Public Health England

Protecting and improving the nation's health

UK Recovery Handbooks for Radiation Incidents 2015

Food Production Systems Handbook

Version 4

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Public Health England exists to protect and improve the nation's health and wellbeing, and reduce health inequalities. It does this through world-class science, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. PHE is an operationally autonomous executive agency of the Department of Health.

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UK Recovery Handbooks for Radiation Incidents 2015

Food Production Systems Handbook

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Abstract

This handbook to assist in the management of contaminated food production systems following a radiation incident has been developed following a series of UK and European initiatives involving a wide range of stakeholders. It is aimed at national and local authorities, central government departments and agencies, radiation protection experts, agricultural and food production sectors and others who may be affected.

The handbook includes management options for application in the pre-release, emergency and longer term phases of an incident. Sources of contamination considered in the handbook include nuclear accidents and radiological dispersion devices. Agricultural and domestic food production systems are considered, including the gathering of free foods from the wild. The handbook is divided into several sections which provide supporting scientific and technical information: an analysis of the factors influencing recovery; compendia of comprehensive, state-of-the-art datasheets for 42 management options; and guidance on planning in advance. A decision-aiding framework comprising colour-coded selection tables as well as look-up tables to assist in the elimination of options and a worked example are also included.

The handbook can be used as a preparatory tool, under non-crisis conditions, to engage stakeholders and to develop local and regional plans. It can also be applied as part of the decision-aiding process to develop a recovery strategy following an incident. In addition, the handbook is useful for training purposes and during emergency exercises. The handbook for food production systems complements the other two handbooks for inhabited areas and drinking water.

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Quick Guide to the Food Production Systems Handbook

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

Planning

Go to Section 4 'Planning in advance'

Consider customising handbook for local conditions (eg land use) using a stakeholder engagement process

Response

Go to Section 5'Constructing a management strategy'

Follow the 8-step process:

- Identify contaminated production system
- Consult selection table of management options for the production system
- Check applicability of management options for radionuclides released
- ELIMINATE OPTIONS
- Check key constraints of management options
- ELIMINATE OPTIONS
- Check effectiveness of management option
- ELIMINATE OPTIONS
- Check for incremental doses and production of waste
- ELIMINATE OPTIONS
- Go to Section 7 'Datasheets' for detailed information on the remaining options
- ELIMINATE OPTIONS
- Use selection table to select and combine options and build management strategy

Training - new user

Go to all sections

Section 1 'Introduction'
Section 2 'Management options'
Section 3 'Factors influencing implementation'
Section 4 'Planning in advance'
Section 5 'Constructing a management strategy'
Section 6 'Worked example'
Section 7 'Datasheets'
Consult appendices for supporting information if required

Training - refresher

Go to Section 6 'Worked example'

This goes through the 8-step process for an incident involving ^{131}I contamination of milk

Contents

1 Introduction to the Food Production Systems Handbook

The Food Production Systems Handbook has been developed as a result of a series of European and, in particular, UK initiatives which started in the early 1990s. A full account of the history of development of the handbook is given in Appendix A. The 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 arising 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 Production Systems Handbook help?

The Food Production Systems 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 handbook is also helpful for contingency planning.

1.1 Objectives of the Food Production Systems Handbook

The Food Production Systems 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 Production Systems 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 Food Production Systems Handbook is specifically targeted at:

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

1.3 Application

The Food Production Systems 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 (ie not as part of a participatory process), the full potential of the 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, frameworks and 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 Production Systems Handbook is radiological protection, or, in other words, reducing exposure of humans to radiation. However, experience from past contamination events, particularly the incidents at Chernobyl and Fukushima nuclear power plants, have shown that the consequences of widespread and long-lasting contamination are complex and multidimensional. Radiological protection should be considered as only one aspect of the situation, especially where agricultural production and food supply are 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 3).

1.5 Scope

The sources of contamination considered in the Food Production Systems 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 eg 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).

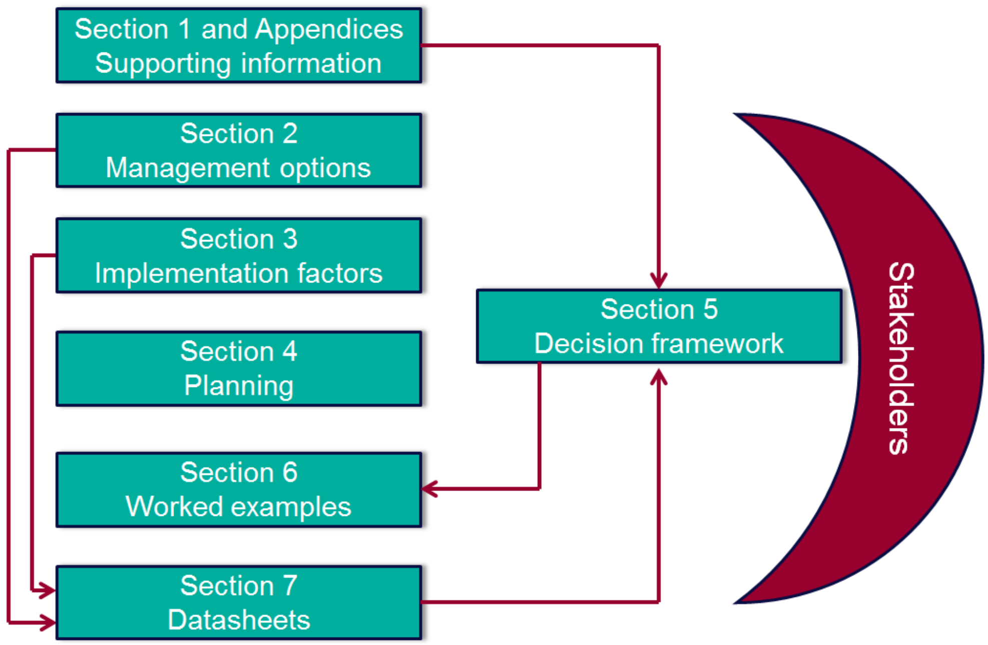
Table 1.1 Radionuclides considered in the Food Production Systems Handbook

Radionuclide		Dominant radiation type	Radioactive half-life
Symbol	Name		
^{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	35.15 d
^{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
^{131}I	Iodine-131	Gamma	8.04 d
^{132}Te	Tellurium-132	Gamma	78.2 h
^{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	Alpha/gamma	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	Alpha/gamma	432.2 y
^{252}Cf	Californium-252	Alpha/gamma	2.638 y

1.6 Structure of the Food Production Systems Handbook

The overall structure of the Food Production Systems Handbook is illustrated in Figure 1.1. 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. Section 2 provides an overview of management options for different types of food production system. Factors influencing the implementation of management options in contaminated areas are described 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. Datasheets for individual management options are presented in Section 7. Supporting and background information is provided in the four appendices. As noted in Section 1.3, the handbook should be used as part of a participatory process involving relevant stakeholders.

Figure 1.1 Structure of the Food Production Systems Handbook



1.7 Food production systems included in the Food Production Systems Handbook

1.7.1 Agricultural production systems

Most agricultural production in the UK is carried out under intensive management systems. There are nevertheless a few examples such as meat and fish production, where extensive systems make an important contribution to the diet. Table 1.2 and Table 1.3 give an overview of the types of agricultural food products for which the handbook can be applied to develop a recovery 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.

Table 1.2 Classification of intensive food production systems*

Food product	Sources/examples
Milk and other dairy products	Dairy cattle, sheep and goats
Meat	Grazing livestock: beef cattle, sheep and lamb, deer Free range: pig, poultry (chicken, turkey, geese and duck)
Eggs	Hens
Cereal	Wheat, barley, oats, oil seed rape, rye and maize
Vegetables and horticultural crops	Root crops (carrots, parsnips), tubers (potatoes), onions, legumes (peas, beans) brassicas (Brussel sprouts, cabbage, broccoli, cauliflower), salad (lettuce), other glasshouse and other protected crops
Industrial crops	Oil seeds, pulses, sugar beet, hops and watercress (watercress is grown in water)
Fodder plants	Silage, hay and root vegetables
Fruit	Orchard (apples, pears and plums), bush (blackberry, gooseberry), canes (raspberry), herbaceous (strawberry) and grapes
Honey	Commercial beehive
Fish	Fish farm (salmon and trout)
* The list is not exhaustive	

Table 1.3 Classification of extensive food production systems

Food product	Sources/examples
Meat	Hill lamb and hill beef
Fish	Marine fish, wild salmon, freshwater fish, shellfish, mussels, oysters, cockles, scallops, crab and lobster

1.7.2 Domestic food production and free foods

Table 1.4 and Table 1.5 give an overview of the types of domestic and free foods for which the handbook can be applied to develop a recovery strategy. 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 1.4 Classification of domestic food production

Food product	Sources/examples
Meat	Domesticated livestock and 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	For example: 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 1.5 Classification of free foods

Food product	Sources/examples
Meat	Waterfowl, wildfowl, game fowl such as pheasant, partridge, grouse, goose, duck, snipe and 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 and 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 and mackerel Shellfish such as clam, scallop, oyster, cockle, mussel, winkle, crab, lobster, prawn and shrimp
Freshwater fish and shellfish	Fish such as trout, carp, eel, grayling, perch, pike and salmon Shellfish such as crayfish
Honey	Feral beehive

1.7.3 Organic farming

Food produced from organic farming has to meet the same legal requirements as conventional food regarding chemical contamination. Some of the major aspects specific to organic food classification are as follows:

- restricted use of artificial fertilisers or pesticides
- use of conventional veterinary medicines is focused on treating sick animals
- emphasis on soil health and maintaining this through application of manure, compost and crop rotation
- processors of organic foods have a restricted set of additives to use

The datasheets (see Section 7) state where relevant if their implementation may affect the organic status of food.

1.7.4 City farms and community gardens

There are a number of city farms and community gardens in the UK. Each city farm and community garden is different. This is to be expected, as each one has developed in response to the needs of the local people, and has been affected by the availability of land. City farms and community gardens are commonly found in built up areas, where their creation was a response to the local communities' lack of access to green space. They can vary in size from a few square metres (the smallest community garden) to a number of hectares (the largest city farm). City farms and community gardens are usually set up by local volunteers. Some larger community farms and gardens go on to employ paid workers, while smaller groups rely on dedicated volunteers. Most groups are run by a management committee of local people and some are run as partnerships with local authorities, while retaining strong local involvement. It is envisaged that following a radiation incident these areas are likely to be treated as larger agricultural areas although for remediation of small areas of soil the inhabited section of the handbook should also be consulted.

1.8 Radiological protection criteria for food

1.8.1 Maximum permitted activity concentrations in foodstuffs

The Commission of the European Communities, now known as the European Commission, issued a number of Regulations concerning contamination levels in food that apply for accidents (CEC, 1989a; CEC, 1989b; CEC, 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 MPLs. At the time of writing these regulations are under review, and it is therefore possible that the regulations may soon be consolidated and replaced, and that this may alter some or all of the MPLs. MPLs represent an EU judgement on the optimum balance between the beneficial and harmful consequences of introducing food restrictions in the EU. In case the MPLs should prove inappropriate under the specific circumstances of a future accident, provision has been made within the regulations for the MPLs to be revised shortly after an accident. Such a revision depends on a qualified majority agreement by the member states. There is also a precedent for the European Commission to implement more restrictive levels using non-risk based criteria. For example, the regulations on imports from Japan following the Fukushima nuclear accident in 2011 introduced much lower maximum permitted levels to match those used internally by the Japanese authorities despite this being non-proportionate. This was because it was felt by some member states that allowing higher levels of activity concentration than were allowed in Japan would be perceived by the public as a lower level of protection.

The MPLs are listed in Table 1.6 (NRPB, 1994). There are MPLs available for 20 foods (CEC, 1989a; CEC, 1989b), and 3 are for animal feeds (CEC, 1990). The MPLs 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 definition of these food groups is summarised in NRPB (1994). The MPLs 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 MPLs 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.

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 MPL. 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 MPL of 1,250 Bq kg^{-1}.

Table 1.6 Maximum permitted levels (MPLs) for foods and animal feeds

Radionuclide	Intervention levels (Bq kg^{-1}) Baby foods	Dairy produce*	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#	1	20	800	80	20
All other radionuclides of half-life greater than 10 days†	400	1,000	12,500	1,250	1,000
Animal feed intended for	**Intervention levels‡ (Bq kg^{-1})**				
Pigs	1,250				
Poultry, lambs and calves	2,500				
Other	5,000				

* Milk and cream only

\# This category includes ^{238}Pu and ^{241}Am

† 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

‡ Intervention levels are for ^{134}Cs and ^{137}Cs only

The MPLs 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 MPL given for each group, then the food will not be subject to restrictions.

The relationship between MPLs 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 MPLs 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.

Practical guidance has been developed for the UK on the activity concentrations of radiocaesium and radiostrontium in feedstuffs and drinking water for animals that would give rise to concentrations equivalent to the relevant MPL in the final animal products, based on UK husbandry practices (Woodman and Nisbet, 1999).

1.8.2 Food and Environment Protection Act

In the immediate aftermath of a nuclear accident, the Food Standards Agency (FSA) would issue precautionary advice to cover any area where it is assessed that food may be unsafe, for example where levels of radioactivity in food may exceed the MPLs. The FSA may consider using legislative controls where advice or guidance is not sufficient to protect the public. This may take the form of a statutory food order under the Food and Environment Protection Act 1985 (FEPA). This restricts the movement, supply or sale of certain foods or food products from within a designated area, and may be implemented within as little as 24 to 48 hours. A FEPA order may impose an outright ban on the movement and sale of affected products and livestock from the designated area. Alternatively, particularly if controls are applied for a longer period, the FEPA order may specify monitoring controls or other conditions which must be met before food can be released onto the market. The size of the area affected by food restrictions may be large as the numerical values of the MPLs are low in radiological terms. Monitoring carried out following an accident would enable the boundaries of restricted areas to be reviewed on a regular basis.

A FEPA order typically applies to all forms of agricultural production, however, there are also provisions for prohibiting the gathering and picking of wild plants (eg fungi), and the gathering of wild game and fish. Domestically produced food is not covered by a FEPA order, which means the public cannot be prevented formally from eating its own produce from an allotment or garden. Nevertheless, it is possible to prohibit the processing and supply of domestic produce and its movement outside the FEPA area. A FEPA order is likely to be accompanied by advice and guidance covering non-commercial food.

The size of the area covered by FEPA orders may vary considerably depending on the radiation incident. They may cover a relatively small area or extend to tens or possibly hundreds of kilometres from the site of the incident. Thus, it is likely that many gardens and allotments would lie within a region where commercial production is subject to restrictions. Despite there being no legally binding intervention levels that can be applied to domestic production, the FSA has a statutory responsibility to advise the public on whether food is safe to eat. The immediate advice from FSA in the first few hours of a nuclear emergency would be for the public not to eat any home produce from within the area covered by its precautionary advice. After monitoring the area, the next stage would be to assess the level of risk from eating the produce and to communicate this to the public. PHE recognises that it is difficult to enforce restrictions on the consumption of foods that are not marketed. Nevertheless it recommends that the MPLs should be used to trigger advice intended to restrict the intake of radionuclides by individuals producing their own food (NRPB, 1994).

1.8.3 Additional radiological criteria for food in the longer term

Initially, during the emergency phase, protection from the ingestion of contaminated foodstuffs will be provided by the intervention levels described above. In the years that follow, it may be possible to take a more holistic risk-based approach that avoids unnecessary restrictions being imposed on the foodchain, while maintaining consumer safety. The approach involves probabilistic dose modelling in conjunction with monitoring affected foodstuffs to estimate the distribution of doses to a more highly exposed consumer over a year. This approach is most applicable where the ingestion pathway dominates and only one or two foodstuffs are affected. In this case, a reference level of effective dose over a year, applicable to an existing exposure situation (ICRP, 2007), would be used as a benchmark for comparison with annual doses calculated for high rate consumers. For most foreseeable situations in the UK, reference levels recommended by the international community for existing exposure situations are appropriate for guiding recovery decisions (ie < 20 mSv y^{-1}). For example, the probabilistic dose modelling approach was used successfully in 2012 to release sheep farming areas in the UK that had been held under restriction following the Chernobyl accident in 1986. In this case doses to high rate consumers of lamb from the restricted areas were less than 1 mSv y^{-1} (FSA, 2011; FSA, 2012).

1.9 Terminology

1.9.1 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 Food and Agriculture Restoration Management Involving Networked Groups (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. Management options encompass interventions aimed at reducing or averting contamination, or the likelihood of contamination, of food production systems and span both emergency and recovery phases.

1.9.2 Timescales for implementing management options

It will be necessary to implement management options following a nuclear or radiation incident 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 to 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 to 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 recognised among organisations responsible for emergency and long-term management that planning and preparing in advance of a nuclear or radiation 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.

