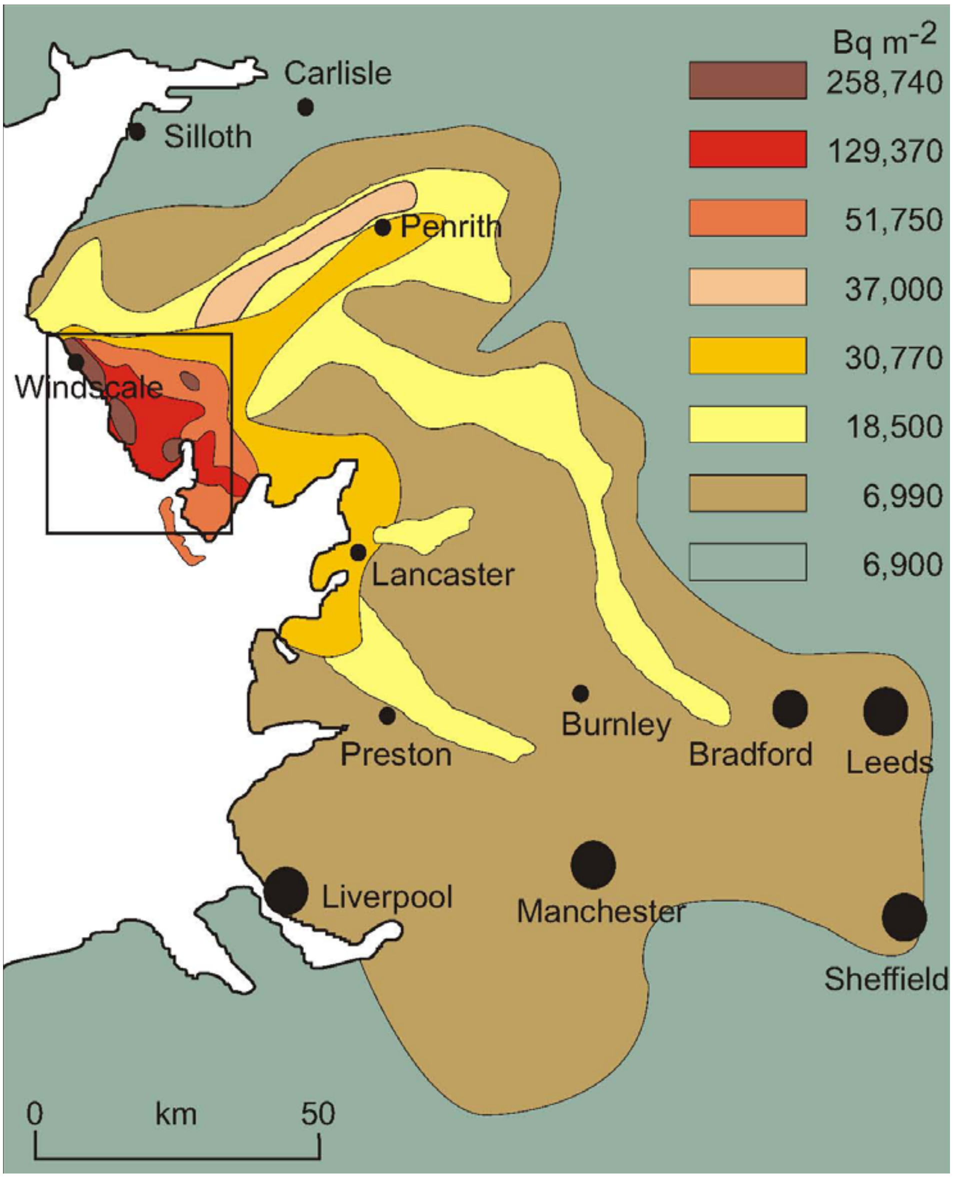
6.1.1 Background

The scenario is based on the accident that took place at the Windscale site on 10 October 1957, for which ^{131}I was the major radionuclide present in ground deposits (Crick and Linsley, 1982). Estimates of the quantity of ^{131}I released ranged from 600 to 740 TBq. Restrictions on milk were based on activity concentrations of ^{131}I of 3700 Bq l^{-1}. These were the limiting levels developed at the time, and are well above the current European Council Food Intervention Level of 500 Bq l^{-1}. Using published deposition data (Loutit et al., 1960; Crick and Linsley, 1982), Wilkins et al. (2001) produced a deposition map for the Windscale ^{131}I scenario (Figure 6.1); some manipulation of the data was necessary to resolve the 6,990 Bq m^{-2} deposition contour corresponding to an activity concentration of 500 Bq l^{-1}. The duration of restrictions on milk within each deposition contour is presented in Table 6.1. The total quantity of contaminated milk produced was estimated using the duration of milk restrictions and agricultural production data for the affected area (also Table 6.1). The total quantity of contaminated milk produced in the Windscale scenario would be about 86 million litres, assuming that no management options were implemented to reduce ^{131}I transfer to milk.

Table 6.1 Example 1: Estimated areas and duration of restrictions on milk within each deposition contour (taken from Wilkins et al., 2001)

Deposition level (Bq m^{-2})	Area (ha)	Duration of restrictions (d)	Milk requiring disposal (l d^{-1})	Total milk requiring disposal (l)
6,990	$6.8\ 10^5$	11	$6.6\ 10^6$	$7.2\ 10^7$
18,500	$2.39\ 10^5$	14	$2.48\ 10^6$	$7.4\ 10^6$
30,770	$8.65\ 10^4$	16	$1.11\ 10^6$	$2.24\ 10^6$
37,000	$4.00\ 10^4$	17	$5.9\ 10^5$	$5.9\ 10^5$
51,750	$3.90\ 10^4$	23	$3.8\ 10^5$	$3.8\ 10^5$
129,370	$2.18\ 10^4$	26	$1.7\ 10^5$	$1.7\ 10^5$
258,740	$1.13\ 10^4$	44	$5.9\ 10^4$	$5.9\ 10^4$
Total	$1.12\ 10^6$	-		$8.6\ 10^7$

Figure 6.1 Example 1: ^{131}I deposition map (taken from Wilkins et al., 2001)



6.1.2 Decision framework for developing a recovery strategy for milk following the Windscale accident

The development of a recovery strategy for milk makes use of the decision framework described in Section 5. Before going through the generic steps involved in selecting and combining options it is important for users to appreciate that when using the Food Handbook to develop a recovery strategy they should establish a dialogue with national and local stakeholders; familiarisation with the structure and content of the Handbook; develop knowledge of technical information underpinning a recovery strategy; and an understanding of the factors influencing implementation of options and selection of a strategy (Section 2).

The development of a recovery strategy for milk using the Windscale accident scenario is described in Table 6.2 below, based on the eight generic steps described in Section 5.1. The numbers in brackets in Tables 6.3 – 6.15 refer to the datasheet number.

Table 6.2 Example 1: Steps involved in selecting and combining options for milk contaminated with ^{131}I

Step	Action
1	**Identify one or more production systems that are likely to be/have been contaminated**
	From the scenario described in Section 6.1, milk is the production system that has been affected. Management options are required for producing clean milk in the contaminated area as well as for disposing of contaminated milk above the CFIL. These options will have to be in place for a period of up to 44 days in the zone closest to the Windscale site.
2	**Refer to selection tables for specific production systems (Table 5.2- Table 5.18). These selection tables provide a list of all of the applicable management options for the production system selected.**
	The relevant selection tables for milk are Table 5.8 which lists the options for producing clean milk/continuing milk production and Table 5.9 for disposing of contaminated milk. For ease of reference they are reproduced in Table 6.3 and Table 6.4. From this information, there are 17 management options for producing clean milk/continuing milk production and 5 options for disposing of contaminated milk. Subsequent steps will endeavour to eliminate options which are not applicable to this scenario.
3	**Refer to look-up tables (Table 5.19 – Table 5.24) showing applicability of management options, including those for waste disposal, for each radionuclide being considered.**
	The information is provided in look-up tables (Table 5.19 - Table 5.24). The relevant data for ^{131}I are summarised in Table 6.5 for options for producing clean milk/continuing milk production options and Table 6.6 for options for disposing of contaminated milk, respectively. These data have been used to eliminate options from the selection tables that are not applicable to ^{131}I. Ten of the management options listed in Table 6.5 could be eliminated on the basis of (i) being specific for either Cs or Group II elements of the periodic table, or (ii) requiring relatively long timescales for implementation and therefore inappropriate for radionuclides with short half lives such as ^{131}I. One option could be eliminated from Table 6.6 on the basis that ^{131}I would volatilise (and potentially be released to the environment) below the operating temperature of the process The original selection tables for milk have been revised to show which options for continuing production (Table 6.7) and disposing of waste milk (Table 6.8) are still to be considered. From the information provided, there are 7 management options for producing clean milk/continuing milk production and 4 options for disposing of contaminated milk. Subsequent steps will endeavour to eliminate further options which are not applicable to this scenario.
4	**Refer to look-up tables (Table 5.25 – Table 5.26) showing checklists of key constraints for each management option, including those for waste disposal.**
	The key constraints for the management options still remaining in the selection tables for milk are summarised in Table 6.9 and Table 6.10 for options for producing clean milk/continuing milk production options and for options for disposing of contaminated milk, respectively. *Options for producing clean milk/maintaining milk production* Options to be implemented before arrival of the plume (i.e. short-term sheltering of dairy animals, closing air intake systems at processing factories) depend on the period of notification given. In the case of the Windscale accident in 1957 there would have been no advanced warning. For most foreseeable future accidents (except Magnox/AGR) some form of early notification of a possible release would be expected, making implementation of precautionary options more likely, especially at increasing distances from the site. Constraints such as availability of suitable housing and supplies of alternative clean feeds for the short-term sheltering and subsequent clean feeding of livestock are unlikely to exist. For instance, dairy livestock in north west England are brought indoors during the winter (mid October until the end of March) suggesting that housing would be available. Furthermore, as the Windscale scenario is based on an October accident, there should be no shortage of stored clean feed, harvested earlier in the year. Restrictions on the entry of milk into the foodchain are based on FEPA food restriction orders imposed by the Food Standards Agency and will be legally binding, irrespective of any constraints. There are three options (dilution, feeding of animals with milk in excess of intervention levels and processing of milk for subsequent human consumption) that have been identified as unacceptable to UK farmers, the food industry and consumers (Nisbet et al., 2005). These options would not be implemented in the UK and are therefore eliminated from this scenario.

Table 6.2 Example 1: Steps involved in selecting and combining options for milk contaminated with ^{131}I

Step	Action
	Options for disposing of waste Table 6.1 provides information on the volumes of milk requiring disposal following the Windscale accident assuming that no management options had been implemented to reduce ^{131}I transfer to milk. It is likely that the volumes of waste milk would be considerably less than this (but not insignificant) following implementation of a clean feeding programme for dairy livestock. Biological treatment facilities have very limited capacity for milk and would not be able to provide a major disposal route in this particular scenario. Furthermore, feedback from United Utilities in north west England has suggested that it would not permit their waste water treatment works to be used for contaminated milk. This option has been eliminated for this scenario. Disposal of contaminated milk to sea via long sea outfalls may be possible though the Sellafield site as well as sewage treatment works along the north west coast of England. For example, United Utilities have 4 long sea outfalls in Cumbria and have stated that they would be prepared to make the pipelines available for the disposal of contaminated milk, subject to authorisation by the Environment Agency. For milk held on the farm, landspreading of milk is another possibility dependent on suitability of land. An option that 'buys time' is the processing of milk into powder and its storage for a period until a suitable disposal route is found. There are several processing factories in north west England. However, the owners of such facilities (e.g. Nestlé) have suggested that they would not accept contaminated milk into their factories due to issues of consumer confidence. These plants would therefore have to be requisitioned at a cost of around £50 million. Processing and storage of milk products for disposal requires the availability of processing plants and storage facilities. The selection tables for milk have been revised again to show which options for continuing production (Table 6.11) and disposing of waste milk (Table 6.12) are still to be considered. From the information provided, there are 4 management options for producing clean milk/continuing milk production and 3 options for disposing of contaminated milk.
5	**Refer to look-up Table 5.27 showing maximum activity concentrations in the target medium for which the option would be effective**
	Information presented in the look up Table 5.27 that is relevant to the remaining management options is summarised in Table 6.13. This clearly shows that all of the options are highly effective and should produce milk or processed milk products with activity concentrations of ^{131}I less than the CFIL. No options can be excluded on the basis of being ineffective.
6	**Refer to look-up Tables 5.28-5.29 which show management options that incur an incremental dose to those involved in their implementation either directly or through the management of any secondary wastes produced.**
	Information on which of the remaining management options incur incremental doses and generate secondary waste is summarised in Table 6.14 and Table 6.15 for options aimed at continuing production and options for disposing of waste milk, respectively. Clearly the placing of restrictions on the entry of milk into the food chain generates waste, the management of which leads to incremental doses to those carrying out disposal. Calculations using the methodology developed by Hesketh et al. (2006) can be carried out to determine the magnitude of the incremental doses on a site specific basis. Clean feeding of housed dairy livestock incurs small incremental doses to the farmer from carrying out a grassland management programme whilst the animals are indoors. This involves cutting and disposing of contaminated grass before animals are returned to pasture. Waste in the form of contaminated slurry is generated by housed animals during their period of clean feeding. The collection and disposal of this waste incurs a further small incremental dose to the farmer.
7	**Refer to individual datasheets (Section 3) for all options remaining in the selection table and note the relevant constraints**.
	This step involves a detailed analysis of all remaining options by careful consideration of the relevant datasheets. It can only be done on a site specific basis and in close consultation with local stakeholders to take into account local circumstances.
8	**Based on Steps 1-7, select and combine options that should be considered as part of the recovery strategy.**
	Options for producing clean milk/maintaining milk production Pre-deposition phase: short-term sheltering of dairy animals; close ventilation systems at milk processing plants, both options assume adequate notification of release is given. The sheltering of dairy animals can be prolonged into the early phase and combined with clean feeding. Early-medium phase: restrict entry of milk into foodchain by placing a FEPA order; provide housing and clean feed until levels of ^{131}I in pasture decrease (around 44 days for Windscale scenario).

Table 6.2 Example 1: Steps involved in selecting and combining options for milk contaminated with ^{131}I

Step	Action
	Note: the implementation of a clean feeding programme in the early phase should reduce the quantities of contaminated milk requiring disposal to manageable levels.
	Options for disposing of waste
	For milk held on the farm within the restricted area: landspreading of milk assuming soil conditions are suitable, making use of storage capacity in slurry tanks
	For milk already collected or when landspreading is inappropriate, consider disposal to sea via a long sea outfall with prior authorisation from Environment Agency. Otherwise, investigate the requisitioning of a processing plant to convert milk into powder for storage and subsequent disposal. Carry out assessment of incremental doses to workers at the plant.

Go to greyscale table

Table 6.3 Example 1: Selection table of management options for milk to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Dilution (7)	Red	Yellow	Yellow	Red	E-M
Feeding animals with milk in excess of intervention levels (8)	Red	Dark red	Dark red	Dark red	E-M
Restriction on the entry of food into the foodchain (11)	Red	Green	Green	Green	E-M-L
Selection of alternative land use (12)	Red	Red	Red	Yellow	L
Options for maintaining production					
Close air intake systems at processing plants (1)	Green	Yellow	Red	Red	P
Short-term sheltering of dairy animals (6)	Green	Green	Red	Red	P
Addition of AFCF to concentrate ration (24)	Red	Red	Green	Green	E-M-L
Addition of calcium to concentrate ration (25)	Red	Red	Green	Green	E-M-L
Administration of AFCF boli to ruminants (26)	Red	Red	Yellow	Yellow	M-L
Administration of clay minerals to feed (27)	Red	Red	Yellow	Yellow	E-M-L
Clean feeding (29)	Red	Green	Green	Yellow	E-M-L
Decontamination techniques for milk (30)	Red	Red	Dark red	Dark red	M-L
Distribution of saltlicks containing AFCF (31)	Red	Red	Yellow	Yellow	M-L
Processing of milk for subsequent human consumption (34)	Red	Red	Red	Red	E-M
Selective grazing regime (36)	Red	Red	Green	Green	E-M-L
Slaughtering of dairy livestock (37)	Red	Dark red	Dark red	Dark red	M-L
Suppression of lactation before slaughter (38)	Red	Dark red	Dark red	Dark red	M-L

Key

Green	Recommended with few constraints.
Yellow	Recommended but requires further analysis to overcome some constraints.
Dark red	Economic or social constraints exist, requiring full analysis and consultation period.
Red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 6.4 Example 1: STEP 2 Selection table of waste management options for contaminated milk

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated milk					
Biological treatment (digestion) of milk (48)					E-M-L
Disposal of contaminated milk to sea (52)					E-M-L
Incineration (53)					E-M-L
Landspreading of milk and/or slurry (55)					E-M-L
Processing and storage of milk products for disposal (57)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Table 6.5 Example 1: STEP 3 Applicability of management options for ^{131}I, based on physical, chemical or environmental factors

Management options*	
Addition of AFCF to concentrate ration (24)	a
Addition of calcium to concentrate ration (25)	b
Administration of AFCF boli to ruminants (26)	a
Administration of clay minerals to feed (27)	a
Clean feeding (29)	✓
Closure of air intake systems at food processing plants (1)	✓
Decontamination techniques for milk (30)	c
Dilution (7)	✓
Distribution of saltlicks containing AFCF (31)	a
Feeding of animals with crops/milk in excess of intervention levels (8)	✓
Processing of milk for subsequent human consumption (34)	✓
Restriction on the entry of food into the foodchain (food ban) (11)	✓
Selection of alternative land use (12)	c
Selective grazing regime (36)	c
Short-term sheltering of dairy animals (6)	✓
Slaughtering of dairy livestock (37)	c
Suppression of lactation before slaughter (38)	c

Key:

* Only options listed in selection table for milk are shown

✓ Selected as target radionuclide (i.e. *known or probable applicability* , see Section 5.3)

a Management option specific for Cs

b Management option specific for radionuclides in Group II of Periodic Table

c Comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option

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Table 6.6 Example 1: STEP 3 Applicability of waste disposal options for ^{131}I, based on physical, chemical or environmental factors

Waste disposal options*	Duration	
Biological treatment (digestion) of milk (48)	30 day	✓
Disposal of contaminated milk to sea (52)	30 day	✓
Incineration[1] (1100 ^{0}c)[2] (53)	60 days	a
Landspreading of milk and slurry (55)	90 day	✓
Processing and storage of milk products for disposal (57)	30 day	✓

Key

* Only options listed in selection table for milk are shown.

✓ Selected as target radionuclide (i.e. k*nown or probable applicability*, see Section 5.3)

1. Nuclides placed or deposited onto surface layers of soil – only plant uptake is considered.
2. Maximum temperature at which option is carried out. Operating temperature is typically between 850-1100°C but is usually 900°C.
3. Period of time waste disposal option is carried out for.

a Not recommended as boiling temperature is below temperature of option. Volatilisation may occur.

Go to greyscale table

Table 6.7 Example 1: STEP 3 Selection table showing remaining management options for cow milk to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for maintaining production					
Closure of air intake systems at processing plants (1)	[green]	[yellow]	[red]	[red]	P
Short-term sheltering of dairy animals (6)	[green]	[green]	[red]	[red]	P
Clean feeding (29)	[red]	[green]	[green]	[yellow]	E-M-L
Processing of milk for subsequent human consumption (34)	[red]	[red]	[red]	[red]	E-M
Options of general applicability or societal relevance					
Dilution (7)	[dark red]	[dark red]	[dark red]	[dark red]	E-M
Feeding animals with milk in excess of intervention levels (8)	[red]	[dark red]	[dark red]	[dark red]	E-M
Restriction on the entry of food into the foodchain (11)	[red]	[green]	[green]	[green]	E-M-L
Food labelling (41)	[red]	[red]	[yellow]	[yellow]	M-L

Key

[green]	Recommended: few constraints.
[yellow]	Recommended: requires further analysis to overcome some constraints.
[dark red]	Economic or social constraints exist, requiring full analysis and consultation period.
[red]	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 6.8 Example 1: STEP 3 Selection table of remaining waste management options for contaminated cow milk

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated milk					
Biological treatment (digestion) of milk (48)					E-M-L
Disposal of contaminated milk to sea (52)					E-M-L
Landspreading of milk and/or slurry (55)					E-M-L
Processing and storage of milk products for disposal (57)					E-M-L

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Table 6.9 Example 1: STEP 4 Checklist of key constraints to consider for remaining management options for maintaining production

Remaining management options	Key constraints
Closure of air intake systems at food processing plants (1)	Time between notification of release and deposition
Short-term sheltering of dairy animals (6)	Availability of suitable housing with water supply
	Distance between pastures and shelters
	Availability of stored feed
Restriction on the entry of food into the foodchain (food ban) (11)	Fate of banned foodstuffs (waste disposal issues)
	Establishing a monitoring and surveillance programme
	Availability of appropriate monitoring equipment
Dilution (7)	Acceptability by food industry and consumers
Feeding of animals with milk in excess of intervention levels (8)	Acceptability by farmers, food industry and consumers
	Animal welfare issues concerning new diet
Clean feeding (29)	Availability of suitable housing with water, power supply and ventilation
	Availability of alternative clean feeds and straw for bedding
Processing of milk for subsequent human consumption (34)	Acceptability by food industry and consumers
	Availability of processing equipment
	Disposal of waste

Table 6.10 Example 1: STEP 4 Checklist of key constraints to consider when selecting management options for disposing of waste

Waste disposal	Key constraints
Biological treatment (digestion) of milk (48)	Capacity of biological treatment facility
Disposal of contaminated milk to sea (52)	Identification of long sea outfalls with capacity to discharge milk
	Authorisation to discharge milk to sea
	Transportation and offloading at discharge points
Landspreading of milk and/or slurry (55)	Suitability of land for landspreading (not waterlogged, frozen, in nitrate sensitive area)
	Capacity of slurry tank to store milk at times when land not suitable for spreading
Processing and storage of milk products for disposal (57)	Availability of processing plant
	Availability of storage facility

Go to greyscale table

Table 6.11 Example 1: STEP 4 Selection table showing remaining management options for cow milk to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for maintaining production					
Closure of air intake systems at processing plants (1)					P
Short-term sheltering of dairy animals (6)					P
Clean feeding (29)					E-M-L
Options of general applicability or societal relevance					
Restriction on the entry of food into the foodchain (11)					E-M-L

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 6.12 Example 1: STEP 4 Selection table of remaining waste management options for contaminated cow milk

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated milk					
Disposal of contaminated milk to sea (52)					E-M-L
Landspreading of milk and/or slurry (55)					E-M-L
Processing and storage of milk products for disposal (57)					E-M-L

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Table 6.13 Example 1: STEP 5 Effectiveness of management options for reducing activity concentrations of ^{131}I in milk below CFIL

Management option	Target medium	Effectiveness[a] (%)	Max. act. conc. (Bq l^{-1})[b]
Clean feeding (29)	Grazing livestock	Up to 100	No limits
Closure of air intake systems at food processing plants (1)	Foodstuffs for processing	~ 100	No limits
Restriction on the entry of food into the foodchain (food ban) (11)	Crops, grazing dairy animals	100	No limits
Short-term sheltering of dairy animals (6)	Grazing dairy animals	Up to 100	No limits

a Amount, in percentage terms, by which the activity concentration in the foodstuff can be reduced by applying the management opion.

b Maximum activity concentration – the limiting concentration of a radionuclide that can be present if the application of a management option is capable of reducing the activity concentration to below the CFIL. The values of CFILs may be subject to change.

Table 6.14 Example 1: STEP 6 Incremental doses incurred following implementation of remaining management options for milk production

Management option	Incremental dose from management option	Waste produced	Incremental dose from waste management
Clean feeding (29)	✓	✓	✓
Closure of air intake systems at food processing plants (1)	x	x	x
Restriction on the entry of food into the foodchain (food ban) (11)	x	✓	✓
Short-term sheltering of dairy animals (6)	x	x	x

Key:

✓ Yes

X No

Table 6.15 Example 1: STEP 6 Incremental doses incurred following implementation of remaining waste disposal options for milk

Management option	Incremental dose to implementers	Incremental dose to members of the public – Primary waste	Incremental dose to members of the public – Secondary waste
Biological treatment of milk (48)	✓	x	✓
Disposal of contaminated milk to sea (52)	✓	✓	x
Landspreading of milk/slurry (55)	✓	✓	x
Processing and storage of milk products for disposal (57)	✓	x	x

Key:

✓ Yes

X No

6.2 Example 2: Simulated scenario in Belgium with mixed source term

6.2.1 Description of the simulated scenario

The scenario described in this section is a simulated severe Pressurised Water Reactor accident caused by a break in the primary circuit with 100% cracking of fuel claddings. The accident takes place on 1 July in Belgium and is assumed to last for 24 h. The total amount of activity released is 6.72 10^{16} Bq noble gases, 4.37 10^{14} Bq radioiodine (^{131}I, ^{132}I, ^{133}I, ^{135}I) and 1.13 10^{13} Bq of radiocaesium (^{134}Cs, ^{136}Cs and ^{137}Cs). Historical weather forecast data were used to carry out a simulation of this scenario with the RIMPUFF atmospheric dispersion model (Thykier-Nielsen et al, 2004). For the purpose of this worked example, the focus is on radiocaesium and radioiodine. In practice, other radionuclides could play an important role in the short term after a release especially for a food product such as leafy vegetables which are affected primarily by direct deposition. Figure 6.2 and Figure 6.3 show the estimated ground deposition of all radiocaesium isotopes and of ^{131}I, respectively.

Figure 6.2 Example 2: Ground deposition of all radiocaesium isotopes for the simulated scenario

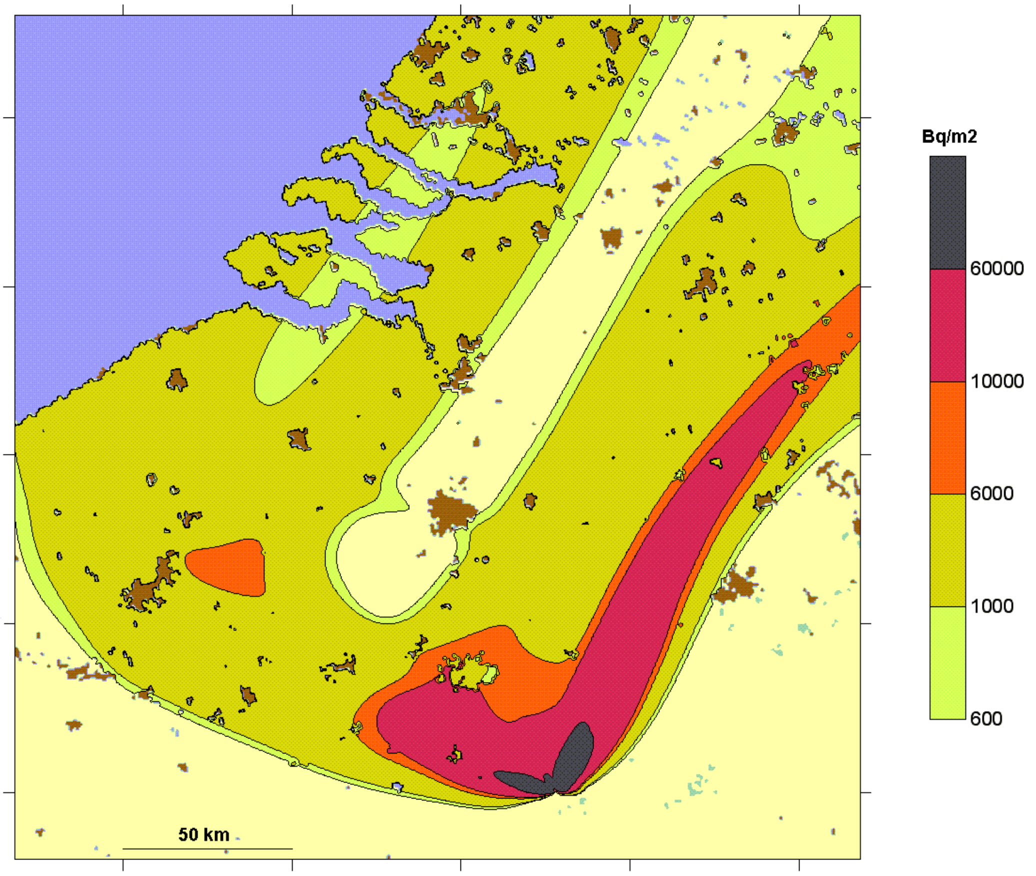
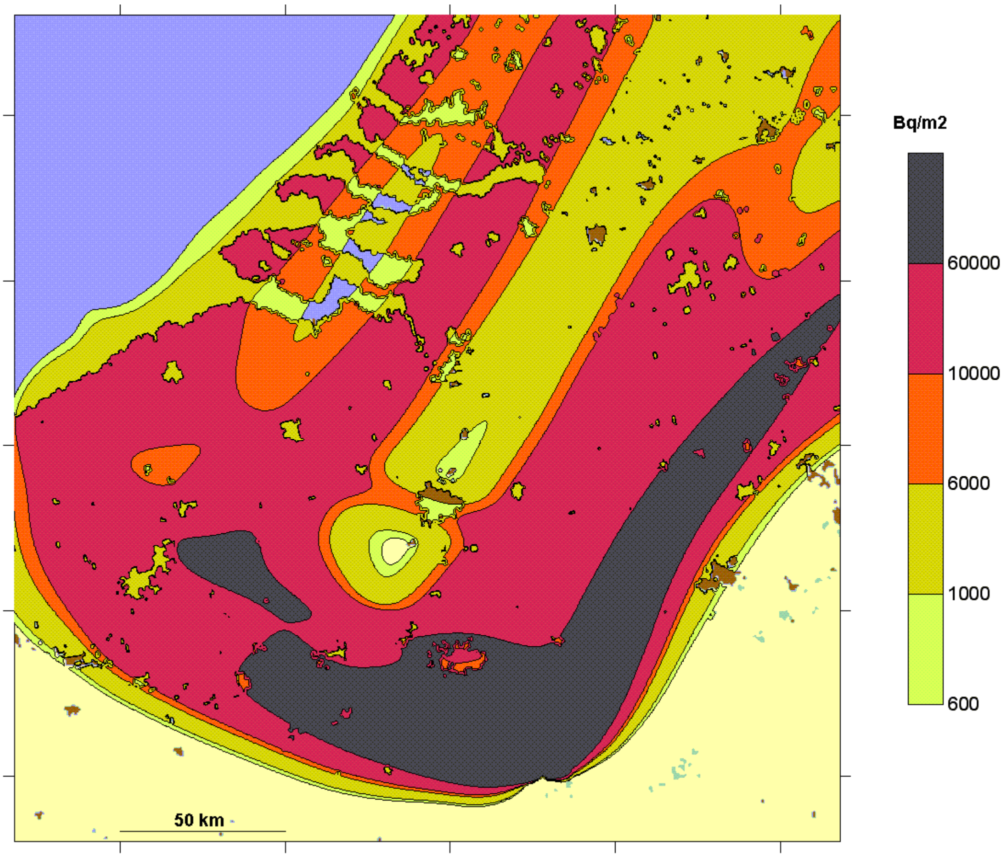


Figure 6.3 Example 2: Ground deposition of ^{131}I for the simulated scenario



As described in Appendix B, the transfer and accumulation of radionuclides in agricultural food products following a release to atmosphere and subsequent ground deposition, depends on factors such as environmental parameters, farming practices, type of crop and its stage of development. This example considers the commercial production of leafy vegetables and makes use of Belgian guidelines (cf. Garsou, 1992) for relating ground deposition of radiocaesium and radiodine to predicted activity concentrations in the crop. There are two areas where restrictions on leafy green vegetables will be enforced because CFILs are likely to be exceeded:

- firstly (zone 1), where ground deposition for ^{131}I exceeds 10000 Bq m^{-2} and for radiocaesium isotopes exceeds 6000 Bq m^{-2}
- secondly (zone 2), where only CFIL's for radioiodine are likely to be exceeded.