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2 Management Options

A large number of management options for use in agricultural, domestic and semi-natural ecosystems have been developed since the accident at the Chernobyl nuclear power plant, Ukraine in 1986. Some of these have been adapted and improved for site-specific conditions following the accident at Fukushima Dai-ichi nuclear power plant, Japan, in 2011. However, not all of these are applicable for implementation in the UK. Extensive discussion and debate within the UK Agricultural and Food Countermeasures Working Group (AFCWG) since 1997 has enabled a subset of options to be selected for inclusion in the handbook. Appendix B presents a list of the management options that have been excluded from the handbook and reasons are given for their exclusion.

The 42 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, other animal products and food produced domestically or gathered from the wild. The management options are not only aimed at addressing health concerns but also a wide range of other issues at stake, such as the local economy, societal concerns and disposal of wastes. While many options are of a technical nature involving some form of physical or chemical intervention to reduce transfer of radionuclides in the foodchain, there are a few options that simply provide advice, reassurance monitoring and information, and support to the public for self-help actions. Table 2.1 provides a list of all the management options considered in the 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 7 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.

Intervention along the soil-to-plant pathway includes options that remove contamination by removing topsoil, or reduce soil-to-plant transfer of radionuclides by ploughing or application of ameliorants. In animal production systems, the ingestion of contaminated feed by livestock can be managed by the provision of uncontaminated feed or the movement of animals to less contaminated pasture for a period of time before slaughter. Livestock can also be given chemicals to reduce the uptake of radionuclides by the gut, eg administration of Prussian blue in feed for incidents involving radiocaesium.

Considerable volumes of contaminated waste can be generated as a result of the placing of restrictions on the marketing of crops, milk and meat. As these restrictions are based on statutory requirements it is essential that appropriate routes of disposal be identified in advance of future accidents or incidents. These waste disposal options range from relatively simple in-situ methods (ploughing-in, composting and landspreading) to offsite commercial treatment facilities (ie landfill and incineration).

Table 2.1 provides a list of all 42 management options that are applicable to food production systems. Figure 2.1 to Figure 2.8 give the options considered in the handbook for each of the food types described in Table 1.2. The number in brackets refers to the relevant datasheet (see Section 7).

Table 2.1 List of management options considered for food production systems

Number	Name
Pre-deposition phase	
(1)	Close air intake systems at food processing plant
(2)	Prevent contamination of greenhouse crops
(3)	Protect harvested crops from contamination
(4)	Short-term sheltering of animals
Early to late phase	
General applicability	
(5)	Natural attenuation (with monitoring)
(6)	Product recall
(7)	Restrict entry into foodchain (including FEPA orders)
(8)	Select alternative land use
Soil/crops/grassland	
(9)	Application of lime to soils
(10)	Application of potassium fertilisers to soils
(11)	Deep ploughing
(12)	Land improvement
(13)	Removal of topsoil
(14)	Shallow ploughing
(15)	Skim and burial ploughing
Livestock and animal products	
(16)	Addition of AFCF to concentrate ration
(17)	Addition of calcium to concentrate ration
(18)	Addition of clay minerals to feed
(19)	Administer AFCF boli to ruminants
(20)	Clean feeding
(21)	Live monitoring
(22)	Manipulation of slaughter times
(23)	Selective grazing
(24)	Slaughtering (culling) of livestock
(25)	Suppression of lactation before slaughter
Domestic production and wild foods	
(26)	Clean feeding (domestic livestock)
(27)	Dietary advice (domestic)
(28)	Processing or storage of domestic food products
(29)	Provision of monitoring equipment (domestic produce)
(30)	Restrictions on foraging (gathering wild foods)
(31)	Restrictions on hunting and fishing seasons
Waste disposal options	
(32)	Biological treatment (digestion) of milk
(33)	Burial of carcasses
(34)	Composting
(35)	Disposal of contaminated milk to sea
(36)	Incineration
(37)	Landfill

Number	Name
(38)	Landspreading of milk and/or slurry
(39)	Ploughing in of a standing crop
(40)	Processing and storage of milk products for disposal
(41)	Rendering
(42)	Soil washing

Figure 2.1 Management options for cereals and grassland (commercial – for domestic production see Figure 2.8)

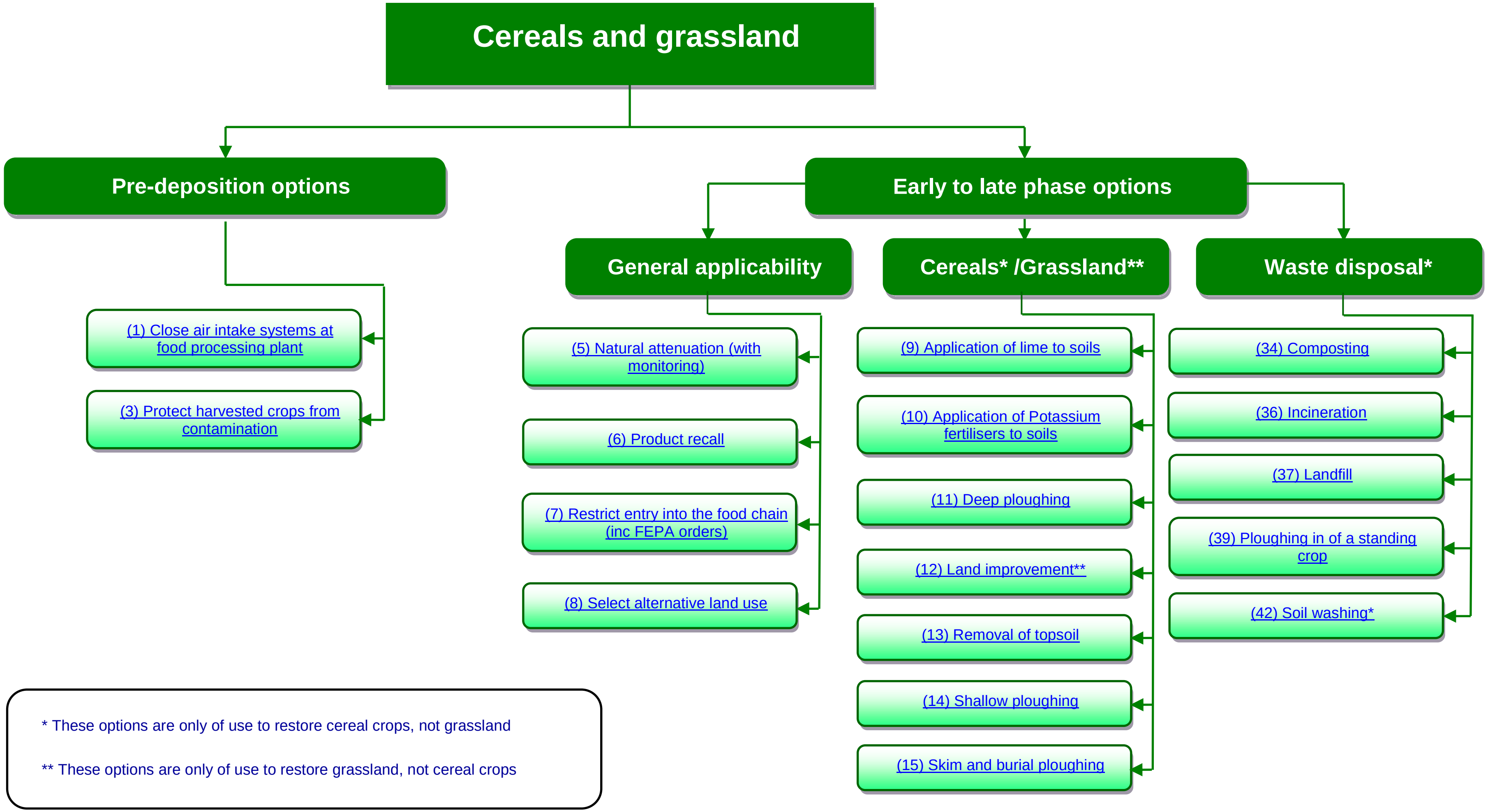


Figure 2.2 Management options for fruit and vegetables (commercial – for domestic production see Figure 2.8)

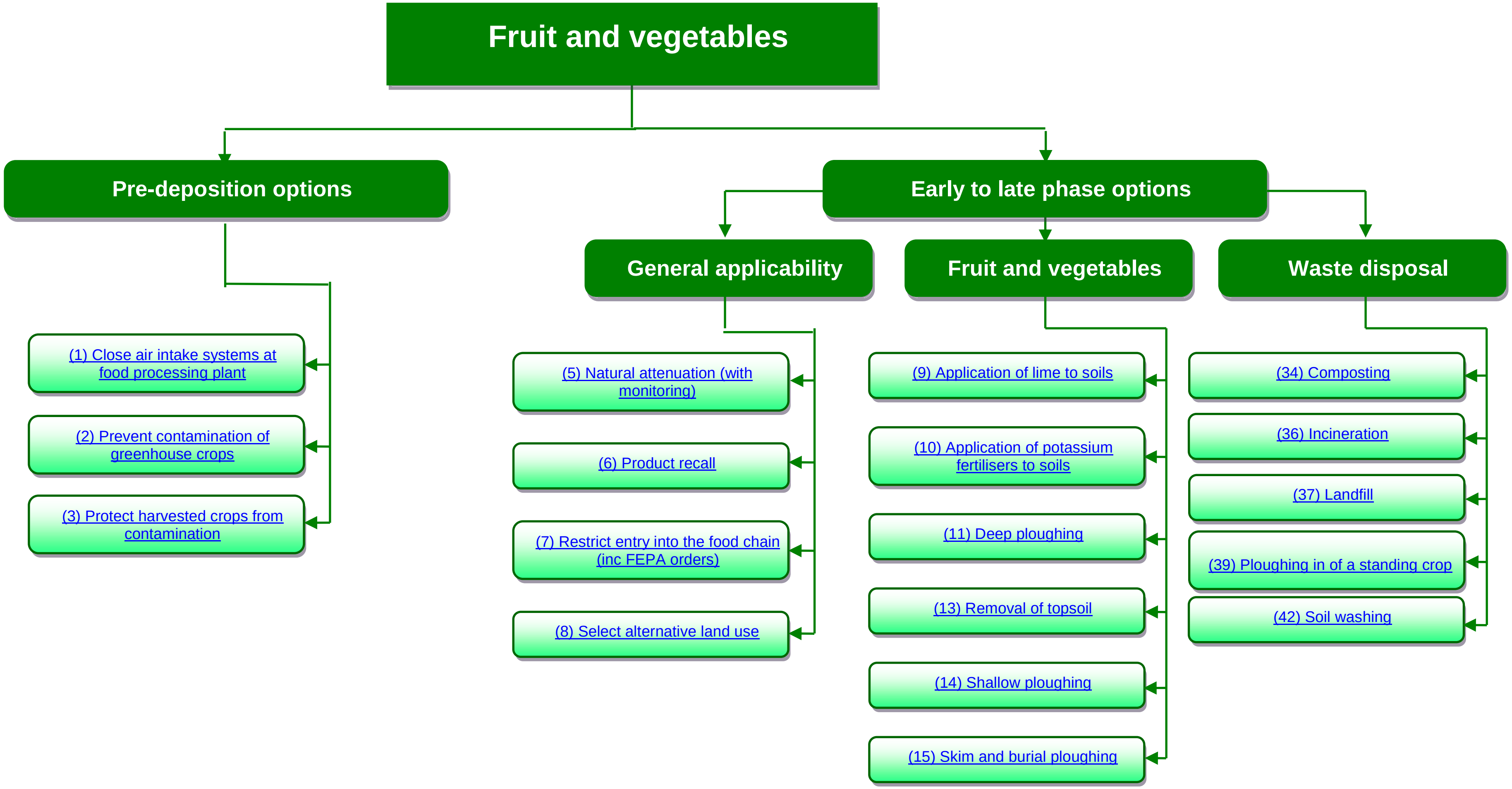


Figure 2.3 Management options for milk (commercial – for domestic production see Figure 2.8)

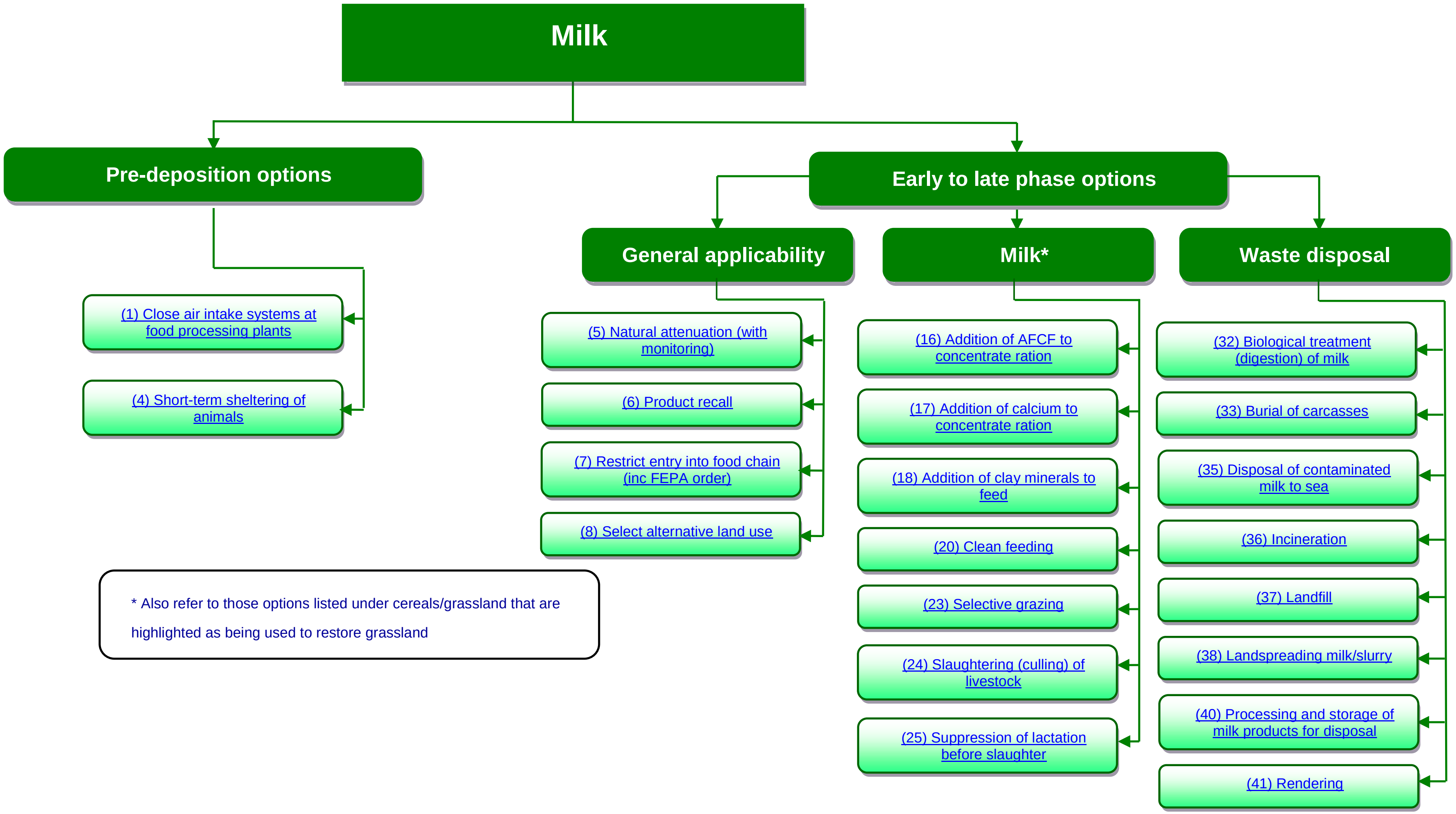


Figure 2.4 Management options for meat (commercial – for domestic production see Figure 2.8)

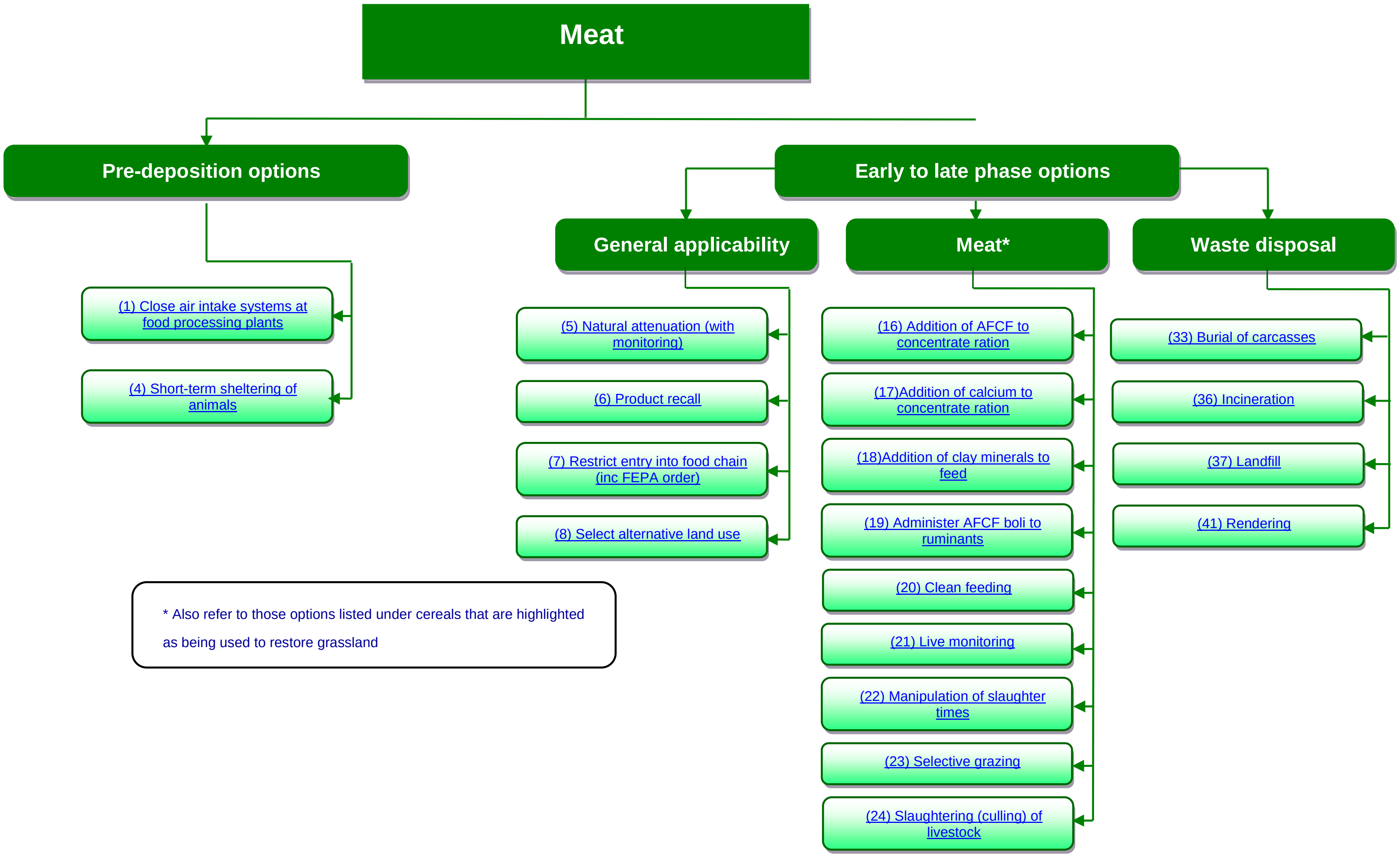


Figure 2.5 Management options for eggs (commercial – for domestic production see Figure 2.8)

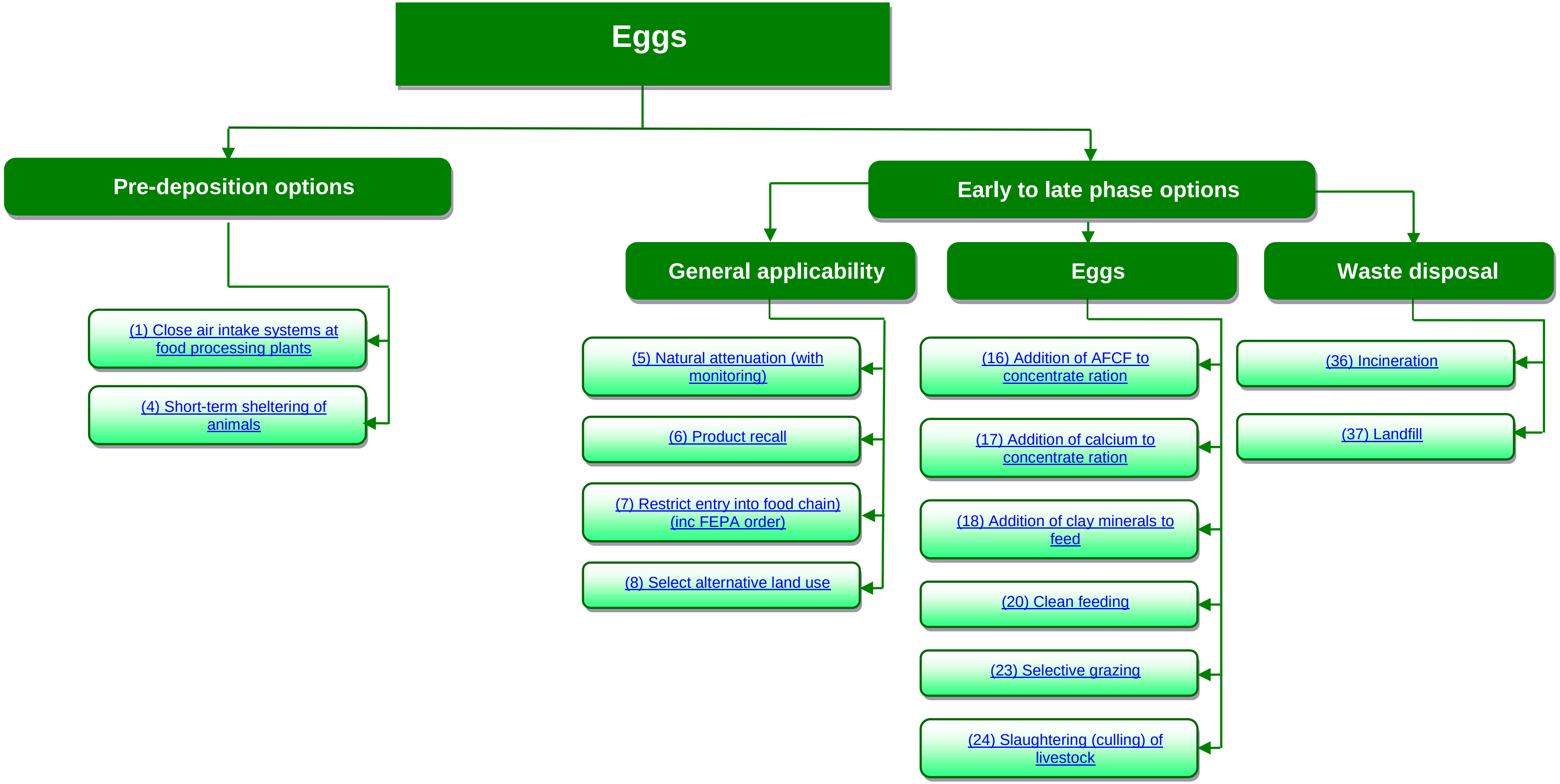


Figure 2.6 Management options for honey (commercial – for domestic production see Figure 2.8)

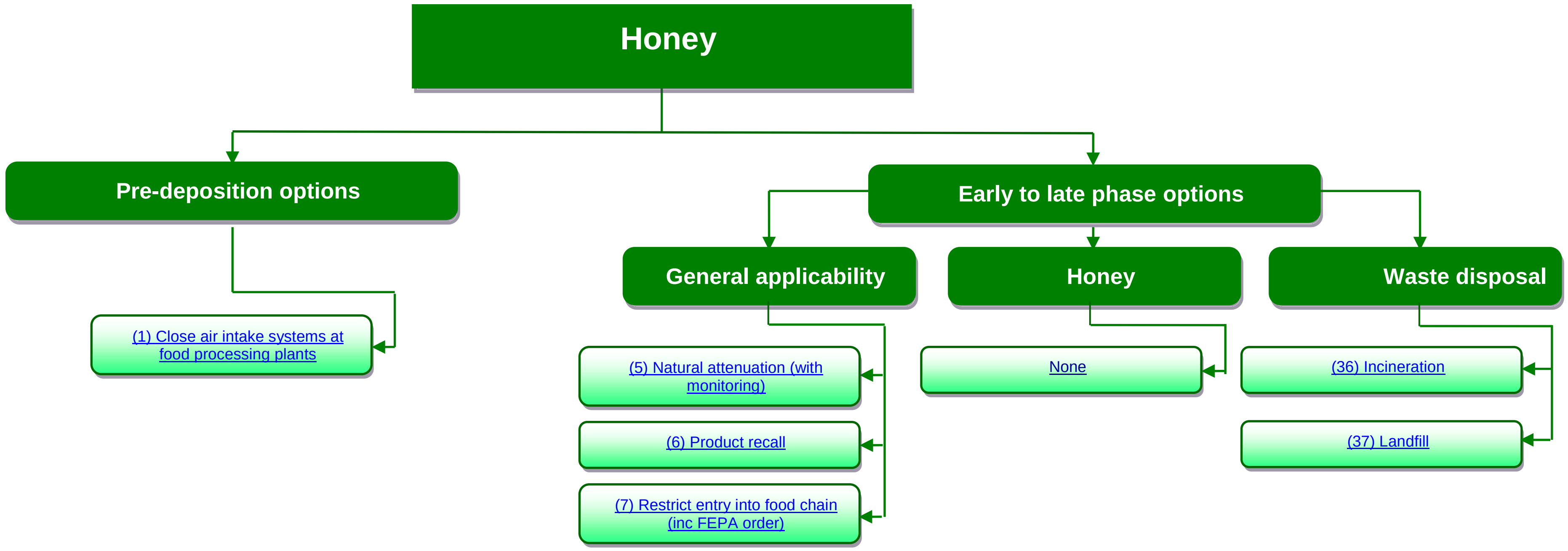


Figure 2.7 Management options for freshwater and marine fish (commercial – for domestic production see Figure 2.8)

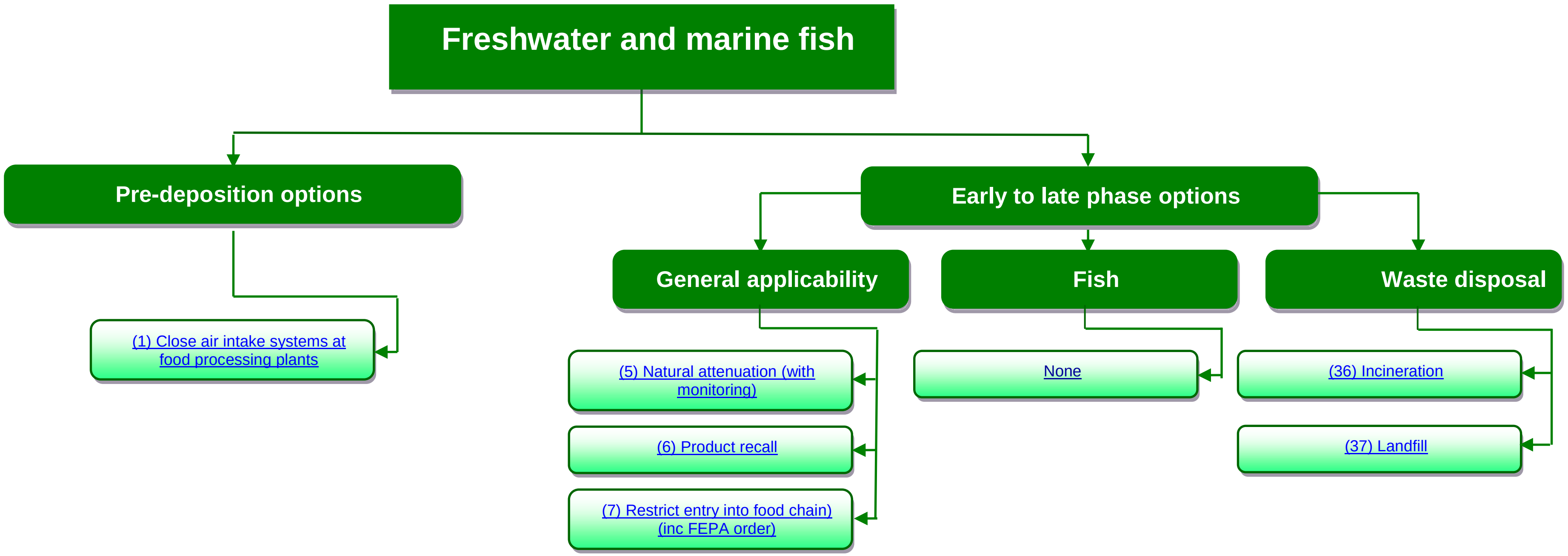
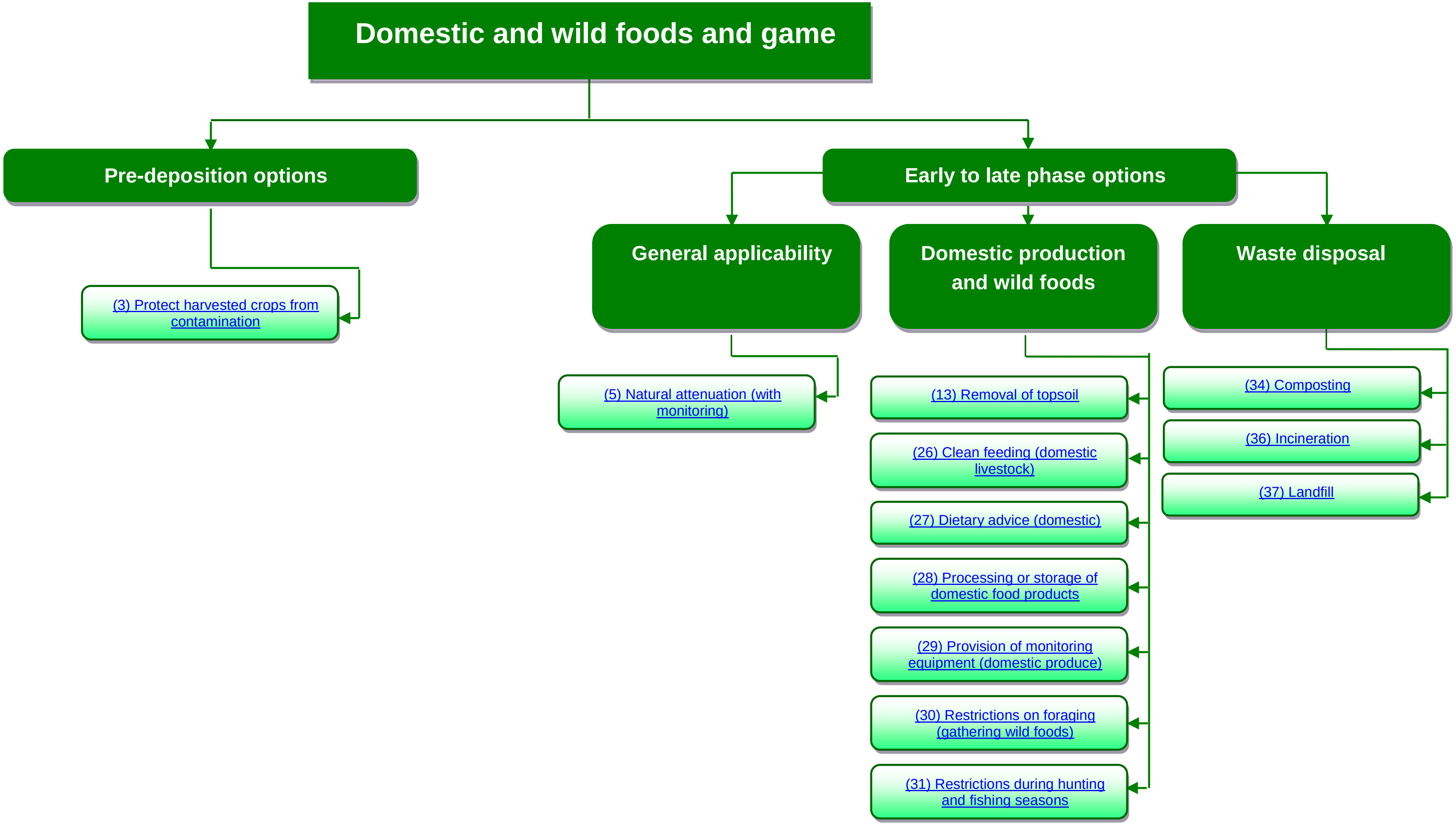