Assuming a mean yield of 2 kg m^{-2} for leafy vegetables, this could result in large quantities of leafy vegetables unfit for human consumption.

6.2.2 Decision framework for developing a recovery strategy for leafy vegetables for the simulated scenario

The development of a recovery strategy for leafy vegetables is presented in Table 6.16 based on the eight generic steps described in Section 5.1. The numbers in brackets in Tables 6.16-6.29 refer to the datasheet number of the respective management option.

Stakeholder opinion from the FARMING network and other stakeholder processes in Belgium are used in the discussion.

Table 6.16 Example 2: Steps involved in selecting and combining options for leafy vegetables contaminated with radiocaesium and/or radioiodine

Step	Action
1	**Identify one or more production systems that are likely to be/have been contaminated**
	The food production system that has been contaminated is leafy vegetables. This type of crop is one of the most sensitive as it nears maturity due to the surface deposition of radionuclides posing an immediate radiological risk to the population from ingestion of contaminated food. Due to the high levels of deposited radioactive material, management options are required in the contaminated areas for producing clean vegetables, continuing production and disposing of products exceeding the CFILs.
2	**Refer to selection tables for specific production systems (Table 5.2- Table 5.18). These selection tables provide a list of all of the applicable management options for the production system selected.**
	The relevant selection tables for the commercial production of leafy vegetables are given in Table 5.4 which lists the options for continuing production and Table 5.5 for disposing of contaminated leafy vegetables produced commercially. For ease of reference they are reproduced in Table 6.17 and Table 6.18. From this information, there are 17 management options for continuing production and 5 options for disposing of contaminated leafy vegetables. Subsequent steps will help to eliminate options that are not applicable to this scenario.
3	**Refer to look-up tables (Table 5.19 – Table 5.24) showing applicability of management options, including those for waste disposal, for each radionuclide being considered.**
	The information is provided in look-up tables (Table 5.19 - Table 5.24). The data for the nuclides relevant for this scenario are summarised in Table 6.19 for options for continuing the commercial production of leafy vegetables and in Table 6.20 for options for disposing of contaminated leafy vegetables, respectively. Based on these data some options may be eliminated. It should be noted that in the first few weeks after the deposition, both radioiodine and radiocaesium have to be considered, although ^{131}I is the dominant radionuclide. A few months later however, the main radionuclides of importance for the food chain are the longer lived isotopes of radiocaesium (^{137}Cs and ^{134}Cs). Therefore when screening the possible management options, a distinction has to be made between zone 1 (where both radioiodine and radiocaesium exceed the CFILs) and zones 2 (where only ^{131}I exceeds the CFILs). From the management options listed in Table 6.19, a number of options may be eliminated as follows: • zone 1 - two options (13, 8) are not applicable for radiocaesium isotopes; • zone 2 - eight options (13, 15-16, 12, 20-23) that require relatively long timescales of implementation, are inappropriate for radionuclides with short half lives such as ^{131}I. From Table 6.20, the following waste management options may be eliminated: • zone 1- one option (54) is not applicable due to potential rapid movement of the radionuclides in the ground after burial, another option (53) is not recommended for any of the radionuclides of interest in this scenario due to potential volatilisation • zone 2 - two options (47, 51) are not recommended for radionuclides with short half lives The original selection tables for leafy vegetables (commercial production) have been revised to show which options for continuing production () and disposing of waste (Table 6.22) are still to be considered. An additional column has been added to these tables showing whether the options can be applied in each zone. Subsequent steps will help to eliminate further options that are not applicable to this scenario.
4	**Refer to look-up tables (Table 5.25 – Table 5.26) showing checklists of key constraints for each management option, including those for waste disposal.**
	The key constraints for the remaining management options for commercially produced leafy vegetables are summarised in Table 6.23 and Table 6.24 for options aiming at continuing production and for options dealing with disposing of contaminated production, respectively. *Options for continuing production* Options to be implemented in the pre-deposition phase (1-5) depend on the time period available between notification and start of the release. One remark made by the FARMING stakeholder panel in Belgium (http://www.eu-neris.net/, Farming website Archive/BE stakeholders) was that for such management options the authorities would need to provide early notification so that there would be sufficient time for implementation. The communication to the farmers in such a wide area was considered a major problem. Covering standing crops from deposition was seen as a potentially risky

Table 6.16 Example 2: Steps involved in selecting and combining options for leafy vegetables contaminated with radiocaesium and/or radioiodine

Step	Action
	option, taking into consideration the possibility that people may still be outside during the passage of the plume. This option should be limited for example to valuable products close to a place that could be used for sheltering. It can only be recommended when the time between the release notification and the arrival of the plume is long enough to assure a safe retreat for the workers. The latter constraint is also relevant for the prevention of contamination of greenhouse crops: any people remaining inside the greenhouse during passage of the plume would not necessarily be adequately protected against external irradiation. For this scenario it is assumed that the time between notification of farmers and the start of release is not sufficient, and these pre-deposition options have therefore been eliminated. Early removal of crops is in general not seen as an effective management option in Belgium where the use of technical equipment is optimised and unlikely to be available in advance. Moreover it is considered that early removal of crops would lead to an unacceptable increase exposure of the farmers and field workers. If crops are not present in the field, ploughing and soil removal could be considered. This depends on subsequent land use and soil condition. Such techniques cannot be applied if the soil is very wet, sandy or frozen. Moreover, contamination levels would need to be low enough following implementation for public trust to be restored. For deep ploughing it should be noted that sandy soils, commonly found in Belgium, are friable and may crumble during ploughing, resulting in incomplete inversion of the surface layer. This option would not be acceptable in regions with thin top-soils as soil fertility and structure would be negatively affected. In addition to the constraints on soil condition, top soil removal is only applicable on a small scale (e.g. for the most contaminated area) due to the amount of waste produced. More advanced management options such as application of fertilisers and specific crop selection are not applicable in the Belgian context, because there is already a high level of soil fertility and a high degree of optimisation of the land use. Feeding animals with crops/milk > CFIL could lead to contamination of another otherwise uncontaminated sector of agricultural production. This is likely to be unacceptable to farmers and consumers. This option would also cause marketing problems. Furthermore, the amount of material that might be recycled in such a way would be marginal compared to the total amount needing disposal. For these reasons, this management option is not supported by the Belgian stakeholders. Processing of contaminated vegetables for subsequent consumption is unlikely to be acceptable, due to the sensitivity of the Belgian consumer, confronted with numerous food crises in recent years. *Options for disposing of waste* Biological digestion of crops would depend on the availability of an adequate facility and the quantities of waste that could be processed via this route. Capacity would be extremely limited in Belgium and because of this the option has been eliminated. Composting in situ might prove difficult to implement due to several constraints, including suitability of land. The selection tables for leafy vegetables have been revised again in the light of the numerous constraints highlighted above. Table 6.21 and Table 6.22 present the options to be considered further for continuing production and disposing of waste, respectively.
5	**Refer to look-up Table 5.27 showing maximum activity concentrations in the target medium for which the option would be effective**
	Information presented in the look up Table 5.27 that is relevant to the remaining management options is summarised in Table 6.27. Some of the options (e.g. shallow ploughing) are not highly effective and have limitations of applicability with respect to the maximum activity concentration in the target medium (here: soil). These might however be applied on areas with less contamination or in combination with other options. No further options can be excluded on the basis of effectiveness.
6	**Refer to look-up Table 5.28 – 5.29 which show management options that incur an incremental dose to those involved in their implementation either directly or through the management of any secondary wastes produced.**
	Information on those remaining options incurring incremental doses and generating secondary waste is summarised in Table 6.28 and Table 6.29. Except for the pre-release measures, the other options would all lead to generation of waste. The collection and disposal of this waste would incur an incremental dose to the farmer or the operator carrying out disposal. Incremental doses for implementers and members of the population can be estimated using the methodology developed by Hesketh et al. (2006) using parameters relevant to the site specific scenario.

Table 6.16 Example 2: Steps involved in selecting and combining options for leafy vegetables contaminated with radiocaesium and/or radioiodine

Step	Action
7	**Refer to individual datasheets (Section 3) for all options remaining in the selection table and note the relevant constraints**.
	This step involves a detailed analysis of all remaining options by careful consideration of the relevant datasheets. It can only be done on a site specific basis and in close consultation with local stakeholders to take into account local circumstances.
8	**Based on Steps 1-7, select and combine options that should be considered as part of the recovery strategy.**
	Options for continuing (commercial) production of leafy vegetables Pre-deposition phase: if there is sufficient time following notification, consider: closure of air intake systems of food processing plants; closure of irrigation systems. Early-medium phase: restrict the entry of leafy vegetables in excess of CFILs into the foodchain. If crops are in the field, consider management options for waste leafy vegetables. If no crops are present in the field at the time of deposition and if soil conditions permit, consider as early as possible, shallow ploughing or skim and burial ploughing in zone 1 (with important deposits of radiocaesium in addition to radioiodine) in order to reduce radionuclide uptake by crops, as well as to reduce external doses from contaminated land; topsoil removal could be an option for hotspots provided the area involved is not too large. For all of these options the constraints on the maximum activity concentration in the target medium (e.g. the effectiveness of shallow ploughing is of only 50%), as well as the doses to implementers should be carefully assessed. *Options for disposing of waste* For the in-situ management of contaminated produce in zone 1, consider ploughing in of the standing crop. Composting could be implemented in areas where it is impractical to plough contaminated crops into the soil (e.g. on shallow soils). For zone 2, crops could be left in situ until the iodine has decayed.

Go to greyscale table

Table 6.17 Example 2: STEP 2 Selection table of management options for leafy vegetables (commercial) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Feeding of animals with crops in excess of intervention levels (8)					E-M
Restrictions on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					M-L
Options for producing vegetables and vegetable products < CFIL					
Closure of air intake systems at food processing plants (1)					P
Closure of irrigation systems (2)					P
Covering of standing crops (3)					P
Prevention of contamination of greenhouse crops (4)					P
Protection of harvested crops from deposition (5)					P
Application of lime to arable soils and grassland (13)					E-M-L
Application of K fertilisers to arable soils and grassland (14)					E-M-L
Deep ploughing (15)					E-M-L
Early removal of crops (16)					P-E
Processing of crops for subsequent consumption (18)					E-M
Selection of edible crop that can be processed (20)					M-L
Shallow ploughing (21)					E-M-L
Skim and burial ploughing (22)					E-M-L
Topsoil removal (23)					E-M

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 6.18 Example 2: STEP 2 Selection table of waste management options for contaminated leafy vegetables produced commercially

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated vegetables					
Biological treatment (digestion) of crops (47)	[red]	[dark red]	[dark red]	[dark red]	E-M-L
Composting (51)	[red]	[yellow]	[yellow]	[yellow]	E-M-L
Incineration (53)	[red]	[yellow]	[yellow]	[yellow]	E-M-L
Landfill (54)	[red]	[yellow]	[yellow]	[yellow]	E-M-L
Ploughing in of a standing crop (56)	[red]	[green]	[green]	[green]	E-M

Key

[green]	Recommended: few constraints.
[yellow]	Recommended: requires further analysis to overcome some constraints.
[dark red]	Economic or social constraints exist, requiring full analysis and consultation period.
[red]	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Table 6.19 Example 2: STEP 3 Applicability of management options for radionuclides relevant for the simulated scenario, based on physical, chemical or environmental factors

Management options	Radionuclide		
	^{131}I	^{134}Cs	^{137}Cs
Radionuclide half-life	8.04 d	2.062 y	30 y
Application of lime to arable soils and grassland (13)	a	b	b
Application of K fertilisers to arable soils and grassland (14)	c	✓	✓
Closure of air intake systems at food processing plants (1)	✓	✓	✓
Closure of irrigation systems (2)	✓	✓	✓
Covering of standing crops (3)	✓	✓	✓
Deep ploughing (15)	a	✓	✓
Early removal of crops (16)	a	✓	✓
Feeding of animals with crops/milk in excess of intervention levels (8)	✓	d	d
Prevention of contamination of greenhouse crops (4)	✓	✓	✓
Processing of crops for subsequent consumption (18)	✓	✓	✓
Protection of harvested crops from deposition (5)	✓	✓	✓
Restriction on the entry of food into the foodchain (food ban) (11)	✓	✓	✓
Selection of alternative land use (12)	a	✓	✓
Selection of edible crop that can be processed (20)	a	✓	✓
Shallow ploughing (21)	a	✓	✓
Skim and burial ploughing (22)	a	✓	✓
Topsoil removal (23)	a	✓	✓

Key:

Half-life: h = hours, d = days, y = years

✓ Selected as target radionuclide (i.e. *known or probable applicability* see Section 5.3)

a Comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option

b Management option (lime) increases mobility of some radionuclides in soil (pH effect)

c Management option specific for Cs

d Radionuclide has high feed-to-meat or milk transfer, making management option inappropriate for production animals

Table 6.20 Example 2: STEP 3 Applicability of waste disposal options for radionuclides relevant for the simulated scenario, based on physical, chemical or environmental factors

Management options	Radionuclide	^{131}I	^{134}Cs	^{137}Cs
	Half-life	8.04 d	2.062 y	30 y
	Duration[1]			
Biological treatment (digestion) of crops[2] (47)	60 days	a	✓	✓
Composting (51)	60 days	a	✓	✓
Incineration[3] (1100 ^{0}C)[4] (53)	60 days	b	b	b
Landfill[3] (54)	60 days	a, c	✓	✓
Ploughing in of a standing crop[2] (56)	13 days	✓	✓	✓

Key:

Half-life: h = hours, d = days, y = years

✓ Selected as target radionuclide (i.e. *known or probable applicability* see Section 5.3)
1. Period of time waste disposal option is carried out for.
2. Nuclides placed or deposited onto surface layers of soil – only plant uptake is considered.
3. Nuclides are considered to be buried under clean soil – only mobility is considered.
4. Maximum temperature at which option is carried out. Operating temperature is typically between 850-1100°C but is usually 900°C.

a Not recommended due to the short half-life of the nuclide, taken to be represented by the implementation time being greater than 5 decay half-lives.

b Not recommended as boiling temperature is below temperature of option. Volatilisation may occur.

c Not recommended due to the potential rapid movement of the radionuclide in the ground after burial, taken to be represented by a soil mobility (K_d) of between 0 and 30.