Figure 2.8 Management options for domestic and wild foods and game



3 Factors Influencing Implementation of Management Options and Recovery Strategy

3.1 Application of radiological protection principles when developing a recovery strategy

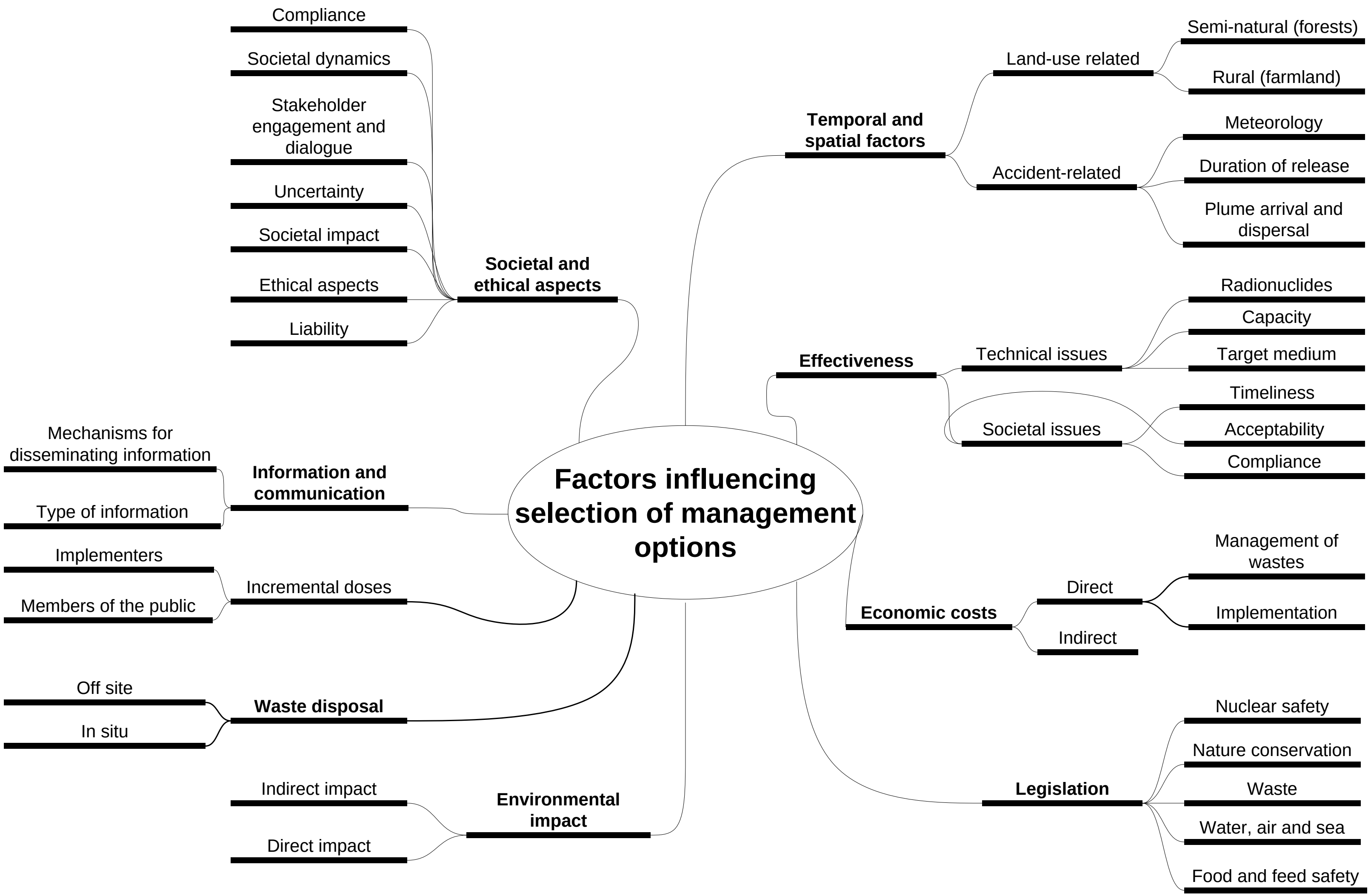
The implementation of a recovery strategy has to be justified and the protection afforded by the strategy must be optimised. Reference levels of effective dose are used to constrain the optimisation process by either assisting in the planning of recovery strategies so that individual doses fall below the reference level or acting as a benchmark for judging the effectiveness of strategies after implementation. These concepts are consistent with those recommended by the ICRP (ICRP, 2007; ICRP, 2009) and are elaborated further below.

Justification of a recovery strategy goes far beyond the scope of radiological protection as implementation of recovery options may also have various economic, environmental, social and psychological impacts. What is important is that the overall recovery strategy is justified in as much as it brings sufficient individual or societal benefit to offset any associated detriments. For example, a range of individually justified options may be available but not provide a net benefit when considered as an overall strategy because collectively, they may bring too much disruption or may be too complex to manage.

The principle of optimisation is applied to situations where the implementation of a recovery strategy is already justified. Optimisation should ensure selection of the best strategy under the prevailing circumstances to maximise the margin of good over harm, and to meet key recovery goals. Unlike emergency situations, where there is a need to take urgent action, the optimisation process during recovery can be implemented step by step. The best strategy is not necessarily the one that results in the lowest dose for individuals. Furthermore, it is not relevant to determine, a priori, a dose level below which the optimisation process should stop as this depends on incident specific and location specific factors.

When carrying out optimisation of recovery strategies there are a number of factors that need to be taken into account. This section identifies the most important criteria although decision-makers, implementers and other stakeholders may identify additional ones that are incident and site specific. The illustration presented in Figure 3.1 gives an overview of the key criteria that might need to be considered, broken down into their main components.

Figure 3.1 Diagram showing some of the factors that might influence the selection of management options



3.2 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 its use, have a significant influence on the selection of management options. Such a selection should also take account of issues relating to time (eg when the incident occurred, time since it occurred, variation of activity concentrations of radionuclides over time, movement of radionuclides through the foodchain over time (Appendix C) and space (eg area affected, contamination zones based on deposited activity, and how these change over time). The dynamics of an event strongly depend on the kind of facility that is involved (eg 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 (eg 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. An example is the accident that occurred at the Chernobyl nuclear power plant.

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 may be a short period during which particulates continue to settle to ground from the atmosphere. Resuspension may occur, and resuspended material may then re-deposit in new areas. Otherwise, assuming the release does not restart, 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 C).

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, eg 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 the option to be effective, eg short-term sheltering of livestock or protection of harvested crops. However, many actions take time to organise and prepare (eg clean feeding or distribution of feed additives). Where the deposit contains short-lived radionuclides an option needs to be implemented quickly for it to be worthwhile. For less urgent situations (eg 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 or deep ploughing. In such situations, stakeholder dialogue and consultation will be essential and sufficient time must be allowed (ie 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 (eg 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 (eg 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.

3.2.1 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, 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.

3.2.2 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 (it can be delayed for days, weeks or even months).

3.2.3 Management options that are applicable in the medium 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.

3.3 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 (ie soil, crop or animal products) after implementing the option.

Other than the imposition of food restrictions, there are many other recovery options that can be implemented to great effect in agricultural food production systems, either singly or in combination. Substitution of an animal’s diet with uncontaminated feed or adoption of a selective grazing regime are particularly effective at reducing radionuclide transfer to livestock. Removal of topsoil is effective in crop and grassland production but the amounts of waste generated tend to favour a combination of less effective and less disruptive options involving various forms of ploughing and ameliorants.

There are some management options, which may be considered more as supporting measures (eg 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 effectiveness guidance is provided on individual datasheets (see Section 7). Generic non-exhaustive information on the more commonly encountered factors that affect effectiveness is listed below.

3.3.1 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 3.3.2). They have been subdivided in Table 3.1 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 3.1 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 eg 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

3.3.2 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 3.2.

Table 3.2 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

3.4 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.

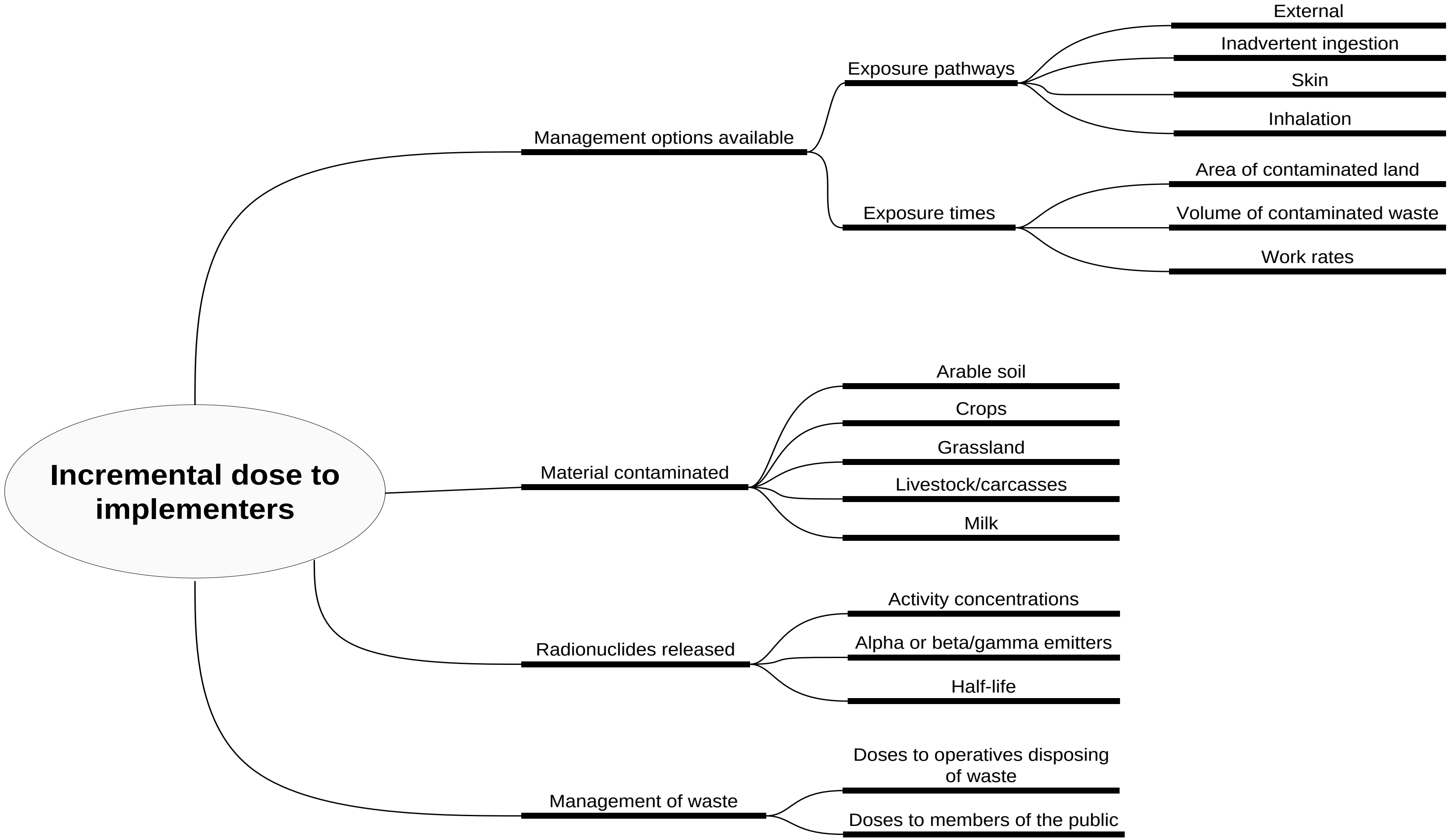
A number of factors influence the doses people receive as a consequence of implementing management options (see Figure 3.2). The most important factors to consider are the radionuclides released into the environment and the type of medium that is contaminated (eg arable soil, crops, grassland, livestock or milk).

When implementing a management option the major exposure pathways to consider are external irradiation, inhalation of resuspended 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 beta or gamma emitting radionuclides the highest dose is generally due to external exposure to soil, whereas for some alpha emitting radionuclides the highest dose is due to the inhalation of resuspended material.

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 (eg topsoil removal, see Section 3.5), 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 (eg application of contaminated sewage sludge to land following anaerobic digestion of waste milk).

Figure 3.2 Key factors to be considered when calculating incremental doses



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.

3.5 Waste disposal issues

3.5.1 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 C), some or all of this produce may contain activity concentrations of radionuclides in excess of maximum permitted levels (Table 1.6). 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 (eg if the radionuclide has short half-life and/or crop is immature, or livestock are 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

Of the four categories listed above, re-introduction of food products following removal of contamination and feeding of contaminated products to animals were deemed unacceptable from a consumer confidence perspective by the Agriculture and Food Countermeasures Working Group (see Appendix B), and have not been considered further in this handbook.

3.5.2 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 (see Table 3.3).

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

Ten options have been identified for the disposal of these wastes. Comprehensive guidance on these options is given in the individual datasheets (see Section 7). 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 3.4). 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 in Figure 3.3.

Table 3.3 Management options giving rise to waste

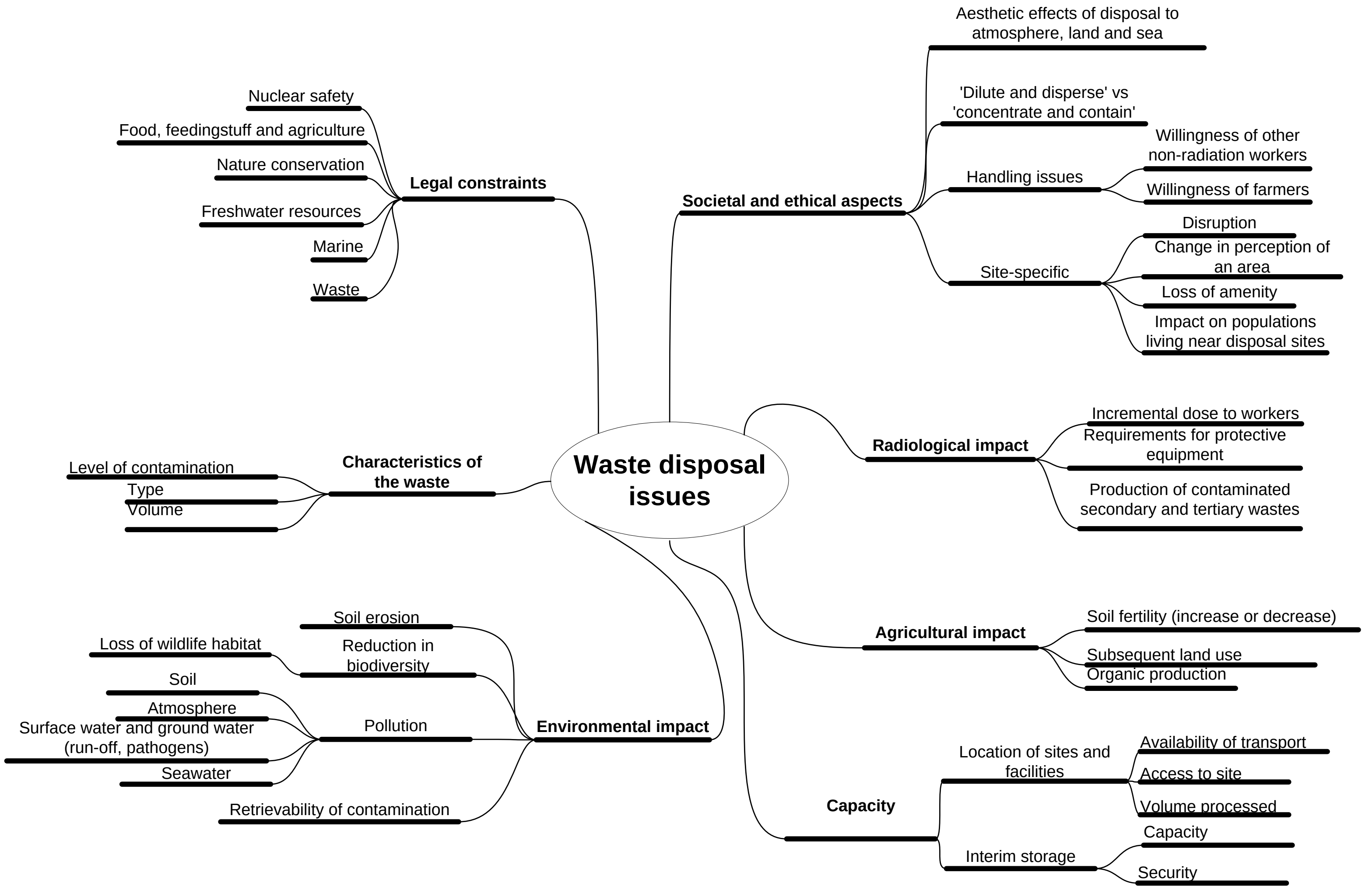
Management option	Waste produced
Clean feeding	Cut grass and slurry
Restriction on the entry of food into the foodchain (food ban)	Crops, milk and meat
Slaughtering of dairy livestock	Animal carcasses
Topsoil removal	Soil

Table 3.4 Classification of waste disposal options

In situ	Target medium
Composting*	Crops and cut grass
Landspreading of milk and/or slurry*	Milk
Ploughing in of a standing crop	Crops and pasture
Off-site	**Target medium**
Biological treatment (digestion) of milk	Milk
Burial 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

* Can also be carried out off-site

Figure 3.3 Diagram illustrating some of the main waste disposal issues to be considered when constructing a strategy of management options



3.6 Societal and ethical factors

The consequences of a radiation 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 (ie 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).

3.6.1 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 from 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.

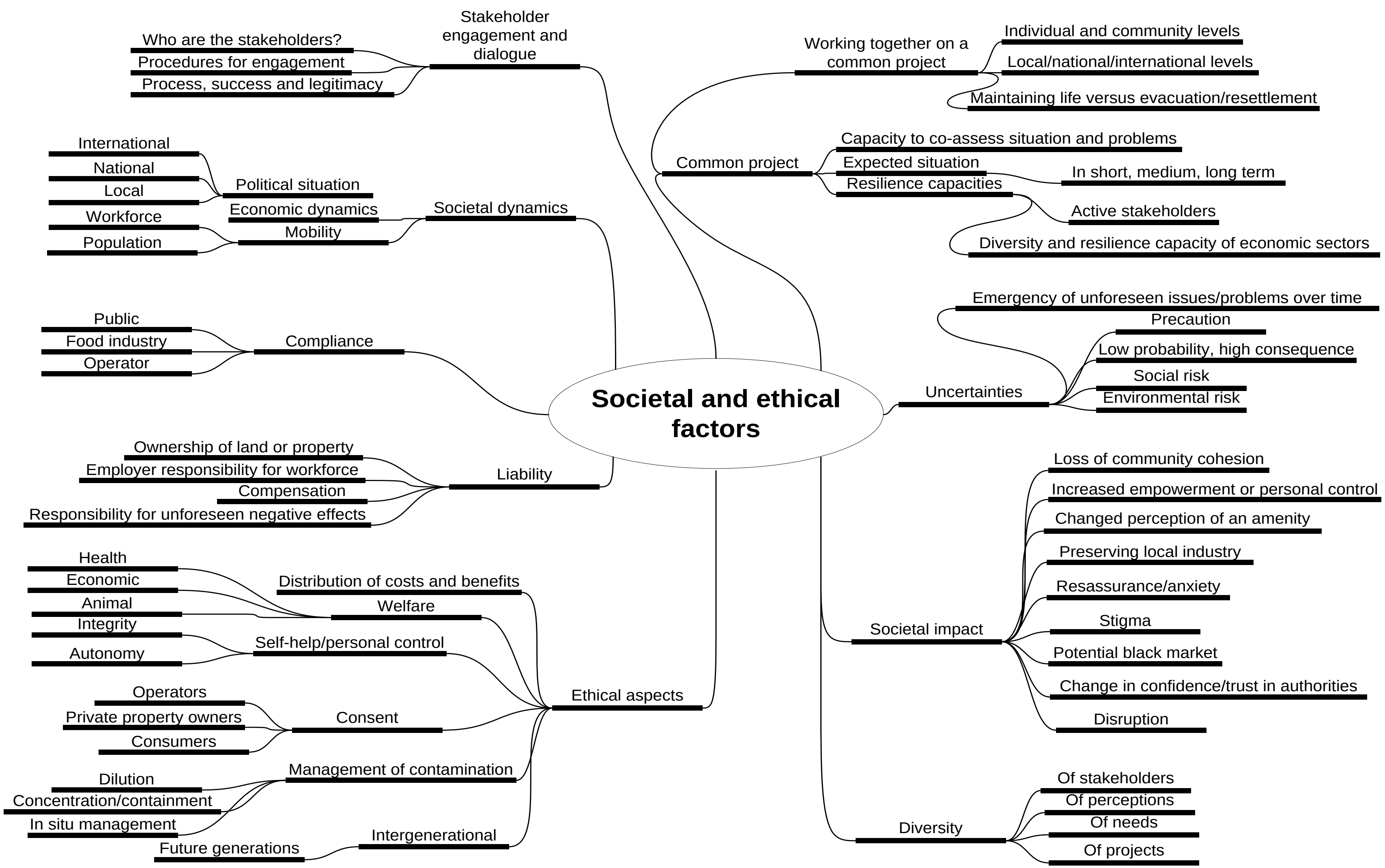
3.6.1.1 Overview of criteria affecting societal and ethical aspects

Figure 3.4 presents an overview of some of the main societal and ethical factors associated with a radiation 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 (eg compliance may depend on the perceived disruption) and may produce knock-on effects (eg 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 3.10).

Figure 3.4: Societal and ethical factors to be considered when constructing a strategy of management options



3.7 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 (ie air, soil and water, as well as natural habitats and ecosystems such as forests, moorlands). Each environment has a diversity of uses for different stakeholders (ie those involved in farming, recreation and leisure, study and ecology). 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 (eg 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).

3.7.1 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, (Table 3.5). specific options given in parentheses. Management options also have indirect impacts on the environment which have societal consequences (Table 3.6).

Table 3.5 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 and land improvement)
Change in mineralisation of organic matter (potassium and lime applications, ploughing and land improvement)
Changes in bioavailability and mobility of nutrients and pollutants may lead on to effects on water quality (potassium and lime applications, ploughing and land improvement)
Soil fertility destroyed (topsoil removal and 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 and 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 and 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 and landspreading of milk) could lead to pollution of water courses and re-distribution of radionuclides

Table 3.5 Direct environmental impact of management options
Changes in grazing pressure could cause changes to landscape and increases in biodiversity (manipulation of slaughtering time and selective grazing)
Options directed at changing land use
Change in ecosystem and biodiversity (select alternative land use, to non-food products)

Table 3.6 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 (eg 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

3.8 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 3.7), handling of wastes (Table 3.8), as well as indirect costs such as those incurred through impact on the environment and loss of market share (Table 3.9). 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 3.7 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 (eg ammonium ferric hexacyanoferrate (AFCF) or other additives)
Specific equipment: some management options (eg 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 (eg civil protection, police, military, overseas consultants), leading to extra costs for travelling and subsistence, fees or salaries, etc
Transportation
Verification of laboratory analyses or screening techniques

Table 3.8 Direct economic costs of handling waste products

Labour
Special consumables for interim storage and processing of byproducts after the intervention
Dedicated equipment: special containers etc
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 3.9 Indirect costs

Indirect loss down the supply chain when production is stopped, as particular supplies and services will no longer be required
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 (eg in the case of deep ploughing) or acidity, and pollution of surface water (not only radiological, but also biological or chemical)
Loss of market share. Even if the food products originating from the affected area comply with the maximum permitted levels (MPLs) 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 (eg county, province or 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 (eg 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)

3.9 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 (maximum permitted levels, MPLs). These MPLs 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 MPLs shortly after the event. MPLs 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 and wildlife. This legislation will impact on whether particular management options can be implemented. The datasheets presented in Section 7 contain information on relevant European and UK legislation for each management option. A non-exhaustive summary of key legislation applicable to the management of food production systems is presented in Table 3.10. This table was compiled in 2009 and legislation may have been subsequently updated or superseded.

Table 3.10 Non-exhaustive summary of key legislation applicable to the management of food production systems

EC legislation	UK legislation	Management options affected by legislation
Nuclear safety		
Council Directive 2013/59/Euratom of 5 Dec 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29 Euratom, 97/43/Euratom and 2003/122/Euratom. Official Journal of the European Union 7/01/2014 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	The Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) (not applicable to transport) Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 The Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1983 Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000	All management options 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 feeding stuffs. 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 feeding stuffs following a	Animal Welfare Act 2006 The Welfare of Farmed Animals (England) Regulations 2000; Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000 Food and Environment Protection Act, 1985 Food Safety Act, 1990	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 Restriction on the entry of food into the foodchain Live monitoring Manipulation of slaughter time Slaughtering of dairy livestock Suppression of lactation before slaughter

Table 3.10 Non-exhaustive summary of key legislation applicable to the management of food production systems

EC legislation	UK legislation	Management options affected by legislation
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 feeding stuffs 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		
Nature conservation and terrestrial living resources		
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	Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981 National Parks and Access to the Countryside Act 1949, as amended by NERC The Game Act 1831 and Game Act 1970. The Game (Scotland) Act 1832. Game Preservation (Amendment) Act (Northern Ireland) 2002: Ground Game Act 1880 and Ground Game (Amendment) Act 1906 Salmon and Freshwater Fisheries Act 1975: Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003 Conservation (Natural Habitats & c) Regulations 1994 as amended, in England, Scotland and Wales, and the Conservation (Natural Habits etc) Regulations (Northern Ireland 1995 as amended.	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 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 ground water against pollution caused by certain dangerous substances	The Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999 Urban Waste Water Treatment (England and Wales) Regulations 1994 as amended, the Urban Waste Water Treatment (Scotland) Regulations 1994 as amended or the Urban Waste Water Treatment Regulations (Northern Ireland) 1995 as amended Groundwater Regulations 1998 and Groundwater Regulations (Northern Ireland) 1998 Water Resources Act (England and Wales) 1991, the Control of Pollution Act 1974 and Water Environment and Water Services (Scotland) Act 2003 in Scotland, and the Water (Northern Ireland) Order 1999	Select alternative land use Application of lime to arable soils and grassland 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 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) Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972)		Disposal of contaminated milk to sea
Waste		
Council Directive 96/61/EC (Integrated Pollution Prevention and Control Directive) of 24 September 1996 concerning integrated pollution prevention and control 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 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 Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972 Council Directive 1999/31/EC of 26 April 1999 on the landfill	Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, Pollution Prevention and Control (Scotland) Regulations 2000 as amended or Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended, made under the Pollution Prevention and Control Act 1999 (PPC) Sludge (Use in Agriculture) Regulations 1989 (as amended) and the Sludge (Use in Agriculture) Regulations (Northern Ireland) 1990 (as amended) Radioactive Substances Act 1993 (RSA93). Environmental Protection Act 1990 (EPA90) Waste Management Licensing Regulations 1994 as amended (WMLR) in England, Scotland and Wales. For Northern Ireland the Waste Management Licensing	Biological treatment of milk Burial of carcasses Composting Disposal of contaminated milk to sea Incineration Landfill Landspreading of milk Processing and storage of milk products for disposal Rendering

of waste	Regulations (Northern Ireland) 2003
The Euratom Treaty Article 37 (1957) on the provision of general data on the disposal of radioactive waste Council Directive 2000/76/EC (Waste Incineration Directive) of 4 December 2000 on the incineration of waste 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 Council Directive 91/689/EEC of 12 December 1991 on hazardous waste	Water Resources Act 1991. Control of Pollution Act 1974 and the Water Environment and Water Services (Scotland) Act 2003 and in Northern Ireland by the Water and Sewerage Services (NI) Order 1973 and the Water (Northern Ireland) Order 1999 as amended. Water Industry Act 1991 in England and Wales, the Sewerage (Scotland) Act 1968 and the Water and Sewerage Services (Northern Ireland) Order 1973. Animal By-Products Regulations 2005, the Animal By-Products (Scotland) Regulations 2003, the Animal By-Products (Wales) Regulations 2003 and the Animal By-Products Regulations (Northern Ireland) 2003 Landfill (England and Wales) Regulations 2002 as amended, Landfill (Scotland) Regulations 2003 as amended and the Landfill Regulations (Northern Ireland) 2003 as amended The Waste Incineration (England and Wales) Regulations 2002, the Waste Incineration (Scotland) Regulations 2003 and the Waste Incineration Regulations (Northern Ireland) 2003 as amended Rendering (Fluid Treatment) (England) Order 2001 or the Rendering (Fluid Treatment) (Scotland) Order 2001 made under the Animal Health Act 1981. For Northern Ireland the Rendering (Fluid Treatment) Order (Northern Ireland) 2001 is used, which is made under the Diseases of Animals (Northern Ireland) Order 1981

3.10 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.

3.10.1 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.

3.10.1.1 Communication of general event information

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 (eg media, internet and 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.

3.10.1.2 Communication of information for 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 are 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, and 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.

3.10.2 Mechanisms for communication and dissemination

3.10.2.1 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.

3.10.2.2 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 (ie those inside and outside the affected area, those involved in implementing actions and 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

3.11 References

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4 Planning for Recovery in Advance of an Incident

The response to the effects of a major UK accident or emergency is managed primarily at the local level. It is a general principle that there should be a detailed emergency planning zone (a few square kilometres) for civil nuclear accidents up to the worst case most reasonably foreseeable accident (also known as the reference or design basis accident) and extendibility for accidents in excess of this. Emergency plans are drawn up in advance of an incident in order to provide an effective response within the emergency planning zone. They are easily applied and are universally accepted. Emergency plans do not include actions to be taken in the post-emergency phase (ie recovery phase) when it is much more difficult to be prescriptive about actions to take due to variations in local circumstances. Nevertheless it is recognised that there should be planning for recovery up to the reference basis accident, albeit in much less detail.

It is important to note that in agricultural areas, significant quantities of contaminated foodstuffs can arise following a release of radionuclides representative of the reference accident. Restrictions on the movement and sale of this produce are likely to extend out to distances up to 25 km from the site for such reference accidents (ie well beyond any areas subject to emergency countermeasures within the detailed emergency planning zone). The larger the area affected the more complicated and demanding the level of planning required will be. Given the perishable and biodegradable nature of foodstuffs it is particularly important to develop outline arrangements for disposing of waste food. These arrangements are likely to be site specific according to the characteristics of the local infrastructure. The UK Agriculture and Food Countermeasures Working Group has made good progress in this area in its guidance document 'Dealing with milk following a nuclear emergency' (AFCWG, 2007), which contains information on responsibilities of organisations involved in the response and practical aspects of many of the disposal options. Under the auspices of the Nuclear Emergency Planning Liaison Group (NEPLG), a UK Nuclear Recovery Planning Group has been established to provide a focus for sharing and driving improvements in recovery planning for civil and military nuclear accidents. The Group has developed the UK Nuclear Recovery Plan Template (DECC, 2013) which is a living document that provides guidance on all aspects of the decision making process, including who to involve, issues to address and a template for a recovery action plan.

Consideration of topics such as 'requirements for information' and 'outline arrangements' prior to an emergency would benefit the speed of recovery response in the event of an incident and 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. Some of these databases may already exist, but even then, it is not widely known who would be the point of contact and who would have responsibility for maintaining the databases (the type of information stored could rapidly become out-of-date). The list of information requirements presented in Table 4.1 appears quite wide ranging and it is not yet clear how much effort would be required to assemble such information. Clearly, priorities would need to be assigned to help make best use of available resources. 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 outline arrangements for a recovery strategy, focused at the local level, in advance of an incident.

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 or access to databases providing information on the following: rapid identification of milk producers in an area rapid identification of milk purchasers within an area, since the 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 (eg 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 or 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 or 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 or access to database of people with licenses for fishing and hunting in the area (Environment Agency)
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 (eg 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 Availability of or access to national database of suppliers of monitoring equipment, including arrangements for dispatching equipment
	Infrastructure	Availability of or 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

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

Topic	Category	Data and information requirements
	Personnel	Availability of or 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 (consult eg Public Health England for criteria it uses) Prepare template for risk assessment Identify training requirements where shortage of skilled workers
	Impact of geography and weather on implementation	Availability or access to meteorological information, including weather forecasts for local area and region Availability or 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, eg Sites of Special Scientific Interest; national parks; Areas of outstanding natural Beauty; nature reserves, historic buildings
	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 or 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 or 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 or 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 (eg long-sea outfalls, sewage treatment works)
	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 eg 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 (ASSI), a Special Protection Area (SPA), a Special Area of Conservation (SAC), 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

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

Topic	Category	Data and information requirements
	Workers and public	Establish dose limits for all those involved in recovery
		Establish criteria for transportation of radioactive wastes eg foodstuffs, soils
Training		Local authorities might wish to consider developing a competence framework and training programme for the recovery roles required
Contacts	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
	Farmers	Helpdesk number or emergency email address in organisations that have a role in the event of a radiological emergency: National Farmers' Union (NFU), State Veterinary Service, Department for Environment, Food and Rural Affairs (Defra), Environment Agency (EA), Food Standards Agency (FSA), Government Decontamination Service (GDS), State Veterinary Service
		Lists of contacts with local information
		Eligibility and how to claim compensation
	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 and relevant timelines
		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 and 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, put into action, 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 (eg non-compliance or 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 (ie through dissemination of NEPLG guidance). Identify leading agencies and legal responsibilities. This has been well defined for incidents involving milk (AFCWG, 2007) 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, eg the use of army or 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 eg Parish councils, community groups, schools. 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
Management options	Identify practicable and acceptable recovery options for use at the local level based on information provided in the UK Recovery Handbook for Radiation Incidents 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

4.1 References

AFCWG (2007). *Dealing with milk following a nuclear emergency. Guidance document.* Agriculture and Food Countermeasures Working Group available from Food Standards Agency.

DECC (2013). *Nuclear Emergency Planning Consolidated Guidance. Chapter 18: UK Nuclear Recovery Plan Template.* Department for Energy and Climate Change.

5 Constructing a Management Strategy

In the event of a radiation 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 one or two management options that could be applied over the first few days or weeks following the accident. For wide-scale, releases of multiple nuclides 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 42 management options (Section 7) subdivided into the following categories:

- options for the pre-deposition phase (4)
- options for the early-late phase: general applicability (4); soils/crops/grassland (7); animal products (10); domestic production and wild/free foods (6); disposal of waste foods (11)

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 3. 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. A worked example is 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 eight 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 (ie cereals, vegetables, woody fruit trees, milk, meat, home-grown produce, foods from the wild).