Go to greyscale table

Table 6.21 Example 2: STEP 3 Selection table for remaining management options for leafy vegetables (commercial) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide	Zone type
Options of general applicability or societal relevance						
Feeding of animals with crops/milk > intervention levels (8)	Red	Dark red	Dark red	Dark red	E-M	2
Restrictions on the entry of food into the foodchain (11)	Red	Green	Green	Yellow	E-M-L	1, 2
Selection of alternative land use (12)	Red	Red	Red	Yellow	M-L	1
Options for producing vegetables and vegetable products < CFIL						
Closure of air intake systems at food processing plants (1)	Green	Yellow	Red	Red	P	1, 2
Closure of irrigation systems (2)	Green	Yellow	Red	Red	P	1, 2
Covering of standing crops (3)	Yellow	Yellow	Red	Red	P	1, 2
Prevention of contamination of greenhouse crops (4)	Green	Yellow	Red	Red	P	1, 2
Protection of harvested crops from deposition (5)	Green	Yellow	Red	Red	P	1, 2
Application of K fertilisers to arable soils and grassland (14)	Red	Red	Green	Green	E-M-L	1
Deep ploughing (15)	Red	Red	Red	Red	E-M-L	1
Early removal of crops (16)	Red	Yellow	Red	Red	P-E	1
Processing of crops for subsequent consumption (18)	Red	Dark red	Dark red	Dark red	E-M	1, 2
Selection of edible crop that can be processed (20)	Red	Red	Dark red	Dark red	M-L	1
Shallow ploughing (21)	Red	Green	Green	Green	E-M-L	1
Skim and burial ploughing (22)	Red	Red	Yellow	Yellow	E-M-L	1
Topsoil removal (23)	Red	Yellow	Yellow	Red	E-M	1

Key

Green	Recommended: few constraints.
Yellow	Recommended: requires further analysis to overcome some constraints.
Dark red	Economic or social constraints exist, requiring full analysis and consultation period.
Red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 6.22 Example 2: STEP 3 Selection table of remaining waste management options for contaminated leafy vegetables produced commercially

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide	Zone type
Options for managing contaminated vegetables						
Biological treatment (digestion) of crops (47)					E-M-L	1
Composting (51)					E-M-L	1
Ploughing in of a standing crop (56)					E-M	1, 2

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Table 6.23 Example 2: STEP 4 Checklist of key constraints to consider for remaining options for maintaining commercial production of leafy vegetables

Pre-deposition phase	Key constraints
Closure of air intake systems at food processing plants (1)	Time between notification of release and deposition
Closure of irrigation systems (2)	Time between notification of release and deposition
Covering of standing crops (3)	Time between notification of release and deposition
	High winds
	Availability of covering materials and means to secure it
	Manpower if area large
	Difficulty in covering tall crops
Prevention of contamination of greenhouse crops (4)	Time between notification of release and deposition
Protection of harvested crops from deposition (5)	High winds
	Availability of covering materials and means to secure it
	Manpower if area large
	Difficulty in covering tall crops
Early to late phase	
General applicability	
Feeding of animals with crops in excess of intervention levels (8)	Acceptability by farmers, food industry and consumers
	Animal welfare issues concerning new diet
Restriction on the entry of food into the foodchain (food ban) (11)	Fate of banned foodstuffs (waste disposal issues)
	Establishing a monitoring and surveillance programme
	Availability of appropriate monitoring equipment
Selection of alternative land use (12)	Restrictions imposed by agri-environment schemes
	Market for alternative products and know-how
Soils/crops/grassland	
Application of K fertilisers to arable soils and grassland (14)	Applicable if soil has low K status
	Restrictions imposed by environmental protection schemes
	Carried out with ploughing so not for very wet, dry, frozen or steep areas
Deep ploughing (15)	Restrictions imposed by environmental protection schemes
	Not applicable if crop is present
	Not applicable if soil is very wet, sandy, frozen, stony, steep
	Availability of specialist equipment
Early removal of crops (16)	Not applicable after first rainfall
	Disposal of waste
Processing of crops for subsequent consumption (18)	Acceptability by food industry and consumers
	Availability of processing equipment
	Disposal of waste
Selection of edible crop that can be processed (20)	Acceptability by food industry and consumers
	Availability of processing equipment
Shallow ploughing (21)	Restrictions imposed by environmental protection schemes
	Not applicable if crop is present
	Not applicable if soil is very wet, sandy, frozen, stony, steep
Skim and burial ploughing (22)	Restrictions imposed by environmental protection schemes
	Not applicable if crop is present
	Not applicable if soil is very wet, sandy, frozen, stony, steep

Table 6.23 Example 2: STEP 4 Checklist of key constraints to consider for remaining options for maintaining commercial production of leafy vegetables

	Availability of specialist equipment
Topsoil removal (23)	Restrictions imposed by environmental protection schemes
	Not applicable if crop is present
	Not applicable if soil is very wet, sandy, frozen, stony, steep

Table 6.24 Example 2: STEP 4 Checklist of key constraints to consider for remaining management options for disposing of waste leafy vegetables

Waste disposal	Key constraints
Biological treatment (digestion) of crops (47)	Capacity of biological treatment facility
	Availability of maceration equipment
Composting (51)	Suitability of land for composting in situ
	Availability of commercial facilities in the area
Ploughing in of a standing crop (56)	Restrictions imposed by agri-environment schemes
	Unsuitable if soil depth < 30cm

Go to greyscale table

Table 6.25 Example 2: STEP 4 Selection table for remaining management options for leafy vegetables (commercial) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide	Zone type
Options of general applicability or societal relevance						
Restrictions on the entry of food into the foodchain (11)					E-M-L	1, 2
Options for producing vegetables and vegetable products < CFIL						
Closure of air intake systems at food processing plants (1)					P	1, 2
Closure of irrigation systems (2)					P	1, 2
Shallow ploughing (21)					E-M-L	1
Skim and burial ploughing (22)					E-M-L	1
Topsoil removal (23)					E-M	1

Key

(green)	Recommended: few constraints.
(yellow)	Recommended: requires further analysis to overcome some constraints.
(dark red)	Economic or social constraints exist, requiring full analysis and consultation period.
(red)	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to greyscale table

Table 6.26 Example 2: STEP 4 Selection table of remining waste management options for contaminated leafy vegetables produced commercially

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide	Zone type
Options for managing contaminated vegetables						
Composting (51)	red	yellow	yellow	yellow	E-M-L	1
Ploughing in of a standing crop (56)	red	green	green	green	E-M	1, 2

Key

green	Recommended: few constraints.
yellow	Recommended: requires further analysis to overcome some constraints.
dark red	Economic or social constraints exist, requiring full analysis and consultation period.
red	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Table 6.27 Example 2: STEP 5 Maximum activity concentration present in a medium that can be reduced to below CFIL following implementation of relevant[a] management options.

Management option	Target radionuclide[a]	Target medium	Effectiveness[b] (%)	Max. act. conc. (Bq kg^{-1} or Bq l^{-1})[c]
Closure of air intake systems (1)	All	Foodstuffs for processing	~ 100	No limits
Closure of irrigation systems (2)	All	Irrigated standing crops	Unknown	No limits
Restriction on the entry of food into the foodchain (food ban) (11)	All	Crops	100	No limits
Shallow ploughing (21)	^{134}Cs, ^{137}Cs	Soil	50	2500
Skim & burial ploughing (22)	^{134}Cs, ^{137}Cs	Soil	90	12500
Topsoil removal (23)	^{134}Cs, ^{137}Cs	Soil	90	12500

[a] Target radionuclides – the radionuclides for which the management option is targeted.

[b] Effectiveness – amount, in percentage terms, by which the activity concentration in the foodstuff can be reduced by applying the management option.

[c] Maximum activity concentration – the limiting concentration of a radionuclide that can be present if the application of a management option if capable of reducing the activity concentration to below the CFIL. The values of CFILs may be subject to change.

Table 6.28 Example 2: STEP 6 Incremental doses incurred following implementation of management options

Management option	Incremental dose from management option	Waste produced	Incremental dose from waste management
Closure of air intake systems of food processing plants (1)	x	x	x
Closure of irrigation systems (2)	x	x	x
Restriction on the entry of food into the foodchain (food ban) (11)	x	✓	✓
Shallow ploughing (21)	✓	x	x
Skim and burial ploughing (22)	✓	x	x
Topsoil removal (23)	✓	✓	✓

Key:
✓ Yes
X No

Table 6.29 Example 2: STEP 6 Incremental doses incurred following implementation of management options for waste disposal

Management option	Incremental dose to implementers	Incremental dose to members of the public – Primary waste	Incremental dose to members of the public – Secondary waste
Composting (51)	✓	✓	✓
Ploughing in of standing crop (56)	✓	✓	x

Key:
✓ Yes
X No

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7 GLOSSARY

Term	Definition
Action level	The level of dose rate, activity concentration or any other measurable quantity above which intervention should be undertaken during chronic or emergency exposure.
Activity	The rate at which nuclear decays occur in a given amount of radioactive material. Unit: Becquerel, Bq (1 Bq = 1 decay s^{-1})
Activity concentration	The activity per unit mass of a radioactive material. Unit: Bq kg^{-1}.
Advection	The horizontal movement of water in soils.
AFCF bolus	A large pill (typically 15 mm × 50 mm) containing AFCF (ammonium ferric hexacyanoferrate, also known as Prussian blue) that is administered to animals in the case of a release of radiation. It is used to reduce uptake of radiocaesium into meat and milk: caesium binds to the AFCF and is then excreted by the animal.
AFCWG	Agriculture and Food Countermeasures Working Group. This Group was formed in 1997 following a recommendation from the National Radiological Protection Board (NRPB) to the Ministry of Agriculture, Fisheries and Food (MAFF). The aim was to bring together representatives from government and non government organisations to debate and judge the practicability of management options.
Avertable dose	The dose that could be averted if an intervention is carried out.
Averted dose	The dose saved by carrying out an intervention.
Becquerel, Bq	The SI derived unit for activity. Defined as one nuclear decay per second. Unit: s^{-1}. Symbol: Bq.
Bioavailability	The degree to which or rate at which a substance can be absorbed by living organisms.
Biodegradability	Capability of being decomposed by biological agents, especially bacteria.
Biochemical (biological) oxygen demand	The amount of oxygen required by aerobic microorganisms to decompose the organic matter in a sample of water.
Contamination/radioactive contamination	The deposition of radioactive material on ground or vegetation surfaces in food production systems.
Countermeasure	See *management option*.
Critical group	Characterises an individual receiving a dose that is representative of the more highly exposed individuals in the population.
Datasheet	A compilation of data and information about a management option designed to support decision-makers in the evaluation of a management option and the impact of its implementation.
Domestic food production	Food that is produced by individuals in private or kitchen gardens or allotments.
Deterministic health effect	A radiation-induced health effect characterised by a severity which increases with dose above a threshold, and above which threshold such effects are always observed. Examples of deterministic effects are nausea and radiation burns.
Dose constraint	A restriction on the exposure of people to sources of radiation. Applies to the mean dose in the critical group.
Dose limit	A restriction on the exposure of people to practices.
Dose rate	The dose of ionising radiation received per unit time. For example, Sv hr^{-1}.
Emergency countermeasures	Actions taken during the emergency phase with the aim of protecting people from short-term relatively high radiation exposures, e.g. evacuation, sheltering, taking stable iodine tablets.

Emergency phase (early phase)	The time period during which urgent actions are required to protect people from short-term relatively high radiation exposures in the event of a radiological emergency or incident.
Factor, retention	The ratio of the concentration of a *radionuclide* remaining in a foodstuff after processing to the concentration in the raw food.
Factor, transfer (also: transfer coefficient, concentration ratio, bioaccumulation factor)	The ratio of the concentration of a radionuclide in the organism of interest to the concentration in the source medium. In plants, transfer factors relate to the concentration in soil to the concentration in the plant; for animals, the concentration in animal feed to the concentration in animal products; and for fish, the concentration in water to the concentration in fish muscle tissue.
Flux	The rate of flow of fluid, particles, or energy through a given surface.
Fly-ash	Fine particles of ash of a solid fuel carried out of the flue of a furnace with the waste gases produced during combustion.
Free food	Food collected from the wild.
Half-life, biological	The time required for half the quantity of a radioactive substance deposited in a living organism to be metabolised or eliminated by normal biological processes. Symbol: $t_{1/2,b}$.
Half-life, physical	The time taken for a mass containing a particular radionuclide to decay to half its initial activity through radioactive decay. Symbol: $t_{1/2}$.
Improvised terrorist (explosive) device	A device intended to disperse radioactive material using conventional explosives. Also known as a dirty bomb.
Incremental dose	The additional dose received by an individual as a result of implementing a management option that specifically does not take into account exposure to activity already present in the environment as a result of deposition of radionuclides on the ground.
Ingestion dose	Effective dose received through ingestion of radioactivity into the body.
Intervention	A procedure that is undertaken to reduce exposure or the likelihood of exposure due to a de facto situation whose existence is not a matter of choice (a nuclear accident, for example) or is not part of a controlled practice.
Intervention level	The level of avertable dose at which specific protective action is taken in a situation of long-term exposure or an emergency.
Isotope	Any *nuclide* which shares the same number of *protons* but has a different number of *neutrons* (and therefore *mass number*). For example, deuterium (symbol: ^{2}H or D, containing one proton and one neutron) and tritium (symbol: ^{3}H or T, one proton and two neutrons) are isotopes of the *element* hydrogen (symbol: H, *atomic number*: 1). Distinct from *nuclide*.
Long-lived radionuclides	Defined for the Handbook as radionuclides with a radioactive half-life greater than three weeks.
Management option	An action, which is part of an intervention, intended to reduce or avert the contamination or likelihood of contamination of food production systems. Previously known as a 'countermeasure'.
Molecule	The smallest division of a substance that can exist independently while retaining the properties of that substance.
Noble gas	A series of *elements* so called because they do not readily form compounds with other *atoms*. The noble gases are helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Ra). All have radioactive *isotopes*, and are colourless gases at room temperature.
Operative	An individual that implements a *management option* (for example, a farmer or a worker at a food or waste processing facility).
pH	A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The pH scale commonly in use ranges from 0 to 14.
Phase, early	A period with a time scale of hours to days after deposition of radioactive material.

Phase, late	A period with a time scale of several months to more than a year after deposition of radioactive material.
Phase, medium	A period with a time scale of weeks to months after deposition of radioactive material.
Phase, pre-deposition	A time period (hours to days), starting when a substantial risk of contamination is identified and ending when either deposition occurs or the source is brought back under control.
Photon	A quantum or packet of electromagnetic radiation (e.g. gamma rays or visible light) which may be considered a particle.
Practice	A human activity which introduces a source of *radiation* that is used deliberately and is subject to control. It is adopted as a matter of planned choice in order to gain some individual or societal benefit.
Radioactive decay	The process by which *radionuclides* undergo spontaneous nuclear change, thereby emitting *ionising radiation*.
Radioactivity	The spontaneous emission of ionising radiation from a radionuclide as a result of atomic or nuclear changes. Measured in Becquerel's, Bq.
Radiological emergency or incident	Any event, accidental or otherwise, which involves a release of radioactivity into the environment.
Radionuclide	A type of atomic nucleus which is unstable and which may undergo spontaneous decay to another atom by emission of ionising radiation, usually alpha, beta or gamma radiation.
Recovery phase	The time period during which activities focus on the restoration of normal lifestyles for all affected populations. There are no exact boundaries between the emergency phase and the recovery phase. However, within the Handbook the recovery phase should be seen as starting after the incident has been contained.
Recovery strategy	A strategy which aims for a return to normal living. It covers all aspects of the long-term management of the contaminated area and the implementation of specific management options. The development of the strategy should involve all stakeholders.
Redox	A reversible chemical reaction in which one reaction is an oxidation and the reverse is a reduction.
Respiratory protection	Equipment designed to prevent or reduce the inhalation of radioactive material by individuals.
Resuspension	A renewed suspension of deposited contaminated particles in the air. The subsequent inhalation of radioactivity is recognised as a potentially significant exposure pathway. Many factors influence resuspension, including climate, wind speed, human activities, time since deposition, etc.
Semi-natural ecosystem	An area of high biodiversity which has not been intensively managed for agricultural production.
Short-lived radionuclides	Defined for the Handbook as radionuclides with a radioactive half-life of less than three weeks.
Sievert, Sv	The SI unit of *effective dose.* Symbol: Sv (1 Sv = 1 Jkg^{-1}). The international SI unit of *effective dose*, obtained by weighting the *equivalent dose* in each tissue in the body with ICRP-recommended tissue weighting factors, and summing over all tissues. Because the sievert is a large unit, effective dose is commonly expressed in millisieverts (mSv), i.e. one thousandth of one sievert, and microsieverts (µSv), i.e. one thousandth of a millisievert.
Sorption/desorption	The taking up and holding of one substance by another/ removal of one substance from another.
Stakeholder	A person or group of persons with a direct or perceived interest, involvement, or investment in something
Surfaces	Examples of surfaces considered in this Handbook include: soil, and vegetation. Management options usually target a specific surface. A surface can have a depth,

	(e.g. soil) and this can influence the effectiveness of management options in removing contamination from the surface.
Topography	Relief, vegetative and human-made features of the land.
Wild food	Food collected for free from hedgerows, woodlands, forests etc. Typically game, berries and other fruit, mushrooms and herbs.
Worker	In the handbook, a worker is defined as an individual who is formally involved with the practical implementation of a recovery strategy. Exposures to workers must be controlled.