Step 2: Refer to selection tables for specific production systems (Table 5.2 -Table 5.9). These selection tables provide a list of all of the applicable management options for the production system selected, including those for disposing of any waste arisings. 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 5.10 and Table 5.11) 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 5.12 and Table 5.13) showing checklist of key constraints for each management option, including those for waste disposal.

Step 5: Refer to look-up table (Table 5.14) showing typical effectiveness of management options for reducing radionuclide uptake into food products. Much of the data presented relate to $^{134,137}Cs$, $^{89,90}Sr$ and ^{239}Pu.

Step 6: Refer to look-up tables (Table 5.15 and Table 5.16) 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 7) 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. These steps 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 to Table 5.9). 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 5.10 and Table 5.11 showing applicability of management options, including those for waste disposal, for each radionuclide being considered
4	Refer to look-up tables (Table 5.12 and Table 5.13) showing checklists of key constraints for each management option, including those for waste disposal
5	Refer to look-up table (Table 5.14) showing maximum activity concentrations in the target medium for which the option would be effective
6	Refer to look-up tables (Table 5.15 and Table 5.16) 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 7) 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/grassland - commercially produced (Table 5.2)
- fruit and vegetables - commercially produced (Table 5.3)
- milk - commercially produced (Table 5.4)
- meat - commercially produced (Table 5.5)
- eggs - commercially produced (Table 5.6)
- honey - commercially produced (Table 5.7)
- freshwater and marine fish - commercially produced (Table 5.8)
- domestic production and wild foods (Table 5.9)

These selection tables provide:

- a list of all of the applicable management options for the production system selected, including those for disposal of any waste arisings
- 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 customisation at local or regional level by the relevant stakeholders

The numbers in brackets in Table 5.2 -Table 5.9 refer to the datasheet number.

Go to greyscale table

Table 5.2 Selection table of management options for cereals/grassland (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plant (1)					P
	Protect harvested crops from contamination (3)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
	Select alternative land use (8)					L
Cereals/grassland	Application of lime to soils (9)					E-M-L
	Application of K fertilisers to soils (10)					E-M-L
	Deep ploughing (11)					E-M
	Land improvement (12) (grassland only)					M-L
	Removal of topsoil (13) (cereal crops only)					E-M
	Shallow ploughing (14)					E-M-L
	Skim and burial ploughing (15)					E-M
Waste disposal	Composting (34)					E-M
	Incineration (36)					E-M
	Landfill (37)					E-M
	Ploughing in of a standing crop (39)					E-M
	Soil washing (42) (cereal crops only)					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 5.3 Selection table of management options for fruit and vegetables (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plant (1)	Green	Amber	Red	Red	P
	Prevent contamination of greenhouse crops (2)	Green	Amber	Red	Red	P
	Protect harvested crops from contamination (3)	Green	Amber	Red	Red	P-E
General applicability	Natural attenuation (with monitoring) (5)	Red	Amber	Amber	Dark red	E-M-L
	Product recall (6)	Red	Green	Green	Red	E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)	Red	Green	Green	Amber	E-M-L
	Select alternative land use (8)	Red	Red	Red	Amber	M-L
Fruit/Vegetables	Application of lime to soils (9)	Red	Red	Green	Green	E-M-L
	Application of K fertilisers to soils (10)	Red	Red	Green	Green	E-M-L
	Deep ploughing (11)	Red	Red	Red	Red	E-M-L
	Removal of topsoil (13)	Red	Amber	Amber	Red	E-M
	Shallow ploughing (14)	Red	Green	Green	Green	E-M-L
	Skim and burial ploughing (15)	Red	Red	Amber	Amber	E-M-L
Waste disposal	Composting (34)	Red	Amber	Amber	Amber	E-M-L
	Incineration (36)	Red	Amber	Amber	Amber	E-M-L
	Landfill (37)	Red	Amber	Amber	Amber	E-M-L
	Ploughing in of a standing crop (39)	Red	Green	Green	Green	E-M
	Soil washing (42)	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 5.4 Selection table of management options for milk (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at processing plant (1)	Green	Amber	Red	Red	P
	Short-term sheltering of animals (4)	Green	Green	Red	Red	P
General applicability	Natural attenuation (with monitoring) (5)	Red	Amber	Amber	Dark red	E-M-L
	Product recall (6)	Red	Green	Green	Red	E-M
	Restrict entry into the foodchain (inc FEPA order) (7)	Red	Green	Green	Green	E-M-L
	Select alternative land use (8)	Red	Red	Red	Amber	L
Milk	Addition of AFCF to concentrate ration (16)	Red	Red	Green	Green	E-M-L
	Addition of calcium to concentrate ration (17)	Red	Red	Green	Green	E-M-L
	Addition of clay minerals to feed (18)	Red	Red	Amber	Amber	E-M-L
	Clean feeding (20)	Red	Green	Green	Amber	E-M-L
	Selective grazing (23)	Red	Red	Green	Green	E-M-L
	Slaughtering (culling) of livestock (24)	Red	Dark red	Dark red	Dark red	M-L
	Suppression of lactation before slaughter (25)	Red	Dark red	Dark red	Dark red	M-L
Waste disposal	Biological treatment (digestion) of milk (32)	Red	Amber	Amber	Amber	E-M-L
	Burial of carcasses (33)	Red	Amber	Amber	Amber	E-M-L
	Disposal of contaminated milk to sea (35)	Red	Dark red	Dark red	Dark red	E-M-L
	Incineration (36)	Red	Amber	Amber	Amber	E-M-L
	Landfill (37)	Red	Amber	Amber	Amber	E-M-L
	Landspreading milk/slurry (38)	Red	Green	Green	Green	E-M-L
	Processing and storage of milk products for disposal (40)	Red	Amber	Amber	Amber	E-M-L
	Rendering (41)	Red	Green	Green	Green	E-M-L

Key:

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 management options for meat (cow and sheep) (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plant (1)	Green	Amber	Red	Red	P
	Short-term sheltering of animals (4)	Green	Green	Red	Red	P
General applicability	Natural attenuation (with monitoring) (5)	Red	Amber	Amber	Dark red	E-M-L
	Product recall (6)	Red	Green	Green	Red	E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)	Red	Green	Green	Green	E-M-L
	Select alternative land use (8)	Red	Red	Red	Amber	L
Meat	Addition of AFCF to concentrate ration (16)	Red	Red	Green	Green	E-M-L
	Addition of calcium to concentrate ration (17)	Red	Red	Green	Green	E-M-L
	Addition of clay minerals to feed (18)	Red	Red	Amber	Amber	E-M-L
	Administer AFCF boli to ruminants (19)	Red	Red	Amber	Amber	E-M-L
	Clean feeding (20)	Red	Green	Green	Green	E-M-L
	Live monitoring (21)	Red	Red	Green	Green	E-M-L
	Manipulation of slaughter times (22)	Amber	Amber	Amber	Amber	P-E-M-L
	Selective grazing (23)	Red	Red	Green	Green	E-M-L
	Slaughtering (culling) of livestock (24)	Red	Dark red	Dark red	Dark red	M-L
Waste disposal	Burial of carcasses (33)	Red	Amber	Amber	Amber	E-M-L
	Incineration (36)	Red	Amber	Amber	Amber	E-M-L
	Landfill (37)	Red	Amber	Amber	Amber	E-M-L
	Rendering (41)	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 5.6 Selection table of management options for eggs (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plants (1)	Green	Amber	Red	Red	P
	Short-term sheltering of animals (4)	Green	Green	Red	Red	P
General applicability	Natural attenuation (with monitoring) (5)	Red	Amber	Amber	Dark red	E-M-L
	Product recall (6)	Red	Green	Green	Red	E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)	Red	Green	Green	Green	E-M-L
	Select alternative land use (8)	Red	Green	Green	Amber	L
Eggs	Addition of AFCF to concentrate ration (16)	Red	Red	Green	Green	E-M-L
	Addition of calcium to concentrate ration (17)	Red	Red	Green	Green	E-M-L
	Addition of clay minerals to feed (18)	Red	Red	Amber	Amber	E-M-L
	Clean feeding (20)	Red	Green	Green	Amber	E-M-L
	Selective grazing (23)	Red	Red	Green	Green	E-M-L
	Slaughtering (culling) of livestock (24)	Red	Dark red	Dark red	Dark red	M-L
Waste disposal	Incineration (36)	Red	Amber	Amber	Amber	E-M-L
	Landfill (37)	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 5.7 Selection table of management options for honey (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plants (1)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
Waste disposal	Incineration (36)					E-M-L
	Landfill (37)					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 5.8 Selection table of management options for freshwater and marine fish (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plant (1)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
Waste disposal	Incineration (36)					E-M-L
	Landfill (37)					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 5.9 Selection table of management options for domestic and wild foods and game

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Protect harvested crops from contamination (3)	[green]	[amber]	[red]	[red]	P
General applicability	Natural attenuation (with monitoring) (5)	[red]	[amber]	[amber]	[amber]	E-M-L
Domestic/wild food and game	Removal of topsoil (13)	[red]	[amber]	[amber]	[red]	E-M
	Clean feeding (domestic livestock) (26)	[red]	[amber]	[amber]	[amber]	E-M-L
	Dietary advice (domestic) (27)	[red]	[green]	[green]	[green]	P-E-M-L
	Processing or storage of domestic food products (28)	[red]	[amber]	[green]	[green]	E-M-L
	Provision of monitoring equipment (domestic produce) (29)	[red]	[amber]	[green]	[green]	E-M-L
	Restrictions on foraging (gathering wild foods) (30)	[red]	[amber]	[amber]	[amber]	E-M-L
	Restrictions during hunting and fishing seasons (31)	[green]	[amber]	[amber]	[amber]	E-M-L
Waste disposal	Composting (34)	[red]	[amber]	[amber]	[amber]	E-M
	Incineration (36)	[red]	[amber]	[amber]	[amber]	E-M-L
	Landfill (37)	[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.

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 5.10 and Table 5.11 for those radionuclides likely to be of significance in the foodchain. Table 5.10 contains information on management options for maintaining production and Table 5.11 focuses on disposal options. Complementary look-up tables are also provided in Appendix D for radionuclides not likely to have a significant impact on the foodchain. The information presented in these tables is taken from Beresford et al (2006). The numbers in brackets refer to the datasheet number.

In Table 5.10 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 (eg 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 (eg 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 (ie 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 7). 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.

Table 5.11 indicates whether a waste disposal option is likely to be applicable or otherwise according to radionuclide. Only those radionuclides of greatest significance in the foodchain are presented in the table. A complementary look-up table is also provided in Appendix D for radionuclides not likely to have a significant impact on the foodchain. Six criteria were used to assess applicability:

- 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

Table 5.11 shows 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 (ie ones for which there appear to be no constraints) are given in the datasheets.

Table 5.10 Applicability of management 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	^{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	432.2 y
Predeposition											
(1) Close air intake systems at food processing plants	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(2) Prevent contamination of greenhouse crops	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(3) Protect harvested crops from contamination	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(4) Short-term sheltering of animals	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Early to late phase											
General applicability											
(5) Natural attenuation (with monitoring)	✓	✓	e	e	✓	✓	✓	✓	✓	e, h	e, h
(6) Product recall	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(7) Restrict entry into the food chain (including FEPA orders)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(8) Select alternative land use	✓	d	d	✓	d	f	d	✓	✓	f, g	f, g
Soils/crops/grassland											
(9) Application of lime to soils	✓	c	✓	✓	✓	✓	d	c	c	✓	✓
(10) Application of potassium fertilisers to soils	a	a	a	a	a	a	a	✓	✓	a	a
(11) Deep ploughing	✓	✓	✓	✓	d	✓	d	✓	✓	✓	✓
(12) Land improvement	✓	c	✓	✓	✓	✓	d	✓	✓	✓	✓
(13) Removal of topsoil	✓	✓	✓	✓	d	✓	d	✓	✓	✓	✓
(14) Shallow ploughing	✓	✓	✓	✓	d	✓	d	✓	✓	✓	✓
(15) Skim and burial ploughing	✓	✓	✓	✓	d	✓	d	✓	✓	✓	✓
Livestock and animal products											
(16) Addition of AFCF to concentrate ration	a	a	a	a	a	a	a	✓	✓	a	a
(17)Addition of calcium to concentrate ration	b	b	✓	✓	b	b	b	b	b	b	b
(18) Addition of clay minerals to feed	a	a	a	a	a	a	a	✓	✓	a	a

Table 5.10 Applicability of management 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	^{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**	**432.2 y**
(19) Administration of AFCF boli to ruminants	a	a	a	a	a	a	a	✓	✓	a	a
(20) Clean feeding	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(21) Live monitoring	✓	✓	e	e	✓	✓	✓	✓	✓	e	e
(22) Manipulation of slaughter times	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(23) Selective grazing	✓	✓	✓	✓	d, f	f	d	✓	✓	f	f
(24) Slaughtering (culling) of livestock	✓	✓	✓	✓	d, f	f	d	✓	✓	f	f
(25) Suppression of lactation before slaughter	✓	✓	✓	✓	d, f	f	d	✓	✓	f	f
Domestic production and wild foods											
(26) Clean feeding (domestic livestock)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(27) Dietary advice (domestic)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(28) Processing or storage of domestic food products	h	h	✓	h	h	h	✓	h	h	h	h
(29) Provision of monitoring equipment (domestic produce)	✓	✓	e	e	✓	✓	✓	✓	✓	e	✓
(30) Restrictions on foraging (gathering wild foods)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(31) Restrictions during hunting and fishing seasons	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Key:

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

✓: Selected as target radionuclide (ie 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: No/low photon energy of radionuclide makes detection difficult

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

g: Low soil-to-plant transfer makes radical management option inappropriate

h: Management option only effective for short-lived radionuclides

Table 5.11 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	^{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**	**432.2 y**
(32) Biological treatment (digestion) of milk[#]	✓	a	✓	✓	✓	✓	✓	✓	✓	✓	✓
(33) Burial of carcasses[†]	b	✓	c	c	✓	✓	c	✓	✓	✓	✓
(34) Composting	✓	✓	✓	✓	✓	✓	d	✓	✓	✓	✓
(35) Disposal of contaminated milk to sea	e	e	✓	✓	e	e	✓	✓	✓	e	e
(36) Incineration[†] (1100°C)[‡]	✓	f	✓	✓	✓	✓	f, d	f	f	✓	✓
(37) Landfill[†]	✓	✓	c	c	✓	✓	c, d	✓	✓	✓	✓
(38) Landspreading of milk and/or slurry[#]	✓	a	✓	✓	✓	✓	✓	✓	✓	✓	✓
(39) Ploughing in of a standing crop[#]	b	a	✓	✓	✓	✓	✓	✓	✓	b	b
(40) Processing and storage of milk for disposal	b	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(41) Rendering[†] (150°C)¶	✓	✓	✓	✓	✓	✓	d	✓	✓	✓	✓
(42) Soil washing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Key:

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

✓: Selected as target radionuclide (ie known or probable applicability see Section 5.3)

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 to plant concentration ratio of > 1

b: Not recommended as doses resulting from disposal could be similar to those resulting from consumption of the food.

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

d: Not recommended due to comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option

e: 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

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

*: Period of time waste disposal option is carried out for

[#]: Nuclides placed or deposited onto surface layers of soil - only plant uptake is considered

[†]: Nuclides are considered to be buried under clean soil - only mobility is considered

[‡]: Maximum temperature at which option is carried out. Operating temperature is typically between 850 and 1100°C but is usually 900°C

[¶]: Maximum temperature at which option is carried out, typically between 100 and 145°C

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 7). To assist in eliminating unsuitable options major and moderate constraints for each option are presented in Table 5.12, taking into account factors such as waste, societal needs, technical aspects, cost and timescales for implementation. The grey-scale colour coding in Table 5.13 is based on an evaluation of the evidence database and stakeholder feedback. The colour coding gives an indication of whether options have 'none or minor', 'moderate' or 'major' constraints associated with their implementation. The classification used is a generic guide and not radionuclide specific. If a major constraint is identified it does not indicate that the recovery option should necessarily be eliminated, although this may be done on a site and incident specific basis. These tables can be used in conjunction with the datasheets or beforehand to reduce the subset of options that require more in-depth analysis.

Table 5.12 Major and moderate constraints for management options

Management option	Major (key) constraints for selected management options	Moderate constraints for selected management options
Pre-deposition option		
(1) Close air intake systems at food processing plant	**Time:** a decision needs to be made quickly as this option would need to be implemented as soon as the possibility of a release is identified time between notification and release of contamination occurring	**Technical:** access to machinery and controls
(2) Prevent contamination of greenhouse crops	**Time:** a decision needs to be made quickly as this option would need to be implemented as soon as the possibility of a release is identified time between notification and release of contamination occurring	None
(3) Protect harvested crops from contamination	**Time:** a decision needs to be made quickly as this option would need to be implemented as soon as the possibility of a release is identified time between notification and release of contamination occurring	**Technical:** availability of covering materials and means to secure it high winds can affect implementation there may be difficulty in covering tall crops **Cost:** may be high, taking into account equipment, personnel and size of the affected area. May only be appropriate for high value crops
(4) Short-term sheltering of animals	**Time:** a decision needs to be made quickly as this option would need to be implemented as soon as the possibility of a release is identified time between notification and release of contamination occurring possible exposure of farm workers while moving animals **Technical**: availability of suitable housing with water supply	**Technical:** distance between pastures and shelters and availability of stored feed **Cost:** may be high, taking into account equipment, infrastructure (ie farm buildings) personnel and number of animals requiring sheltering
Early to late phase		
General applicability		
(5) Natural attenuation (with monitoring)	**Time:** it may take a prolonged period of time for the radionuclides to undergo radioactive decay and weathering from land surfaces. **Technical:** monitoring equipment and skilled personnel are required to take measurements and samples location of the contaminated area; this option may be more feasible for semi-natural areas than in areas used for intensive agricultural production	**Social**: this option may be perceived as doing ‘nothing’ by the public, which has negative implications and may be unacceptable to members of the public.
(6) Product recall	**Waste:** there may be significant amounts of contaminated recalled food products (ie milk, meat, eggs and crops) that will require a suitable disposal route	**Social:** contacting members of the public

Table 5.12 Major and moderate constraints for management options

Management option	Major (key) constraints for selected management options	Moderate constraints for selected management options
(7) Restrict entry into the food chain (including FEPA orders)	**Waste:** there may be significant amounts of contaminated food products (ie milk, meat, eggs and crops) that will require a suitable disposal route long term restrictions (eg FEPA order) may also lead to culling and disposal of livestock	**Technical:** requirement to establish a monitoring and surveillance programme **Social:** economic loss occurring as a result of restrictions being imposed
(8) Select alternative land use	**Social:** market for alternative products and know-how	**Technical:** restrictions imposed by environmental protection schemes. It depends on what the site will be used for (ie for non food crops or amenities such as golf course or parkland)
Soils/crops/grassland		
(9) Application of lime to soils	**Technical:** only applicable if soil has low pH or calcium status	**Technical:** may increase mobility of some radionuclides restrictions may be imposed by environmental protection schemes often carried out with ploughing, so may not be applicable for very wet, dry, frozen or steep areas
(10) Application of potassium fertilisers to soils	**Technical:** Only applicable if soil has low potassium status	**Technical:** restrictions may be imposed by environmental protection schemes often carried out with ploughing, so may not be applicable for very wet, dry, frozen or steep areas
(11) Deep ploughing	**Technical:** a soil depth of > 0.5m is required must be implemented before normal ploughing has been undertaken not applicable if crop is present or if soil is very wet, sandy, frozen or stony	**Technical:** restrictions may be imposed by environmental protection schemes complicates further options involving removal of contaminated soil in some cases, the contamination is moved closer to the ground water tie-down may be needed to suppress resuspension of contamination in dust
(12) Land improvement	None	**Technical:** restrictions may be imposed by environmental protection schemes
(13) Removal of topsoil	**Technical:** not applicable if crop is present **Waste:** there may be significant amounts of contaminated soil that will require a suitable disposal route **Cost: m**ay be high, considering; equipment; personnel; size of the affected area and volume of topsoil requiring disposal	**Social:** resistance to topsoil removal (together with associated flora and fauna) and to aesthetic consequences of garden or allotment changes stigma associated with affected area

Table 5.12 Major and moderate constraints for management options

Management option	Major (key) constraints for selected management options	Moderate constraints for selected management options
(14) Shallow ploughing	**Technical:** not applicable if crop is present or if soil is very wet, sandy, frozen or stony	**Technical:** restrictions may be imposed by environmental protection schemes complicates further options involving removal of contaminated soil in some cases, the contamination is moved closer to the ground water tie-down may be needed to suppress resuspension of contamination in dust
(15) Skim and burial ploughing	**Technical:** availability of specialist equipment a soil depth of > 0.5m is required must be implemented before normal ploughing has been undertaken not applicable if crop is present or if soil is very wet, sandy, frozen or stony	**Technical:** restrictions may be imposed by environmental protection schemes complicates further options involving removal of contaminated soil in some cases, the contamination is moved closer to the ground water tie-down may be needed to suppress resuspension of contamination in dust
Livestock and animal products		
(16) Addition of AFCF to concentrate ration	**Technical:** availability of AFCF and identification of feed manufacturing plants that will add AFCF to feed pellets	**Technical:** implications for farms with ‘organic’ status **Social:** acceptability to farmers or food industry and consumers.
(17)Addition of calcium to concentrate ration	None	**Technical:** availability of calcium supplements, or pelleted concentrates with enriched levels of calcium
(18) Addition of clay minerals to feed	**Technical:** availability of clay minerals or infrastructure (ie feed manufacturing plants) to add clay minerals to feed (clay mineral needs to be compliant with animal feed legislation)	**Technical:** implications for farms with ‘organic’ status **Social:** acceptability to farmers or food industry and consumers
(19) Administration of AFCF boli to ruminants	**Technical:** availability of AFCF and identification of manufacturing plants that will can produce AFCF boli	**Technical:** implications for farms with ‘organic’ status **Social:** acceptability to farmers or food industry and consumers. Animal welfare issues
(20) Clean feeding	**Technical:** availability of suitable housing with water, power supply, straw for bedding and ventilation availability of alternative clean feed	**Waste:** slurry or manure produced while livestock are fenced in or housed **Cost:** may be high, considering; number of affected animals; consumables (ie clean feed)
(21) Live monitoring	None	**Technical:** availability of NaI detectors and trained personnel **Time:** time will be required to manufacture and calibrate monitoring kits and train personnel

Table 5.12 Major and moderate constraints for management options

Management option	Major (key) constraints for selected management options	Moderate constraints for selected management options
(22) Manipulation of slaughter times	None	**Technical:** if immediate slaughter is ordered, availability of abattoir or on-farm slaughtering equipment if prolonged slaughter, availability of additional feed and any implications for animal welfare
(23) Selective grazing	**Technical:** availability of monitoring data identifying less contaminated pastures availability of less contaminated land in the area	**Social:** willingness of farmers elsewhere to allow livestock from contaminated areas to graze on their land
(24) Slaughtering (culling) of livestock	**Technical:** availability of slaughtering equipment and licensed slaughter men **Waste:** there may be significant amounts of condemned livestock carcasses that will require further action (ie rendering, incineration and landfill) **Social:** major disruptions to food business and farmers culling requires the consent of the owner, and there may be resistance of the public and impact on the farming community and cost	None
(25) Suppression of lactation before slaughter	None	**Social:** farmer's resistance to being asked to suppress lactation in dairy herd where synthetic oestrogens have been used (rather than more natural methods for drying off dairy animals) there may be opposition of the public due to the perception that hormones may damage the environment
Domestic production and wild foods		
(26) Clean feeding (domestic livestock)	None	**Social:** resistance of animal owners to management option.
(27) Dietary advice (domestic)	None	**Social:** routes for dialogue and dissemination of information to affected populations
(28) Processing or storage of domestic food products	None	**Social:** need to establish appropriate lines of communication to reach target population
(29) Provision of monitoring equipment (domestic produce)	None	**Technical:** availability of NaI detectors and trained personnel. **Time:** time will be required to manufacture and calibrate monitoring kits and train personnel.
(30) Restrictions on foraging (gathering wild foods)	**Social:** difficulties with enforceability and policing	**Social:** need to establish appropriate lines of communication to reach hunters and anglers

Table 5.12 Major and moderate constraints for management options

Management option	Major (key) constraints for selected management options	Moderate constraints for selected management options
(31) Restrictions during hunting and fishing seasons	**Social:** difficulties with enforceability and policing	**Technical:** impact of shortened seasons on increase in fish and game populations **Social:** need to establish appropriate lines of communication to reach hunters and anglers
Waste disposal options		
(32) Biological treatment (digestion) of milk	**Technical:** capacity of biological treatment facilities for milk which has a very high biological oxygen demand in limited	None
(33) Burial of carcasses	**Technical:** availability and suitability of land for engineering a purpose built burial pit. There are strict controls on the burial of carcasses **Social:** acceptability with the public in the locality of the burial site	None
(34) Composting	None	**Technical:** suitability of land for composting in-situ and availability of commercial facilities and capacity in the area **Waste:** subsequent fate of composted material which may still contain radionuclides
(35) Disposal of contaminated milk to sea	**Technical:** identification of long sea outfalls with capacity to discharge milk, authorisation to discharge milk to sea and transportation and offloading at discharge points	**Social:** acceptability with the public
(36) Incineration	None	**Technical:** availability of commercial facilities able to accept contaminated material and capacity in the area
(37) Landfill	None	**Technical:** availability and capacity of commercial facilities for highly biodegradable material
(38) Land spreading of milk and/ or slurry	**Technical:** availability of land for land spreading (not waterlogged, frozen, in nitrate sensitive area) capacity of slurry tank to store milk at times when land not suitable for spreading	**Social:** odour nuisance
(39) Ploughing in of a standing crop	None	**Technical:** unsuitable if soil depth < 30 cm
(40) Processing and storage of milk products for disposal	**Social:** availability of processing plant willing to accept contaminated milk **Technical:** availability of storage facility	**Waste:** there may be by-products from processing that will require a suitable disposal route
(41) Rendering	None	**Technical:** availability of commercial facilities and capacity in the area
(42) Soil washing	None	**Technical:** risk of contamination of ground water and water supplies

Table 5.13 Overview of key constraints for management options

Recovery option	Waste	Social	Technical	Cost	Time
Pre-deposition options					
(1) Close air intake systems at food processing plant					
(2) Prevent contamination of greenhouse crops					
(3) Protect harvested crops from contamination					
(4) Short-term sheltering of animals					
Early to late phase					
General applicability					
(5) Natural attenuation (with monitoring)					
(6) Product recall					
(7) Restrict entry into the food chain (including FEPA orders)					
(8) Select alternative land use					
Soils/crops/grassland					
(9) Application of lime to soils					
(10) Application of potassium fertilisers to soils					
(11) Deep ploughing					
(12) Land improvement					
(13) Removal of topsoil					
(14) Shallow ploughing					
(15) Skim and burial ploughing					
Livestock and animal products					
(16) Addition of AFCF to concentrate ration					
(17)Addition of calcium to concentrate ration					
(18) Addition of clay minerals to feed					
(19) Administration of AFCF boli to ruminants					
(20) Clean feeding					
(21) Live monitoring					
(22) Manipulation of slaughter times					
(23) Selective grazing					
(24) Slaughtering (culling) of livestock					
(25) Suppression of lactation before slaughter					
Domestic production and wild food					
(26) Clean feeding (domestic livestock)					
(27) Dietary advice (domestic)					
(28) Processing or storage of domestic food products					
(29) Provision of monitoring equipment (domestic produce)					
(30) Restrictions on foraging (gathering wild foods)					
(31) Restrictions during hunting and fishing seasons					
Waste disposal options					
(32) Biological treatment (digestion) of milk					
(33) Burial of carcasses					
(34) Composting					
(35) Disposal of contaminated milk to sea					
(36) Incineration					

Table 5.13 Overview of key constraints for management options

Recovery option	Waste	Social	Technical	Cost	Time
(37) Landfill					
(38) Landspreading of milk and/or slurry					
(39) Ploughing in of a standing crop					
(40) Processing and storage of milk products for disposal					
(41) Rendering					
(42) Soil washing					

Considerations/ constraints	None or minor	Moderate	Important (major)
Time - when to implement recovery option	No restrictions on time	Weeks to months/years	Hours - days

5.5 Effectiveness of management options in reducing contamination of food products

Experimental work and field based studies in the regions affected by the accidents at Chernobyl and Fukushima Dai-ichi have enabled the effectiveness of various management options to be measured 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 5.14) on typical effectiveness (expressed as a percentage value) of management options for a range of radionuclides and food products. For some options there are several values, depending on radionuclide, food type and soil type. Not all management options considered in the handbook are directed at reducing activity concentrations in food product; some for example are for reassurance purposes, while others encompass waste disposal routes. The numbers in brackets in Table 5.14 refer to the datasheet number.

Table 5.14 Effectiveness of management options

Management option	Target radionuclide*	Target medium	Effectiveness# (%)	Food product	Comments
Pre-deposition phase					
Close air intake systems at food processing plants (1)	All	Foodstuffs for processing	~ 100	All	
Prevent contamination of greenhouse crops (2)	All	Crops	Up to 100	Crops	
Protect harvested crops from contamination (3)	All	Harvested crops	Up to 100	Crops	
Short-term sheltering of animals (4)	All	Grazing dairy animals	Up to 100	Milk	
Early to late phase					
General applicability					
Natural attenuation (with monitoring) (5)	All	Soil, crops, animals	N/A†	All	This recovery option does not remove the radionuclide; decay will occur but this may take a prolonged period of time.
Product recall (6)	All	Foodstuffs	Unknown†	All	Compliance with the recommendation not to eat certain foodstuffs and returning/ disposing of contaminated food products very unlikely to be 100% effective at reducing exposure, and will never be possible to verify in practice.
Restrict entry into the foodchain (including FEPA orders) (7)	All	Crops	100	Crops	
Select alternative land use (8)	^{134}Cs, ^{137}Cs	Soil	100†	Crops, meat, milk, eggs	This management option does not remove contamination but the ingestion pathway is no longer relevant since inedible crops have replaced crops grown for the foodchain.
Soils/crops/grassland					
Application of lime to soils (9)	^{89}Sr, ^{90}Sr	Soil (mineral)	50	Crops, meat, milk	Only applicable when soil pH 5-7
		Soil (organic)	83	Crops, meat, milk	
Application of K fertilisers to soils (10)	^{134}Cs, ^{137}Cs	Soil	50	Crops, meat, milk	Effectiveness (50%) is pessimistic. May be up to 80%
Deep ploughing (11)	^{89}Sr, ^{90}Sr	Soil	50	Crops, meat, milk	Observed data are for Cs and Sr. It would be reasonable

Table 5.14 Effectiveness of management options

Management option	Target radionuclide*	Target medium	Effectiveness# (%)	Food product	Comments
	^{134}Cs, ^{137}Cs	Soil	50	Crops, meat, milk	
Land improvement (12)	^{134}Cs, ^{137}Cs	Mineral soils	50	Meat	
		Organic soils	67	Meat	
Removal of topsoil (13)	^{89}Sr, ^{90}Sr	Soil	90	Crops, meat, milk	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
	^{134}Cs, ^{137}Cs	Soil	90	Crops, meat, milk	
Shallow ploughing (14)	^{89}Sr, ^{90}Sr	Soil	50	Crops, meat, milk	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.
	^{134}Cs, ^{137}Cs	Soil	50	Crops, meat, milk	
Skim and burial ploughing (15)	^{89}Sr, ^{90}Sr	Soil	90	Crops, meat, milk	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
	^{134}Cs, ^{137}Cs	Soil	90	Crops, meat, milk	
Livestock and animal products					
Addition of AFCF to concentrate ration (16)	^{134}Cs, ^{137}Cs	Beef cow	78	Beef	
		Dairy cow	80	Milk	
		Sheep/lamb	87	Sheep meat	
		Pigs	90	Pork	
Addition of calcium to concentrate ration (17)	^{89}Sr, ^{90}Sr, ^{140}Ba, ^{226}Ra	Dairy cow	50	Milk	
Addition of clay minerals to feed (18)	^{134}Cs, ^{137}Cs	Beef cow	50	Beef	
		Dairy cow	50	Milk	
Administer AFCF boli to ruminants (19)	^{134}Cs, ^{137}Cs	Reindeer	80	Reindeer meat	

Table 5.14 Effectiveness of management options

Management option	Target radionuclide*	Target medium	Effectiveness# (%)	Food product	Comments
		Cows and goats	70	Cow and goat milk	
		Sheep	50	Sheep meat	
Clean feeding (20)	All	Grazing livestock	Up to 100	Meat, milk	
Live monitoring (21)	^{134}Cs, ^{137}Cs	Meat producing livestock	Up to 100†	Meat	This recovery option does not remove the radionuclide but can be highly effective at excluding meat above intervention level from foodchain.
Manipulation of slaughter times (22)	^{134}Cs, ^{137}Cs	Sheep, reindeer	75	Meat	
Selective grazing (23)	All	Grazing livestock	Up to 100	Meat, milk	
Slaughtering (culling) of livestock(24)	^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs	Meat, milk or egg producing livestock	Up to 100†	Meat, milk, eggs	This recovery option does not remove the radionuclide but can be highly effective at excluding foodstuffs above intervention level from foodchain.
Suppression of lactation before slaughter (25)	^{134}Cs, ^{137}Cs	Dairy animals	Up to 100	Milk	Can be considered as 100% effective if lactation is ceased. Can also be highly effective if the rate of milk production is greatly reduced but not ceased.
Domestic production and gathering of wild foods					
Clean feeding (domestic livestock) (26)	All	Domestic livestock, including honey bees	Up to 100	Milk, meat, honey	
Dietary advice (domestic) (27)	All	Home-grown foods	Up to 100	Fruit, vegetables	
		Free foods		Meat, fish	
Processing or storage of domestic food products (28)	^{134}Cs, ^{137}Cs	Processed home-grown produce or gathered free foods	50	Meat, fish, vegetables	Marinating meat in brine may be up to 80% effective for meat
	^{134}Cs, ^{89}Sr, ^{131}I	Stored home-grown produce or gathered free foods	Up to 100	Milk, Meat, fish, Fruit, vegetables, Eggs, nuts, honey	Applicable to short-lived radionuclides
Provision of monitoring equipment (domestic produce) (29)	^{134}Cs, ^{137}Cs	Home grown and/or self-gathered foodstuffs	Up to 100†	All	This recovery option does not remove the radionuclide but can reduce ingestion to below intervention limits
Restrictions on foraging (gathering wild foods) (30)	All (especially Cs)	Wild foods	Up to 100	Meat, fish	

Table 5.14 Effectiveness of management options

Management option	Target radionuclide*	Target medium	Effectiveness[#] (%)	Food product	Comments
Restrictions during hunting and fishing seasons (31)	^{134}Cs, ^{137}Cs	Reindeer	85	Reindeer meat	
		Moose	65	Moose meat	

*: Radionuclides for which the countermeasure is targeted

#: Amount, in percentage terms, by which the activity concentration in the foodstuff can be reduced by applying the countermeasure

†: This recovery option does not remove the radionuclide but can provide reassurance and/or reduce ingestion of contaminated food

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 3.3 and Hesketh et al (2006)). It is also important to note that some management options generate secondary/tertiary wastes that require disposal (eg 'topsoil removal', see Section 3.4). 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 (eg application of contaminated sewage sludge to land following anaerobic digestion of waste milk). Table 5.15 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 5.16 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 (eg milk, crops) or from secondary waste such as leachates or by-products from the treatment process. The numbers in brackets in Table 5.15 - Table 5.16 refer to the datasheet number.