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APPENDIX A

History of development of the handbook

The generic European handbook for food production systems has been developed as a result of a series of European and, in particular, UK initiatives which started in the early 1990's (Figure A1) based on:

- an information-development process derived mainly from the experiences from the accident at the Chernobyl nuclear power plant in 1986;
- a stakeholder involvement process that started in the UK and, through European Commission funding, subsequently expanded in other member states to involve other national groups to tackle accident preparedness and recovery;
- an iterative process involving exchange of state-of-the-art information between stakeholder groups to co-develop the generic handbook.

A1 PREVIOUS EUROPEAN EXPERIENCE ON ACCIDENT MANAGEMENT

Following the Chernobyl accident a number of initiatives were set up to document and evaluate options for accident management. These included the IAEA Handbook 363 (IAEA, 1994) and a Nordic programme supported by the Nordic Reactor Safety Group (NKS) that summarised technical information on the costs, efficiency and limitations of variety of management options (Andersson et al., 2000; Andersson et al., 2002). The NKS programme made use of a datasheet approach which was subsequently taken forward in an EU/IUR (International Union of Radioecologists) project which addressed not only technical issues, but also social aspects of countermeasures (Voigt et al., 2000). Finally, the STRATEGY project started as a European initiative to assess critically the applicability of management options using a wide range of criteria (http://www.strategy-ec.org.uk/). The information was collated in a standardised datasheet format (see Section 3) and addressed issues such as direct and indirect costs, dose distribution, practicability, feasibility, environmental side-effects, and social and ethical aspects (Howard et al., 2004).

A2 UK AND EUROPEAN STAKEHOLDER EXPERIENCE AND OUTPUTS

Many of the above initiatives involved consultation with stakeholders on the applicability of management options. In the UK, consultations with individual experts from a diversity of organisations about the management of food production systems in the UK following a nuclear accident highlighted a divergence of opinion about the suitability of many of the options (Nisbet and Mondon, 2001). This prompted the National Radiological Protection Board (NRPB) in the UK (now the Health Protection Agency Radiation Protection Division, HPA-RPD) to recommend that, for the purposes of contingency planning, a stakeholder working group be set up to bring together key groups that would be involved in the management of rural areas following a nuclear accident. This idea was taken forward by Government and in 1997 the Agriculture and Food Countermeasures Working Group (AFCWG) was established. The AFCWG has 21 representatives of which 11 are from non-governmental organisations. Since its inception, the AFCWG has provided an invaluable resource for debating and judging the practicability of individual management options and recovery strategies (Alexander et al., 2005). In 2005 a Recovery Handbook for Radiation Incidents was published, the food production section of which was produced in close collaboration with the stakeholders (HPA-RPD, 2005). Version 2 of the Handbook was produced in 2008 (HPA-RPD, 2008) and provided a major update to the guidance on the management of food production systems. In addition to supporting scientific information, it includes checklists for planning in advance of an incident, datasheets, advice on how to select and combine management options and a worked example. A full update of the Handbook, Version 3, available in hard copy, CD and PDF formats was produced in 2009 (HPA-RPD, 2009).

Based on the success of the AFCWG in the UK, it was possible in 2000 to extend the approach to Europe by setting up the FARMING network (http://www.eu-neris.net/). This network of more than 100 stakeholders comprises panels in the UK, Finland, Belgium, France and Greece (Nisbet et al., 2005a). State-of-the-art information on management options for the medium- to long-term phases after an accident was made available to the FARMING network in a standardised datasheet format (see Section 3.1) through a complementary European initiative, the STRATEGY project (Howard et al., 2005) (http://www.strategy-ec.org.uk/). The national stakeholder panels met regularly to discuss the issues surrounding long term contamination of the foodchain by radioactivity. They notably studied the datasheets and in many cases were able to reach a consensus about whether an option was acceptable, only acceptable under specific circumstances or not acceptable at all (Nisbet et al., 2005b). The elimination of unsuitable options has been of benefit in the preparation of emergency plans and contingency arrangements at the national level.

A2.1 The European EURANOS initiative

A European initiative, the EURANOS project (http://www.euranos.fzk.de), was set up to increase the coherence of emergency preparedness and management in Europe. One of many important tasks undertaken was the development of a generic handbook for assisting in the management of contaminated food production systems in Europe, taking into account the requirements of stakeholders.

National panels belonging to the FARMING network were reconvened during 2005 to provide feedback on whether a handbook similar to the one published for use in the UK could be developed in a more generic way for application at the European level. Stakeholder opinion was unanimously in favour of the development of such a document. The stakeholders were also enthusiastic about using the handbook as a tool to facilitate dialogue and debate between all those affected by foodchain contamination and its management. Furthermore, the stakeholders provided a wealth of constructive criticism and comment on the structure, format and content of the generic handbook. The project to produce this handbook was co-ordinated at the European level with national coordinators taking lead responsibility for drafting particular sections. Stakeholder opinion was incorporated prior to release of Version 1 of the handbook in December 2006 (Nisbet et al., 2006). Since then the handbook has undergone demonstration in emergency centres not involved in the development process. Feedback from the demonstrations enabled further improvements to be made prior to release of Version 2 of the handbook.

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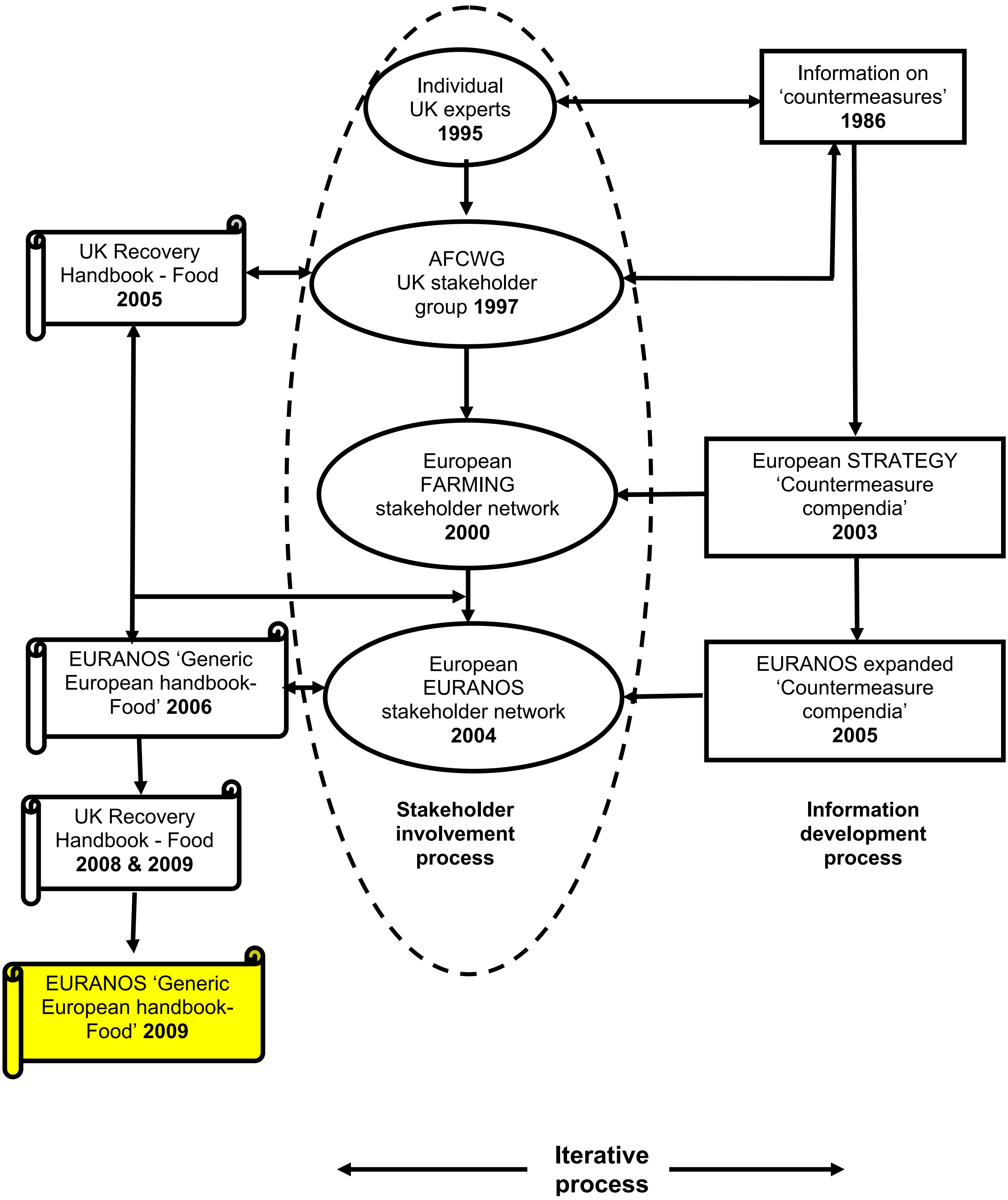
Figure A1 - History of development of the generic European handbook, 1995-2009



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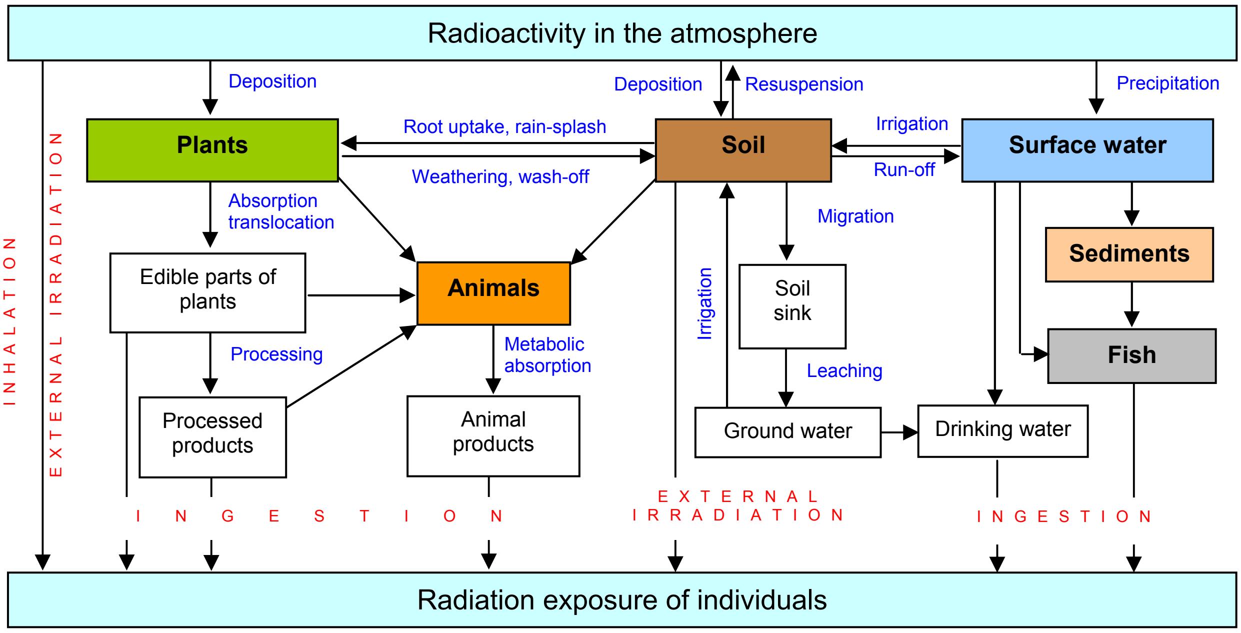
Appendix B

Transfer and impact on foodchain

B1 TRANSFER AND ACCUMULATION OF RADIONUCLIDES IN AGRICULTURAL FOOD PRODUCTS

Following their release in the atmosphere, radionuclides are transferred through soil, surface water and vegetation and accumulate in the human foodchain by various processes. The complexity inherent in the overall transfer is illustrated in Figure B1. Understanding transfer pathways is essential in order to design environmental models and develop effective management options. Each route delineated in Figure B1 is associated with a number of parameters which quantify the flow of radionuclides between interacting compartments and serve to predict radionuclide distribution along the foodchain. Management options generally aim at reducing the flow of radionuclides between compartments. For example, many options included in this Handbook aim to reduce soil-to-plant or plant-to-animal transfer, while others aim to suppress transfer from animals to animal products or remove radionuclides at the processing stage. The information provided in Section B1.1 and Section B1.2 (based on Nisbet et al, 2006) gives an overview of the processes and how they can be modelled; other modelling approaches can also be used.

Figure B1 Major pathways involved in the transfer of radionuclides through the foodchain, following a release of radioactivity in the atmosphere



It should be stressed that radionuclide fluxes may be substantially influenced by farming practices and management of contaminated land and food products. For example, various forms of human intervention may reduce transfer between compartments. On the other hand, vehicles, personnel and goods moving into and out of affected areas are potential secondary vectors of the spread of contamination. Disposal of contaminated foodstuffs or other wastes generated by the implementation of certain management options may also cause additional dispersion of radionuclides. Such processes are not explicitly addressed in this section.

B1.1 Plant uptake and distribution

The processes by which radionuclides become incorporated into plants involve either surface deposition followed by retention, absorption and translocation within the internal parts of the plant; or uptake from soil via the root system and internal redistribution to the various parts of the plant. These two routes are discussed in detail below.

Surface deposition, absorption and translocation

Surface contamination occurs by direct dry or wet deposition of radionuclides from the atmosphere. Secondary contamination may be caused by resuspension, through the action of wind or mechanical agitation, (i.e. agricultural activity or disturbance by grazing animals) or rain splash of radionuclides from the soil. The fraction of deposited radionuclides that is intercepted and retained on plant surfaces depend on various parameters, such as the meteorological conditions at the time of deposition (i.e. wind direction and velocity, precipitation, etc.); the physical and chemical form of the deposit; the type of plant and its stage of development (i.e. its leaf area index and interception capacity).

Some of the radioactive material retained on the plant surface is lost by a variety of processes, including radioactive decay, weathering caused by wind, rain or irrigation, herbivore grazing, leaf fall or addition of new tissue. Another fraction is absorbed and transferred to other parts of the plant. This process, known as translocation, is mainly controlled by the physiological behaviour of radionuclides in the plant and the time at which the deposition occurs during the growth period. Translocation is especially important for plants where the edible part is not directly exposed to deposition (e.g. cereals, potatoes or fruit trees). For plants that are used whole, such as leafy vegetables or maize silage, translocation is relevant only in that it may reduce the activity lost by weathering processes.

Soil to plant transfer

In the absence of direct deposition or significant resuspension of radioactivity, the uptake from soil is the main pathway of plant contamination and becomes increasingly important with time. The process is influenced by a number of factors, including soil characteristics (clay and organic matter content, soil pH, presence of competing electrolytes), soil-radionuclide interactions (speciation and geochemistry of radionuclides in soil systems, vertical distribution of radionuclides along soil profile), plant species, management practices (ploughing, fertilisation, etc).

B1.2 Transfer to animals and animal products (milk, meat and eggs)

The major source of contamination of animals and animal products is ingestion of contaminated feed. However, the ingestion of soil during grazing can also make a significant contribution to intakes of radioactivity. Inhalation of radionuclides is only important under certain circumstances, for example if the animals were outside during the passage of the plume and subsequently given clean feed, the main route of transfer would be inhalation. Also if the release contained a significant proportion of actinides, inhalation would be relatively more important, as these radionuclides are not readily transferred to pasture.

Activity concentrations in animal food products are controlled by the relationship between intake and metabolism of radionuclides. The important metabolic processes involved are:

- absorption of ingested radionuclides by the gastrointestinal tract and subsequent entrance into systemic circulation;
- distribution and concentration of absorbed radionuclides in different organs and tissues of the body;
- secretion of absorbed radionuclides in milk and excretion in urine, faeces and sweat.

The rates of absorption depend on a variety of factors, such as chemical form of the radionuclides (ionic, oxide or organo-complex); composition of the animal diet (fibre, clay and stable analogues content, e.g. K/Cs, Ca/Sr); animal (species, mass, age and growth rate) and milk yield, in the case of lactating species.

B1.3 Aquatic ecosystems

Contamination of aquatic ecosystems occurs by direct fallout deposition onto the water surface or by remobilisation of radionuclides, e.g. via run-off or erosion of contaminated soil in a river catchment. The aquatic environment consists of a liquid phase and a solid phase which is mainly sediment in surface waters and the host bedrock in ground waters. Each radionuclide will be partitioned between the liquid and solid phases by several, very different, processes such as sorption by sediment particles, or the bedrock for ground waters, precipitation/dissolution, diffusion, colloid-facilitated transport, microbial activity and uptake by and release from aquatic biota.

Radionuclide uptake by biota occurs by a number of mechanisms from both liquid and particulate phases. Uptake by the primary producers, e.g. phytoplankton, occurs from solution by surface adsorption and metabolic processes (IAEA, 2004). For invertebrate and vertebrate organisms, ingestion of food is the major uptake mechanism, which depends on the organism concerned, the radionuclide involved and its activity concentration.

B1.4 Natural and semi-natural ecosystems

Natural and semi-natural ecosystems include areas such as heathlands, uplands, marshlands, non-intensively managed forests and mountain pastures. Typical products of natural ecosystems are berries, fungi, honey and game animals such as moose, roe deer and reindeer.

The rate of transfer of certain radionuclides, especially caesium, to food products from natural and semi-natural ecosystems is often higher than for other ecosystems (Howard, 2000). The consumption of these products by the general population is low, but groups such as hunters and berry and fungi pickers may consume relatively large quantities. Such consumption can contribute a major proportion of the ingestion dose to these individuals in the mid to long term after deposition.

B1.5 Processed food

The concentration of radionuclides in food products is affected by industrial and domestic processing, such as washing, blanching, boiling, removing certain parts of the raw food (bran, peel, shell, bone) and drying or dilution. Processing raw milk into dairy products also affects activity concentration in the final foodstuff (Long et al., 1995).

B2 IMPACT OF RADIONUCLIDE CONTAMINATION ON FOOD PRODUCTION SYSTEMS

The radiologically most significant contaminants in food production systems are those that are released in considerable quantities, have relatively long half-lives and are characterized by high rates of transfer to crops and to animal products. In the event of a nuclear reactor accident, the mobile radioactive isotopes of iodine (^{131}I), caesium (^{134}Cs, ^{137}Cs) and, to a lesser extent, strontium (^{89}Sr, ^{90}Sr) are likely to have the greatest radiological impact on the foodchain. Heavier radionuclides, such as actinides like ^{238}Pu and ^{241}Am, are released in smaller quantities and have limited environmental mobility and low biological uptake.

Contamination patterns exhibit a pronounced seasonal dependency related to the dynamics of radionuclide transfer processes along the agricultural compartments (e.g. seasonality in plant growth). Accidents occurring just before harvest or when animals are grazing outdoors are likely to give rise to higher contamination levels in food products than those occurring in winter. To determine the main food products contributing to ingestion doses, dietary habits have to be taken into account. In principle, products consumed in large quantities, such as milk, meat and potatoes, are important from a radiological perspective. For certain population groups, however, minor foodstuffs may be also significant; for example, people consuming foodstuffs from semi-natural ecosystems (e.g. mushrooms and berries) could receive larger doses from the ingestion of radiocaesium. Conversely products like grain which are an important part of the diet, may not make a significant contribution to ingestion dose because the grain is not produced locally.

B2.1 Contamination of agricultural crops

Contamination risk to crops, including those produced domestically		
Time after deposition	**Mechanism**	**Sensitive (vulnerable) crops/soils/radionuclides**
Days, weeks	Surface deposition	Leafy green vegetables Mature fruit
Months	Root uptake Resuspension of soil-associated activity	Important for mobile radionuclides (e.g. radiocaesium from organic soils; radiostrontium from mineral soils) Important for immobile radionuclides (e.g. actinides)

In the early months after the accident, contamination of agricultural crops is dominated by surface deposition of radionuclides (see Section B1.1). The extent of interception depends on the density of the canopy. Deposition on leafy green vegetables, such as lettuce and spinach, is the pathway which poses the most immediate radiological risk from ingestion of food, which is obviously enhanced if deposition occurs just before harvest. Direct contamination of mature fruit is also a cause for concern. However, people will also receive doses from ingestion of fruit even if the tree is in leaf but the fruit is immature, as radionuclides are transferred from the leaves to the fruit by translocation. Contamination of grain seeds and some leguminous vegetables, which are protected from external contamination by other plant parts, is likely to be less of an immediate problem. Root vegetables are not affected directly by deposition, although soil-associated contamination may become attached to the surface of the root or tuber.

Gradually, the activity concentration in plants decreases due to various processes, including weathering, radioactive decay, migration of radionuclides down the soil, dilution by plant growth and reduction in bioavailability. It should be noted that, where the radionuclides are deposited in the form of hot particles (i.e. micron-sized stable formations containing a high level of α, β and γ radiation emitting nuclides), activity concentrations may increase with time, depending on the geochemical stability of the hot particles. This was the case in the areas close to the Chernobyl nuclear power plant, where a large fraction of the radioactivity was deposited as uranium fuel particles. Over the first ten years after deposition, dissolution of these particles resulted in an increase in ^{90}Sr concentration in crops, and a subsequent increase in the ingestion dose from this radionuclide (Kashparov et al., 1999; Sokolik et al., 2001)

After the first few months, contamination of plants largely arises through root uptake (see Section B1.1), a process depending strongly on the behaviour of radionuclides in soil. For example, radiocaesium is strongly absorbed and fixed on clay particles, but it remains rather mobile in organic soils. Radiostrontium is loosely bound on soil components, although it tends to form complexes with organic matter. Therefore, caesium is far less available for root uptake than strontium, especially in soils of low organic content (Nisbet and Woodman, 2000). For short-lived radionuclides such as ^{131}I, root uptake is not important due to the rapid decay of the isotope. For other radionuclides, such as plutonium isotopes and ^{241}Am, transfer from soil to plant is negligible, although resuspension of activity in soil can be an important source of contamination.

As radionuclides become immobilised in soil, the rate of transfer from soil to plants declines and food products become less contaminated with time. In very general terms, the availability of caesium decreases by 50% in the first year after contamination; after three to five years, the uptake is reduced by a further 50%, while after 10 years, usually only 10% of the original radionuclide remains available (although there is great variability with different types of soil). The availability of strontium also decreases with time. However, since strontium is much less strongly fixed in soil as compared to caesium, the rate of decrease in uptake is only a few per cent per year (SCOPE, 1993).

B2.2 Contamination of animal products

Contamination risk to animal products		
Time after deposition	**Mechanism**	**Sensitive (vulnerable) animal products**
Days, weeks	Surface deposition	Rapid transfer of radioiodine, radiocaesium and radiostrontium from pasture to milk, peaking 2-6 days after deposition. Greatest transfers are for radioiodine and radiocaesium.
Months	Root uptake	Important for mobile radionuclides. For example, radiocaesium readily transferred from pasture to lamb on upland organic soils

Consumption of contaminated feed by animals causes radionuclides to be rapidly secreted into milk and also leads to a gradual build-up of radioactivity in animal tissues. The degree of absorption in the gastrointestinal tract varies for different radionuclides. Absorption of radioiodine is practically 100% and that of radiocaesium generally exceeds 80%, although it may vary depending on the chemical form of the isotope. Absorption of radiostrontium is around 20%, depending on calcium intake, whereas only about 0.05% of plutonium is absorbed into the body (Howard, 2002).

Milk

Milk is one of the most vulnerable foodstuffs following radionuclide releases to atmosphere. This is due to the rapid transfer of many radionuclides from pasture to milk, as well as the continuous nature of milk production and its importance in children’s diet. Activity concentrations in milk depend strongly on the time of the year the accident occurs; concentrations are much higher in the summer and autumn months when dairy livestock are grazing outdoors on open pasture. However, if fodder crops are harvested after deposition, the activity concentrations in milk may rise again later, upon consumption of these feedstuffs.

Following deposition, activity concentrations in milk change rapidly with time. Radioiodine concentrations reach a maximum 2-4 days after deposition, the corresponding values for radiocaesium and radiostrontium being about 4-6. Generally, after the early phase of the accident, animals ingest decreasing amounts of radionuclides each day and therefore the activity levels in milk will decrease. The rate of decline is rapid and reported biological half-lives for iodine, caesium and strontium in the milk of different species of dairy ruminants are in the range of 0.5-3.5 days.

The amount of radionuclide transferred from feed to milk depends on the radionuclide and the animal species. Transfer coefficients to both cow and goat milk decrease in the order I>Cs>Sr>>Am. At the same time, all the radionuclides are more effectively transferred to goat than cow milk (IAEA, 1994).

Other animal products

Once absorbed, different radionuclides accumulate in different animal tissues. Radioiodine concentrates primarily in the thyroid and radiostrontium is preferentially taken up in bone. Radiocaesium, on the other hand, is distributed readily and uniformly into the soft tissues. At equilibrium, it will be found in approximately similar concentrations in muscle and in several organs, notably the kidney; its levels in the liver and spleen are lower. Actinides accumulate in bone and the liver, although their absorption is much lower than that of iodine, caesium and strontium.

B2.3 Contamination of food products from natural, semi-natural and aquatic ecosystems

Contamination risk to free foods		
Time after deposition	**Mechanism**	**Sensitive (vulnerable) animals/crops/soils/radionuclides**
Days, weeks	Surface deposition	Mushrooms and berries
Months	Root uptake	Prevalence of organic soils in semi-natural ecosystems. Radiocaesium remains bioavailable resulting in very high levels in mushrooms, berries and game which can persist for decades
Days, weeks, months, years	Uptake to fish	Transfer of radiocaesium to freshwater fish highest in closed lakes. Radiocaesium remains available in some lake sediment for decades

Transfer of radionuclides, particularly radiocaesium, to a wide range of wild/free food products from forests, uplands and other natural areas can be much higher than to products from agricultural land. The soil in natural and semi-natural ecosystems is rich in organic matter and has limited capacity for fixing chemical elements. Deposited radionuclides thus remain readily bioavailable and their uptake by vegetation can persist for decades. Elevated concentrations of ^{137}Cs concentrations derived from the Chernobyl accident can still be found in mushrooms, berries and game, such as roe deer and wild boar. The levels of radiocaesium in game species show a seasonal variation depending on their nutritional habits. For example, caesium concentrations in roe deer increase in autumn because the animals are consuming mushrooms.

Contamination of surface waters declines quickly through dilution, radioactive decay and absorption of radionuclides in bed sediments and catchment soils. However, in closed lakes with no out flowing streams, radioactivity levels in fish will remain high for decades. Post - Chernobyl studies indicate that the concentration of radiocaesium in freshwater fish is closely linked to the content in sediment, which in turn depends on various parameters used to characterise the lake. In particular, it has been observed that caesium concentration in fish is higher in smaller lakes and in lakes where the residence time of water is longer, whereas concentrations are lower in hard water or water rich in phosphorous or potassium. Other factors affecting caesium concentrations include the feeding habits, age and size of the fish. Although the whole process depends on the time elapsed since the accident, in the long-term it may be expected that activity will be higher in predator than in benthic or intermediate fish species and will also be higher in larger fish (SCOPE, 1993). The transfer of radiostrontium in aquatic ecosystems is less important, as the isotope concentrates in bones, which can be easily removed before consumption of most fish species.

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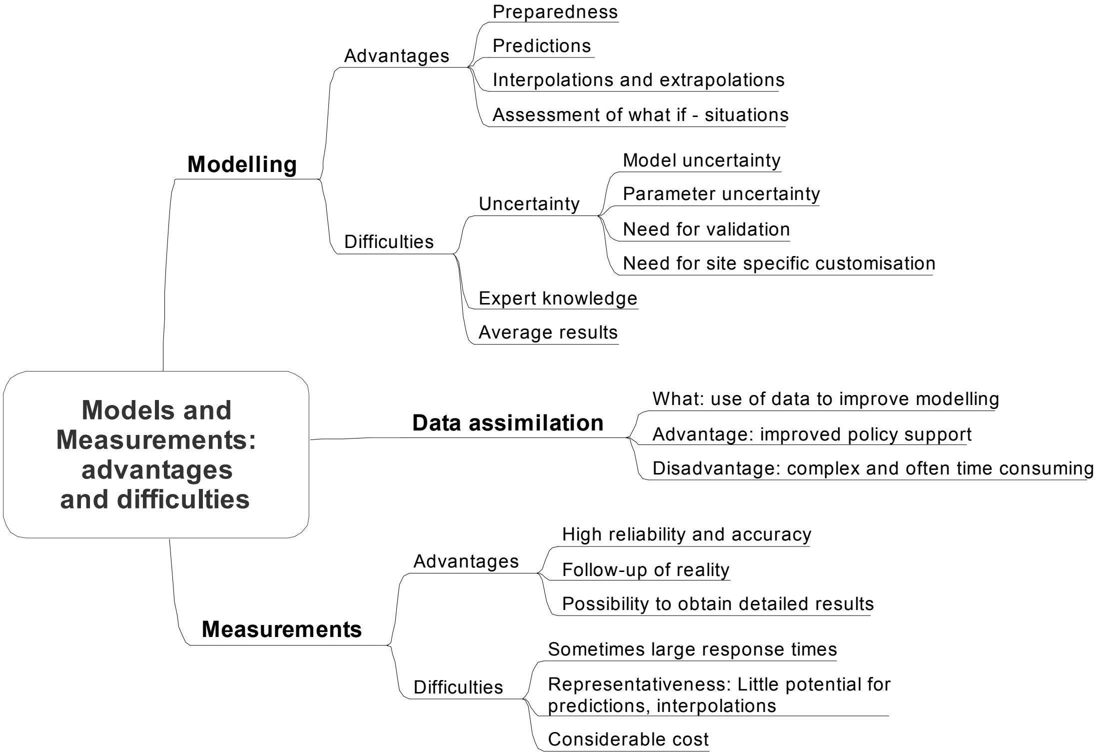
Appendix C

Assessing contamination of the foodchain through modelling, monitoring and measurements

C1 OBJECTIVES OF MODELLING AND MEASUREMENT APPROACHES

Decisions taken to protect the public with regard to safety of food supplies require a relatively accurate assessment of contamination levels in the various compartments of the foodchain as a function of time. Two main sources of information can be used for this assessment: predictions based on model calculations and results from measurements made in the affected area based on an established monitoring strategy and sampling methodology. These approaches (see Figure C1) are essentially complementary and the information provided contributes to the selection of a suitable management strategy. In both cases, expert knowledge is required to interpret the outcomes of the assessments.

Figure C1: Advantages and difficulties of modelling and measurement approaches.



Models are useful before a crisis to assess the impact of potential releases, thereby improving preparedness and can also be used in exercises and training. Models also allow prognoses to be made based on basic or advanced information, over short or longer timescales. They can be used for interpolation and extrapolation, over space and time given some input data and also for the assessment of 'what if' situations. Finally models can give an indication of a need for, and orientation of, a measurement programme for foodstuffs or animal feedstuffs.

The main difficulty related to models is that they are inherently uncertain. This is due in part to implicit model uncertainty (models are always a simplification of reality, and as such provide approximate results), but also to uncertainty in parameter values and uncertainty due to missing or incomplete data, which is typical during a crisis. Ideally, models are validated against experimental data prior to use, but for emergency systems this is very difficult. The reliability and accuracy of models can be improved if use is made of site-specific data, but often only generic or average results are available. In addition depending on the degree of complexity of the models, expert knowledge may be required in order for them to be applied. It should also be noted that outputs might not be sufficiently reliable to form a basis for decisions on restricting the entry of food or animal feed into the foodchain.

Measurement results are on the other hand very reliable and accurate provided quality assurance is guaranteed. Quality assurance is needed at the level of sampling, sample preparation, measurement and the treatment of data. Measurements also have the potential for follow-up of the real situation if automatic systems or rapid methods are available.

There are two main difficulties related to measurements. Firstly, there is a potentially large response time for radionuclides requiring complex measurements. Secondly, the samples collected may not be representative and therefore it may be difficult to interpolate or extrapolate results from measurements, both in space and time. In addition some samples may be highly contaminated, introducing the risk of contamination of the laboratory and other samples (‘cross-contamination’) and increased background levels in the laboratory. Special procedures other than those used for radiological surveillance may also have to be used. Finally costs of a measurement programme may be considerable.

It is widely acknowledged that measurements and modelling have vital roles to play when assessing contamination of the foodchain. When combined, model calculations can help to direct monitoring programmes and measurement results can help to adjust model calculations, by data assimilation. The objectives of these two complementary approaches at different phases of an accident are summarised in Table C1.

Table C1 Role of models and measurements during different phases of accident response.

Models		Measurements	
Tools	Objectives	Tools	Objectives
Pre-release or Pre-deposition			
Atmospheric dispersion and deposition models	Prediction of soil contamination Pre release/deposition management options	Automatic monitoring networks; stack and fence monitoring	Verification of non-release
During release or deposition (Early phase)			
Atmospheric dispersion and deposition models	Follow-up of impact Prediction of future contamination	Automatic monitoring networks; air samplers;	Verification of cloud trajectory, air concentrations
Just after the release or deposition (Early – Medium phase)			
Agriculture models Forest models Aquatic models	Improved assessments of environmental contaminations Predictions of contaminations in foodchain and water bodies	Aerial gamma monitoring; field monitoring with hand-held equipment Sampling of biota Sampling of water bodies	Identification of contaminated areas Identification of radionuclide composition Verification of possible transfer pathways
Hours/days after deposition (Medium phase)			
Agriculture models Forest models Aquatic models	Improved contamination predictions Assessment of impact of management options and strategies	Aerial gamma monitoring; field monitoring with hand-held equipment Intensive sampling campaigns followed by analysis in laboratories	Refined contamination maps Assessment of contamination levels in environment and foodchain
Medium/long term phase			
Agriculture models Forest models Aquatic models	Improved contamination predictions Assessment of impact of management options and strategies	Intensive sampling campaigns followed by analysis in laboratories Whole body counting, bioassay Live monitoring	Assessment of contamination levels in environment/ foodchain Assessment of contamination of the public and live animals

C2 MONITORING AND MEASUREMENT STRATEGIES AT VARIOUS STAGES OF A NUCLEAR ACCIDENT

Monitoring and measurement strategies are implemented to assist in the management of contaminated food production systems following the accidental release of radionuclides. An overview of the objectives of these various activities is given in Table C1 and described in the sections below.

C2.1 Pre-release and pre-deposition measurements

It is important to rapidly establish an overview of the developing situation if a release is expected or has started, so that an estimation of the potential consequences can be made. In the very early phase after a release, data will be available from automatic monitoring stations and from stack and fence monitors at the nuclear power plant. This information may, together with on-line real-time weather data, provide input to prognostic models (e.g. the ARGOS and RODOS decision support systems that are applied in many European countries) to give a rough indication of where the contaminated plume is likely to go and what the consequences might be in different areas. This information can be useful in planning how to deal with the situation when the plume arrives at different locations, and implementing very early (pre-deposition) management options if appropriate. In addition, mobile monitoring stations can be set up and field-based teams assembled ready to start taking measurements in the affected area.

The automatic monitoring stations provide measurement data on gamma dose rate, whilst air samplers provide information on aerosols and iodine isotopes. If no spectrometric information is available, or if gamma spectra are complex (e.g. long-lived isotopes are hidden by short lived isotopes) interpretation of early measurements in the context of management options for food production systems can be difficult and misleading. Furthermore, important food countermeasures can be required even when there are very limited signals from automatic monitoring stations, for example when the release comprises only alpha/beta particles, when there is a low level release over a long period or localised rain showers.

C2.2 Detailed source identification measurements

Management of the off-site consequences of an emergency requires detailed information on the source (e.g. location, radionuclides involved, release rates, particle form and size). The presence of one isotope in a mixed release of radionuclides can strongly influence the types of management options that would be considered. A detailed knowledge of the source characteristics also makes it possible to carry out more accurate dose assessments and to adapt and optimise monitoring and measurement strategies.

Detailed source identification requires specific expertise and equipment, such as high resolution gamma spectrometry (in-situ or laboratory based), alpha and beta spectrometry (mobile or laboratory based), and air sampling over different types of filters. In general it will not be necessary to carry out these types of measurements in highly contaminated areas. Samples should be stored for the purposes of repeat analysis and laboratory intercomparison.

C2.3 Screening of large areas of land

Once deposition has occurred, it is important to obtain an overview of the contamination pattern so that contaminated areas can be identified and divided into zones of different priority/urgency with respect to the needs for intervention. Screening measurements may be combined with predictive models to provide an initial assessment of the contamination. However, site-specific measurements, even at a relatively low resolution, provide complementary information as the deposition pattern is very complex and difficult to predict with models; local rain showers can greatly enhance ground contamination. It is important to note that default data in predictive models originate from assessments made in connection with other incidents or experiments, which may not have features that adequately reflect those of the incident in question. For instance, many data relate directly to the Chernobyl accident. If a different type of release occurs, e.g. involving larger particles, these would deposit over a much smaller area. The different particle sizes would also lead to a different relative distribution of contaminants on different crops and underlying soil.

There is a need to obtain radionuclide-specific measurement results rapidly, because the behaviour of radionuclides in the environment and in the foodchain is strongly radionuclide dependent and CFILs relate to different categories of radionuclides. CFILs relate to a number of categories of foodstuffs, so it is also important to give priority to determining activity concentrations in food products that contribute most to the diet of the population affected.

Radionuclide-specific information can be obtained using germanium detectors or possibly NaI(Tl) detectors in helicopters or aeroplanes when available, or alternatively in cars (ICRU, 1994). Hand-held devices may be suitable if the contaminated area is small. Germanium detectors would be required to resolve spectral interferences in situations where many radionuclides are present, e.g. a major reactor accident. Although dose rate measurements would not yield contaminant-specific information, they could still give a valuable indication of the contamination pattern. Airborne monitoring crews may, depending on the extent of the contamination, be instructed to fly in parallel straight tracks, e.g. with a length of a few kilometres and a distance of a few hundred metres (IAEA, 1999). Over time, radionuclides will migrate into the soil which can lead to an underestimation of the deposited activity when aerial surveys are undertaken, due to partial shielding by the soil.

The monitoring of large areas must be organised in a way that assists management decisions. Areas with no food production and no inhabitants for example, will have low priority for monitoring. Population density and land-use (cities, industry, and farming) will play a role in determining priorities and there will be competition between demands for monitoring of areas with different management objectives.

C2.4 More detailed measurements in contaminated food production systems

Sampling and analysis of contaminated crops and associated topsoil soon after the incident can reveal how much of the contamination in an area has deposited on the vegetation and on the soil. This relationship depends on the deposition mode (dry or wet deposition), and gives valuable information on for instance the appropriateness of implementing early removal of crops as a management option to prevent transfer of the contamination to the soil. These measurements rely on using readily available instruments and simple and pre-validated methods to avoid delay.

Detailed measurements of the vertical distribution of contaminants in the ground are very useful in optimising practical implementation of management options such as topsoil removal, deep ploughing, skim and burial ploughing. As small scale variation can occur, a minimum of five sample cores (each covering 50-100 cm^2 of surface) should be taken from a 2 m by 2 m square and divided into slices a few cm thick for gamma spectrometry (Roed & Togawa, 1996). This procedure will confirm whether a soil management procedure will remove contamination from the rooting zone of crops.

Further in-situ measurements at higher resolution, using hand-held and other mobile instruments (IAEA, 1999), can provide more detailed information on the contamination pattern in a priority zone, thus improving local consequence assessment (including identification of important dose pathways) and optimisation of management strategies. If the contamination problem is caused by pure alpha or beta emitters, samples must be transferred to a laboratory for radiochemical analysis using established methods (e.g. IAEA, 1999). Such measurements are highly time-consuming and can only provide data for improving consequence assessments on a more protracted basis. The availability of mobile alpha and beta spectrometry in the future would hasten this process.

C2.5 Measurements of contamination in food products, live animals and fodder

Following deposition, priority will be given to determining activity concentration in products that will be consumed first, such as pasture for dairy animals, leafy green vegetables and drinking water. Knowledge of food consumption habits in the contaminated area will further direct the sampling programme towards determining activity concentrations in food products that contribute most to the diet of the population affected. Priorities will vary according to the time of year and stage of the growing season for various food products. The provision of monitoring equipment (e.g. NaI(Tl) detectors) at local level monitoring stations will enable inhabitants to check contamination levels in domestically produced foods and foods from the wild.

Live monitoring of animals can determine if activity concentrations in meat are below intervention levels, thereby permitting animal products to enter the foodchain. Live monitoring can also be used to assist in optimising other management options such as selective grazing and manipulation of slaughter times. Furthermore, measurements of contamination levels in animal fodder can be compared to CFILs for animal feed (radiocaesium only).

C2.6 Monitoring to demonstrate that management options have had the desired effect

The effectiveness of management options can be assessed by monitoring whether they have met their objectives. For some options directed at soil or livestock it may simply involve measurements to demonstrate that crop and animal products contain levels of contamination that are below intervention limits. For other options involving ploughing procedures it may be necessary to demonstrate that contamination has been placed at deep in the soil below the rooting depth of most crops. This would involve soil core sampling and spectrometric measurements in the laboratory of vertical sections of the sampled soil core. In this way, monitoring data can be used to demonstrate when to lift management options implemented earlier in the recovery strategy.

C2.7 Personal monitoring

In the context of managing contaminated food production systems personal monitoring can be important from two perspectives. Firstly, to protect those working in contaminated areas or handling contaminated food products (including animals). These workers may be subjected to enhanced external doses, and consideration should be given to the wearing of personal dosimeters (e.g. TLD's, film badges or phosphate in glass dosimeters). In heterogeneous and highly contaminated areas it can also be useful for workers to be equipped with a dose rate meter that immediately displays dose rate (IAEA, 1999). A second requirement for personal monitoring might be to check if food countermeasures have been effective, particularly in areas where local produce forms a large part of the diet. The dose received from ingestion of contaminated products can be assessed by whole body monitoring, thyroid monitoring and laboratory measurements of blood and urine samples.

C2.8 Longer term monitoring to provide control/reassurance

The demand to assess contamination levels in food products may persist over long time periods, both to provide reassurance for local inhabitants and for marketing reasons, even if it has been demonstrated that contamination levels have fallen well below intervention limits. Longer term monitoring is also important as under some circumstances uptake to food products may increase over time, depending on the characteristics of the initial release and subsequent mobility of the contaminants in the environment. There could also be a requirement for the long-term measurement of vertical contamination profiles in soil (e.g. following ploughing procedures) to demonstrate that the more mobile radionuclides have not reached the groundwater.

C2.9 Scientific measurements

If enough measurement capacity is available a series of additional measurements can be made for scientific purposes, during or after an accident. These can provide the following: site specific data; new data on the uptake and transfer of radionuclides to improve models and reduce uncertainties; additional information on which to base a detailed dose reconstruction; and a set of independent measurements.

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Table C2 Overview of monitoring and measurements to assist in the management of contaminated food production systems

Activity	Objectives	Examples and equipment
Pre-release and pre-deposition measurements	Early detection of a release, investigation of plume passage, initiation of early food countermeasures, dose rate from contamination after plume passage	Stack monitoring, fence monitoring
		Fixed and mobile monitoring networks, gamma dose rate measurements
		Air/water sampling with automated measurement or off-line measurement (gross alpha-, beta- & gamma-measurements)
		Dose rate meters (e.g. from field-based measurement teams)
Detailed source identification	Detailed analyses to identify source characteristics: source location, radionuclide identification, particle form and size	Stack monitoring, fence monitoring
		Hand-held spectrometric devices
		In-situ gamma spectroscopy (HPGe, NaI)
		Sampling followed by gamma spectroscopy (laboratory)
Monitoring of large areas, detailed measurements	Identification and mapping of the radioactive contamination, location of hotspots, radionuclide distribution between crop and soil, distribution in the soil profile	Hand-held, car-based and airborne measurements (gross or spectrometric)
		Site specific sampling followed by alpha-, beta- and gamma-spectrometry (mobile or laboratory)
Monitoring of food	Determine activity concentrations in important foodstuffs and feedstuffs, live monitoring of animals to optimise management options and to provide reassurance	Sampling followed by alpha-, beta- and gamma-spectrometry (mobile or laboratory)
		In-situ gamma spectroscopy (HPGe, NaI)
Monitoring of people	Monitoring of workers, estimation of dose to population from food, provide reassurance	Personal dose and dose rate meters
		Personal contamination monitoring (contamination monitor)
		Thyroid monitoring (NaI, HPGe)
		Whole body counter (NaI, HPGe)
		Sampling urine, faeces and blood for contamination and radiochemical analyses using alpha-, beta- and gamma-spectrometry
Long-term site restoration	Demonstrate effectiveness of management options, lifting of management options, provide reassurance, detect increased transfer to food products or groundwater with time	In-situ gamma spectroscopy (HPGe, NaI)
		Sampling followed by alpha-, beta- and gamma-spectrometry (mobile or laboratory)
Measurements for scientific purposes	Provide information for dose reconstruction, provide new transfer parameters, site specific data and independent data sets.	Wide range of samples, measurements and analyses possible.

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APPENDIX D

Practical recommendations for engaging with stakeholders in the management of contaminated areas

In recent years, stakeholder issues have moved steadily to the forefront of policy decisions and are key to the development and implementation of radiological protection strategies. As experience in stakeholder engagement has grown, it has been possible to use many of the lessons learned as a basis for the development of best practice among the radiological protection community. Processes and tools are becoming established that can be generally applied to situations where the input and views of stakeholders are required. The process of engaging with stakeholders involves five distinct steps which follow a logical sequence: preparation, planning, engagement, evaluation and application. Each of these steps is described below. The International Radiation Protection Association (IRPA, 2008) has issued further guidance in its ten guiding principles that should also be considered by radiation protection professionals when engaging with stakeholders. These principles are summarised in Table D1.

Table D1 IRPA Guiding principles on stakeholder engagement (IRPA, 2008)

	Principles
1	Identify opportunities for engagement and ensure the level of engagement is proportionate to the nature of the radiation protection issues and their context
2	Initiate the process as early as possible, and develop a sustainable implementation plan
3	Enable an open, inclusive and transparent stakeholder engagement process
4	Seek out and involve relevant stakeholders and experts
5	Ensure that the roles and responsibilities of all participants and the rules for cooperation are clearly defined
6	Collectively develop objectives for the stakeholder engagement process, based on a shared understanding of issues and boundaries
7	Develop a culture which values a shared language and understanding, and favours collective learning
8	Respect and value the expression of different perspectives
9	Ensure a regular feedback mechanism is in place to inform and improve current and future stakeholder engagement processes
10	Apply the IRPA Code of Ethics in their actions within these processes to the best of their knowledge

D1 STEPS FOR SUCCESS STAKEHOLDER ENGAGEMENT

D1.1 Preparation

Opportunities for proactive engagement need to be identified by developing a good understanding of the issues at stake. The method of engagement should be proportionate to these issues and their context, bearing in mind that there will be resource if not time constraints. The appointment of a leader who is well respected and a good communicator is important. The leader and his/her team can be independent, or selected from central Government departments and agencies, or from local authorities. They should aim to seek out and involve a wide range of stakeholders as all aspects of life need to be considered when undertaking the sustainable management of contaminated areas.

D1.2 Planning

The engagement should be initiated as early as possible and requires the development of a sustainable plan. The engagement could be a one-off process but is more likely to be implemented over an extended period in contaminated areas to build a common understanding and shared vision of how to manage the area. Planning involves establishing the objectives, scope, format and mode of engagement, the identification of potential stakeholders and the design of the engagement i.e. agendas and meeting logistics including any rules to be applied.

D1.3 Engagement

At the start of the engagement, the roles, responsibilities and accountabilities of all participants should be established. Openness, inclusiveness and transparency, which are interrelated, should constitute the essence of a successful engagement and should be present throughout the process. It is important to share the relevant information needed to build a collective understanding of the issues. The information should be presented in a simple non-scientific language. It should be concise, clear to all and honest. Each stakeholder needs to recognise their own and each others' uniqueness and to be aware that other participants may view issues from different perspectives and to respect this. The acceptance of diverse perspectives, thinking and values has the potential to enrich the process, providing that the process is controlled such that any entrenched views and ideologies, if present, are managed by agreed mechanisms.

D1.4 Evaluation

When engaging with stakeholders an opportunity should be provided for both the stakeholders and those responsible for the process to give mutual feedback on the approaches and tools used and on eventual outcomes. This serves to inform and improve ongoing processes as well as influencing how future ventures should be conducted. The following types of criteria can be evaluated: appropriateness of the terms and timing of engagement, the quality and appropriateness of the information provided; comprehensiveness of the issues that were addressed; inclusivity of the stakeholders involved; practicability/feasibility of the eventual outcomes.

D1.5 Application

When a stakeholder engagement process comes to an end, it is important that those responsible for the process make the results known to all those who participated. If these results do not reflect the recommendations/findings from the stakeholders, those responsible must offer an explanation to the stakeholders for any deviation from what was agreed. In this way, the feedback of results and decisions will help to maintain confidence in the process.

D2 REFERENCES

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Table 5.2 Selection table of management options for cereals to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Dilution (7)					E-M
Feeding of animals with crops in excess of intervention levels (8)					E-M
Restrictions on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					L
Options for continuing production					
Close air intake systems at food processing plants (1)					P
Closure of irrigation systems (2)					P
Covering of standing crops (3)					P
Protection of harvested crops from deposition (5)					P
Application of lime to arable soils and grassland (13)					E-M-L
Application of K fertilisers to arable soils and grassland (14)					E-M-L
Deep ploughing (15)					E-M
Early removal of crops (16)					P-E
Processing of crops for subsequent consumption (18)					E-M
Selection of edible crop that can be processed (20)					M-L
Shallow ploughing (21)					E-M-L
Skim and burial ploughing (22)					E-M
Topsoil removal (23)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.3 Selection table of waste management options for contaminated cereals

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated cereals					
Biological treatment (digestion) of crops (47)					E-M-L
Composting (51)					E-M
Incineration (53)					E-M
Landfill (54)					E-M
Ploughing in of a standing crop (56)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.4 Selection table of management options for leafy vegetables (commercial) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Feeding of animals with crops in excess of intervention levels (8)					E-M
Restrictions on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					M-L
Options for continuing production					
Close air intake systems at food processing plants (1)					P
Closure of irrigation systems (2)					P
Covering of standing crops (3)					P
Prevention of contamination of greenhouse crops (4)					P
Protection of harvested crops from deposition (5)					P
Application of lime to arable soils and grassland (13)					E-M-L
Application of K fertilisers to arable soils and grassland (14)					E-M-L
Deep ploughing (15)					E-M-L
Early removal of crops (16)					P-E
Processing of crops for subsequent consumption (18)					E-M
Selection of edible crop that can be processed (20)					M-L
Shallow ploughing (21)					E-M-L
Skim and burial ploughing (22)					E-M-L
Topsoil removal (23)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 5.5 Selection table of waste management options for contaminated leafy vegetables produced commercially

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated vegetables					
Biological treatment (digestion) of crops (47)					E-M-L
Composting (51)					E-M-L
Incineration (53)					E-M-L
Landfill (54)					E-M-L
Ploughing in of a standing crop (56)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.6 Selection table of management options for woody fruit trees to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Feeding of animals with crops in excess of intervention levels (8)					E-M
Restriction on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					L
Options for continuing production					
Close air intake systems at food processing plants (1)					P
Closure of irrigation systems (2)					P
Protection of harvested crops from deposition (5)					P
Application of lime to arable soils and grassland (13)					E-M-L
Application of K fertilisers to arable soils and grassland (14)					E-M-L
Deep ploughing (15)					E-M
Pruning/defoliation of fruit trees and vines (19)					E
Selection of edible crop that can be processed (20)					M-L
Shallow ploughing (21)					E-M-L
Skim and burial ploughing (22)					M-L
Topsoil removal (23)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.7 Selection table of waste management options for contaminated woody fruit trees					
When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated fruit and fruit products					
Biological treatment (digestion) of crops (47)					E-M-L
Composting (51)					E-M
Incineration (53)					E-M-L
Landfill (54)					E-M-L
Ploughing in of a standing crop (56)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.8 Selection table of management options for milk to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Dilution (7)					E-M
Feeding animals with milk in excess of intervention levels (8)					E-M
Restriction on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					L
Options for continuing production					
Close air intake systems at processing plants (1)					P
Short-term sheltering of dairy animals (6)					P
Administration of AFCF to concentrate ration (24)					E-M-L
Administration of calcium to concentrate ration (25)					E-M-L
Administration of AFCF boli to ruminants (26)					M-L
Administration of clay minerals to feed (27)					E-M-L
Clean feeding (29)					E-M-L
Decontamination techniques for milk (30)					M-L
Distribution of saltlicks containing AFCF (31)					M-L
Processing of milk for subsequent human consumption (34)					E-M
Selective grazing regime (36)					E-M-L
Slaughtering of dairy livestock (37)					M-L
Suppression of lactation before slaughter (38)					M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 5.9 Selection table of waste management options for contaminated milk

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated milk					
Biological treatment (digestion) of milk (48)					E-M-L
Disposal of contaminated milk to sea (52)					E-M-L
Incineration (53)					E-M-L
Landspreading of milk and/or slurry (55)					E-M-L
Processing and storage of milk products for disposal (57)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.10 Selection table of management options for meat (cow and sheep) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Restriction on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					L
Options for continuing production					
Closure of air intake system at processing factories (1)					P
Short-term sheltering of (dairy) animals (6)					P
Addition of AFCF to concentrate ration (24)					E-M-L
Addition of calcium to concentrate ration (25)					E-M-L
Administration of AFCF boli to ruminants (26)					E-M-L
Administration of clay minerals to feed (27)					E-M-L
Clean feeding (29)					E-M-L
Distribution of salt licks containing AFCF (31)					E-M-L
Live monitoring (32)					E-M-L
Manipulation of slaughter times (33)					P-E-M-L
Salting of meat (35)					L
Selective grazing regime (36)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 5.11 Selection table of waste management options for managing contaminated meat (cow and sheep)

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated meat					
Burial of carcasses (49)					E-M-L
Burning of carcasses (50)					E-M-L
Incineration (53)					E-M-L
Landfill (54)					E-M-L
Rendering (58)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.12 Selection table of management options for eggs to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Restriction on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					L
Options for continuing production					
Close air intake systems at processing plants (1)					P
Addition of AFCF to concentrate ration (24)					E-M-L
Addition of calcium to concentrate ration (25)					E-M-L
Administration of clay minerals to feed (27)					E-M-L
Clean feeding (29)					E-M-L
Selective grazing regime (36)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.13 Selection table of waste management options for eggs

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for contaminated domestic produce					
Incineration (53)					E-M-L
Landfill (54)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 5.14 Selection table of management options for vegetables, herbs, fruit and berries (domestic)					
When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for maintaining domestic production and gathering of wild foods					
Prevention of contamination of greenhouse crops (4)					P
Protection of harvested crops from deposition (5)					P
Topsoil removal (23)					E-M
Dietary advice (40)					P-E-M-L
Local provision of monitoring equipment (42)					P-E-M-L
Processing and/or storage prior to consumption (44)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 5.15 Selection table of waste management options for vegetables, herbs, fruit and berries (domestic)

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for contaminated domestic produce					
Composting (51)					E-M
Incineration (53)					E-M-L
Landfill (54)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 5.16 Selection table of management options for nuts, mushrooms, fruit, berries and game (wild food)					
When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for maintaining domestic production and gathering of wild foods					
Protection of harvested crops from deposition (5)					P
Change of hunting season (28)					E-M-L
Dietary advice (40)					P-E-M-L
Local provision of monitoring equipment (42)					P-E-M-L
Processing and/or storage prior to consumption (44)					E-M-L
Restrictions on gathering wild foods (46)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 5.17 Selection table of waste management options for nuts, mushrooms fruit, berries and game (wild food)

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for contaminated domestic produce					
Composting (51)					E-M
Incineration (53)					E-M-L
Landfill (54)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 5.18 Selection table of management options for reindeer to continue production					
When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Restrictions on the entry of food into the foodchain (11)					E-M-L
Options for continuing production					
Addition of AFCF to concentrate ration (24)					E-M-L
Addition of calcium to concentrate ration (25)					E-M-L
Administration of AFCF boli to ruminants (26)					E-M-L
Administration of clay minerals to feed (27)					E-M-L
Clean feeding (29)					E-M-L
Distribution of salt lick containing AFCF (31)					E-M-L
Live monitoring (32)					E-M-L
Manipulation of slaughter times (33)					E-M-L
Salting of meat (35)					E-M-L
Selective grazing (36)					E-M-L
Dietary advice (40)					P-E-M-L
Local provision of monitoring equipment (42)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 6.3 Example 1: Selection table of management options for milk to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Dilution (7)					E-M
Feeding animals with milk in excess of intervention levels (8)					E-M
Restriction on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					L
Options for continuing production					
Close air intake systems at processing plants (1)					P
Short-term sheltering of dairy animals (6)					P
Administration of AFCF to concentrate ration (24)					E-M-L
Administration of calcium to concentrate ration (25)					E-M-L
Administration of AFCF boli to ruminants (26)					M-L
Administration of clay minerals to feed (27)					E-M-L
Clean feeding (29)					E-M-L
Decontamination techniques for milk (30)					M-L
Distribution of saltlicks containing AFCF (31)					M-L
Processing of milk for subsequent human consumption (34)					E-M
Selective grazing regime (36)					E-M-L
Slaughtering of dairy livestock (37)					M-L
Suppression of lactation before slaughter (38)					M-L
Key					
	Recommended with few constraints.				
	Recommended but requires further analysis to overcome some constraints.				
	Economic or social constraints exist, requiring full analysis and consultation period.				
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.				

Go to colour table

Table 6.4 Example 1: STEP 2 Selection table of waste management options for contaminated milk

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated milk					
Biological treatment (digestion) of milk (48)					E-M-L
Disposal of contaminated milk to sea (52)					E-M-L
Incineration (53)					E-M-L
Landspreading of milk and/or slurry (55)					E-M-L
Processing and storage of milk products for disposal (57)					E-M-L

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 6.7 Example 1: STEP 3 Selection table showing remaining management options for cow milk to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for continuing production					
Close air intake systems at processing plants (1)					P
Short-term sheltering of dairy animals (6)					P
Clean feeding (29)					E-M-L
Processing of milk for subsequent human consumption (34)					
Options of general applicability or societal relevance					
Dilution (7)					E-M
Feeding animals with milk in excess of intervention levels (8)					E-M
Restriction on the entry of food into the foodchain (11)					E-M-L
Food labelling (41)					M-L

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 6.8 Example 1: STEP 3 Selection table of remaining waste management options for contaminated cow milk

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated milk					
Biological treatment (digestion) of milk (48)					E-M-L
Disposal of contaminated milk to sea (52)					E-M-L
Landspreading of milk and/or slurry (55)					E-M-L
Processing and storage of milk products for disposal (57)					E-M-L

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 6.11 Example 1: STEP 4 Selection table showing remaining management options for cow milk to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for continuing production					
Close air intake systems at processing plants (1)					P
Short-term sheltering of dairy animals (6)					P
Clean feeding (29)					E-M-L
Options of general applicability or societal relevance					
Restriction on the entry of food into the foodchain (11)					E-M-L

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 6.12 Example 1: STEP 4 Selection table of remaining waste management options for contaminated cow milk

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated milk					
Disposal of contaminated milk to sea (52)					E-M-L
Landspreading of milk and/or slurry (55)					E-M-L
Processing and storage of milk products for disposal (57)					E-M-L

Key

	Recommended: few constraints.
	Recommended: requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 6.17 Example 2: STEP 2 Selection table of management options for leafy vegetables (commercial) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options of general applicability or societal relevance					
Feeding of animals with crops in excess of intervention levels (8)					E-M
Restrictions on the entry of food into the foodchain (11)					E-M-L
Selection of alternative land use (12)					M-L
Options for continuing production					
Close air intake systems at food processing plants (1)					P
Closure of irrigation systems (2)					P
Covering of standing crops (3)					P
Prevention of contamination of greenhouse crops (4)					P
Protection of harvested crops from deposition (5)					P
Application of lime to arable soils and grassland (13)					E-M-L
Application of K fertilisers to arable soils and grassland (14)					E-M-L
Deep ploughing (15)					E-M-L
Early removal of crops (16)					P-E
Processing of crops for subsequent consumption (18)					E-M
Selection of edible crop that can be processed (20)					M-L
Shallow ploughing (21)					E-M-L
Skim and burial ploughing (22)					E-M-L
Topsoil removal (23)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

Go to colour table

Table 6.18 Example 2: STEP 2 Selection table of waste management options for contaminated leafy vegetables produced commercially

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Options for managing contaminated vegetables					
Biological treatment (digestion) of crops (47)					E-M-L
Composting (51)					E-M-L
Incineration (53)					E-M-L
Landfill (54)					E-M-L
Ploughing in of a standing crop (56)					E-M

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 6.21 Example 2: STEP 3 Selection table for remaining management options for leafy vegetables (commercial) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide	Zone type
Options of general applicability or societal relevance						
Feeding of animals with crops/milk > intervention levels (8)					E-M	2
Restrictions on the entry of food into the foodchain (11)					E-M-L	1, 2
Selection of alternative land use (12)					M-L	1
Options for continuing production						
Close air intake systems at food processing plants (1)					P	1, 2
Closure of irrigation systems (2)					P	1, 2
Covering of standing crops (3)					P	1, 2
Prevention of contamination of greenhouse crops (4)					P	1, 2
Protection of harvested crops from deposition (5)					P	1, 2
Application of K fertilisers to arable soils and grassland (14)					E-M-L	1
Deep ploughing (15)					E-M-L	1
Early removal of crops (16)					P-E	1
Processing of crops for subsequent consumption (18)					E-M	1, 2
Selection of edible crop that can be processed (20)					M-L	1
Shallow ploughing (21)					E-M-L	1
Skim and burial ploughing (22)					E-M-L	1
Topsoil removal (23)					E-M	1

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 6.22 Example 2: STEP 3 Selection table of remaining waste management options for contaminated leafy vegetables produced commercially

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide	Zone type
Options for managing contaminated vegetables						
Biological treatment (digestion) of crops (47)					E-M-L	1
Composting (51)					E-M-L	1
Ploughing in of a standing crop (56)					E-M	1, 2

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 6.25 Example 2: STEP 4 Selection table for remaining management options for leafy vegetables (commercial) to continue production

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide	Zone type
Options of general applicability or societal relevance						
Restrictions on the entry of food into the foodchain (11)					E-M-L	1, 2
Options for continuing production						
Close air intake systems at food processing plants (1)					P	1, 2
Closure of irrigation systems (2)					P	1, 2
Shallow ploughing (21)					E-M-L	1
Skim and burial ploughing (22)					E-M-L	1
Topsoil removal (23)					E-M	1

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.

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Table 6.26 Example 2: STEP 4 Selection table of remining waste management options for contaminated leafy vegetables produced commercially

When to apply	Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide	Zone type
Options for managing contaminated vegetables						
Composting (51)					E-M-L	1
Ploughing in of a standing crop (56)					E-M	1, 2

Key

	Recommended with few constraints.
	Recommended but requires further analysis to overcome some constraints.
	Economic or social constraints exist, requiring full analysis and consultation period.
	Technical or logistical constraints may exist, or the option may only be appropriate on a site specific basis or for a particular time-phase.