Table 5.15 Incremental doses incurred following implementation of management options

Management option	Incremental dose from management option	Waste produced	Incremental dose from waste management
Pre-deposition phase			
(1) Close air intake systems at food processing plants	×	×	×
(2) Prevent contamination of greenhouse crops	×	×	×
(3) Protect harvested crops from contamination	×	✓	✓
(4) Short-term sheltering of animals	×	×	×
Early to late phase			
General applicability			
(5) Natural attenuation (with monitoring)	✓	×	×
(6) Product recall	×	✓	✓
(7) Restrict entry into the foodchain (including FEPA order)	×	✓	✓
(8) Select alternative land use	✓	×	×
Soil/crops/grassland			
(9) Application of lime to soils	✓	×	×
(10) Application of potassium fertilisers to soils	✓	×	×
(11) Deep ploughing	✓	×	×
(12) Land improvement	✓	×	×
(13) Removal of topsoil	✓	×	×
(14) Shallow ploughing	✓	×	×

Table 5.15 Incremental doses incurred following implementation of management options

Management option	Incremental dose from management option	Waste produced	Incremental dose from waste management
(15) Skim and burial ploughing	✓	✓	✓
Animal products			
(16) Addition of AFCF to concentrate ration	×	×	×
(17)Addition of calcium to concentrate ration	×	×	×
(18) Addition of clay minerals to feed	×	×	×
(19) Administration of AFCF boli to ruminants	×	×	×
(20) Clean feeding	✓	✓	✓
(21) Live monitoring	✓	×	×
(22) Manipulation of slaughter times	✓	×	×
(23) Selective grazing	✓	×	×
(24) Slaughtering (culling) of livestock	✓	✓	✓
(25) Suppression of lactation before slaughter	×	×	×
Domestic production and wild foods			
(26) Clean feeding (domestic livestock)	✓	✓	✓
(27) Dietary advice (domestic)	×	×	×
(28) Processing or storage of domestic food products	✓	✓	✓
(29) Provision of monitoring equipment (domestic produce)	✓	×	×
(30) Restrictions on foraging (gathering wild foods)	×	×	×
(31) Restrictions during hunting and fishing seasons	×	×	×

Table 5.16 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	Secondary waste
(32) Biological treatment (digestion) of milk	✓	×	✓
(33) Burial of carcasses	✓	×	✓
(34) Composting	✓	✓	✓
(35) Disposal of contaminated milk to sea	✓	✓	×
(36) Incineration	✓	×	×
(37) Landfill	✓	×	✓
(38) Landspreading of milk and/or slurry	✓	✓	×
(39) Ploughing in of a standing crop	✓	✓	×
(40) Processing and storage of milk products for disposal	✓	×	×
(41) Rendering	✓	×	×
(42) Soil washing	✓	✓	✓

5.7 Greyscale tables

Go to colour table

Table 5.2 Selection table of management options for cereals/grassland (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plant (1)					P
	Protect harvested crops from contamination (3)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
	Select alternative land use (8)					L
Cereals/grassland	Application of lime to soils (9)					E-M-L
	Application of K fertilisers to soils (10)					E-M-L
	Deep ploughing (11)					E-M
	Land improvement (12) (grassland only)					M-L
	Removal of topsoil (13) (cereal crops only)					E-M
	Shallow ploughing (14)					E-M-L
	Skim and burial ploughing (15)					E-M
Waste disposal	Composting (34)					E-M
	Incineration (36)					E-M
	Landfill (37)					E-M
	Ploughing in of a standing crop (39)					E-M
	Soil washing (42) (cereal crops only)					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 5.3 Selection table of management options for fruit and vegetables (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plant (1)					P
	Prevent contamination of greenhouse crops (2)					P
	Protect harvested crops from contamination (3)					P-E
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
	Select alternative land use (8)					M-L
Fruit/Vegetables	Application of lime to soils (9)					E-M-L
	Application of K fertilisers to soils (10)					E-M-L
	Deep ploughing (11)					E-M-L
	Removal of topsoil (13)					E-M
	Shallow ploughing (14)					E-M-L
	Skim and burial ploughing (15)					E-M-L
Waste disposal	Composting (34)					E-M-L
	Incineration (36)					E-M-L
	Landfill (37)					E-M-L
	Ploughing in of a standing crop (39)					E-M
	Soil washing (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.

Table 5.4 Selection table of management options for milk (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at processing plant (1)					P
	Short-term sheltering of animals (4)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA order) (7)					E-M-L
	Select alternative land use (8)					L
Milk	Addition of AFCF to concentrate ration (16)					E-M-L
	Addition of calcium to concentrate ration (17)					E-M-L
	Addition of clay minerals to feed (18)					E-M-L
	Clean feeding (20)					E-M-L
	Selective grazing (23)					E-M-L
	Slaughtering (culling) of livestock (24)					M-L
	Suppression of lactation before slaughter (25)					M-L
Waste disposal	Biological treatment (digestion) of milk (32)					E-M-L
	Burial of carcasses (33)					E-M-L
	Disposal of contaminated milk to sea (35)					E-M-L
	Incineration (36)					E-M-L
	Landfill (37)					E-M-L
	Landspreading milk/slurry (38)					E-M-L
	Processing and storage of milk products for disposal (40)					E-M-L
	Rendering (41)					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 5.5 Selection table of management options for meat (cow and sheep) (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plant (1)					P
	Short-term sheltering of animals (4)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
	Select alternative land use (8)					L
Meat	Addition of AFCF to concentrate ration (16)					E-M-L
	Addition of calcium to concentrate ration (17)					E-M-L
	Addition of clay minerals to feed (18)					E-M-L
	Administer AFCF boli to ruminants (19)					E-M-L
	Clean feeding (20)					E-M-L
	Live monitoring (21)					E-M-L
	Manipulation of slaughter times (22)					P-E-M-L
	Selective grazing (23)					E-M-L
	Slaughtering (culling) of livestock (24)					M-L
Waste disposal	Burial of carcasses (33)					E-M-L
	Incineration (36)					E-M-L
	Landfill (37)					E-M-L
	Rendering (41)					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 5.6 Selection table of management options for eggs (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plants (1)					P
	Short-term sheltering of animals (4)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
	Select alternative land use (8)					L
Eggs	Addition of AFCF to concentrate ration (16)					E-M-L
	Addition of calcium to concentrate ration (17)					E-M-L
	Addition of clay minerals to feed (18)					E-M-L
	Clean feeding (20)					E-M-L
	Selective grazing (23)					E-M-L
	Slaughtering (culling) of livestock (24)					M-L
Waste disposal	Incineration (36)					E-M-L
	Landfill (37)					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 5.7 Selection table of management options for honey (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plants (1)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
Waste disposal	Incineration (36)					E-M-L
	Landfill (37)					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 5.8 Selection table of management options for freshwater and marine fish (commercial - see Table 5.9 for domestic scale production)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at food processing plant (1)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA orders) (7)					E-M-L
Waste disposal	Incineration (36)					E-M-L
	Landfill (37)					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 5.9 Selection table of management options for domestic and wild foods and game

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Protect harvested crops from contamination (3)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
Domestic/wild food and game	Removal of topsoil (13)					E-M
	Clean feeding (domestic livestock) (26)					E-M-L
	Dietary advice (domestic) (27)					P-E-M-L
	Processing or storage of domestic food products (28)					E-M-L
	Provision of monitoring equipment (domestic produce) (29)					E-M-L
	Restrictions on foraging (gathering wild foods) (30)					E-M-L
	Restrictions during hunting and fishing seasons (31)					E-M-L
Waste disposal	Composting (34)					E-M
	Incineration (36)					E-M-L
	Landfill (37)					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.

5.8 References

Beresford NA, Barnett CL, Howard BJ, Rantavaara A, Rissanen K, Reales N, Gallay F, Papachristodoulou C, Ioannides K, Nisbet AF, Brown J, Hesketh N, Hammond D, Oatway WB, Oughton D, Bay I and Smith JT (2006). *Compendium of countermeasures for the management of food production systems, drinking waters and forests.*

The compendium can be accessed via the STRATEGY http://www.strategy-ec.org.uk/EURANOS/euranos.htm or EURANOS http://www.euranos.fzk.de websites.

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.* Health Protection Agency, Chilton, RPD-EA-4. Available at http://www.strategy-ec.org.uk.

6 Worked Example

A worked example has been developed to help users become familiar with the content of the handbook and its structure. It takes 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 example provided is only illustrative and has been included solely to support training in the use of the handbook.** The worked example should not be used as proposed solutions to the contamination scenario selected.

6.1 Windscale scenario

6.1.1 Background

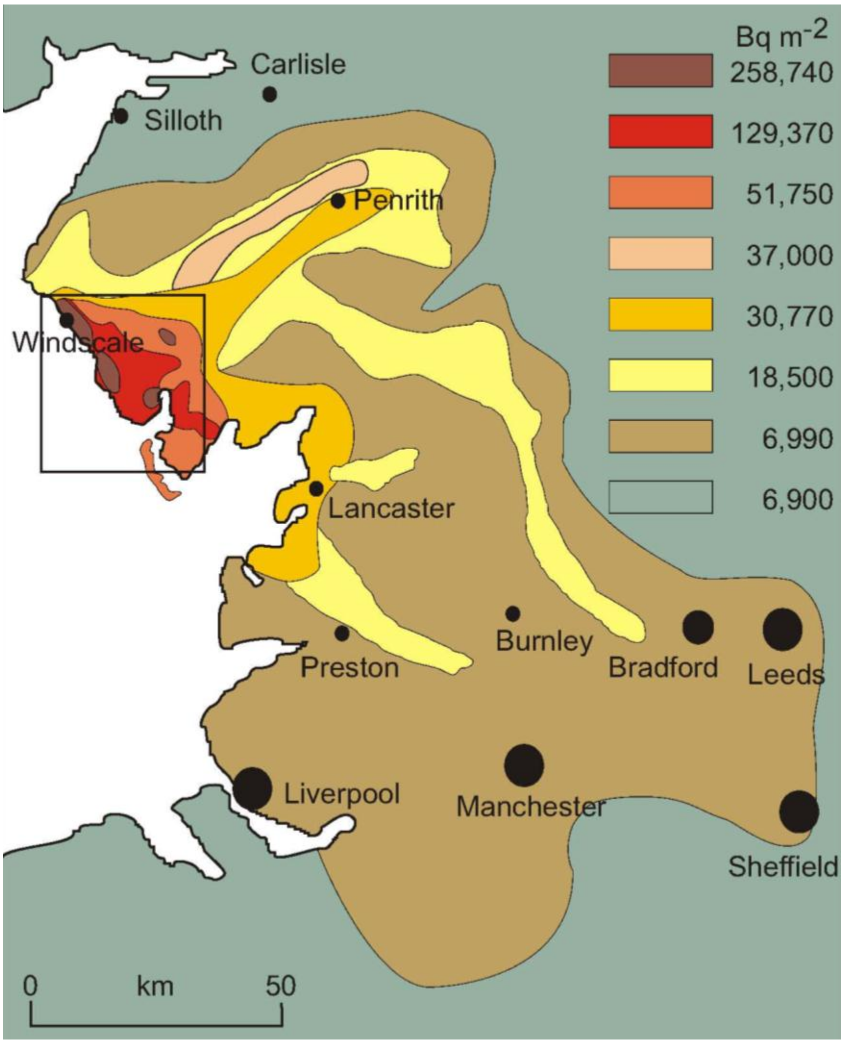
The scenario is based on the accident that took place at the Windscale site on 10 October 1957, for which ^{131}I was the major radionuclide present in ground deposits (Crick and Linsley, 1982). Estimates of the quantity of ^{131}I released ranged from 600 to 740 TBq. Restrictions on milk were based on activity concentrations of ^{131}I of 3,700 Bq l^{-1}. These were the limiting levels developed at the time, and are well above the current maximum permitted level of 500 Bq l^{-1}. Using published deposition data (Crick and Linsley, 1982; Loutit et al, 1960), 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 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	$6.80\ 10^{5}$	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 ^{131}I deposition map from Wilkins et al (2001)



6.2 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 Table 6.3 to Table 6.11 refer to the datasheet number.

Table 6.2 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 Maximum Permitted Level (MPL). 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 5.9). These selection tables provide a list of all of the applicable management options for the production system selected.**
	The relevant selection table for milk is Table 5.4 which lists the options for producing clean milk and milk products/ continuing milk production, and options for disposing of contaminated milk and dairy carcasses. For ease of reference it is reproduced in Table 6.3. There are 21 management options to consider in total. Subsequent steps will endeavour to eliminate options which are not applicable to this scenario.
3	**Refer to look-up tables (Table 5.10 - Table 5.11) showing applicability of management options, including those for waste disposal, for each radionuclide being considered.**
	The information is provided in look-up tables (Table 5.10 to Table 5.11). The relevant data for ^{131}I are summarised in Table 6.4 and Table 6.5 for options for producing clean milk/continuing milk production options and 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. Seven 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. A further four options could be eliminated from Table 6.5: incineration on the basis that ^{131}I would volatilise (and potentially be released to the environment) below the operating temperature of the process; burial of carcasses and landfilling of milk and carcasses on the basis that iodine would be mobile in the ground; and rendering on the basis that slaughter of dairy animals followed by rendering would be too lengthy a process for such a short-lived radionuclide. The original selection table for milk have been revised to show which options for continuing production and disposing of waste milk (see Table 6.6) are still to be considered. From the information provided, there are 6 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 5.12 - Table 5.13) showing checklists of major constraints for each management option, including those for waste disposal.**
	The major constraints for the management options still remaining in the selection table for milk are summarised in Table 6.7. *Options for producing clean milk/maintaining milk production* Options to be implemented before arrival of the plume (ie 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. Where there is uncertainty that contaminated milk products may have entered the food chain before restrictions had been put in place, product recall is a possible option; this requires plans for subsequent management of waste foodstuffs. Natural attenuation with monitoring is unlikely to be feasible for intensive milk production due to the large volumes of milk produced daily that would exceed intervention levels. Natural attenuation can be eliminated. *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.

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

Step	Action
	There are several processing factories in north west England. However, the owners of such facilities (eg 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. The selection table for milk has been revised again to show the remaining management options to be considered (Table 6.8). From the information provided, there are 5 management options for producing clean milk/continuing milk production and 3 options for disposing of contaminated milk
5	**Refer to look-up Table 5.14 showing effectiveness of management options**
	Information presented in the look up Table 5.14 that is relevant to the remaining management options is summarised in Table 6.9. 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 Maximum Permitted Level (MPL).
6	**Refer to look-up Table 5.15 and Table 5.16 which shows 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 6.10 and Table 6.11 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 and product recall 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 while 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 7) 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; product recall; provide housing and clean feed until levels of ^{131}I in pasture decrease (around 44 days for Windscale scenario). 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 Step 2 - Selection table of management options for milk (commercial)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at processing plant (1)	Green	Amber	Red	Red	P
	Short-term sheltering of animals (4)	Green	Green	Red	Red	P
General applicability	Natural attenuation (with monitoring) (5)	Red	Amber	Amber	Dark red	E-M-L
	Product recall (6)	Red	Green	Green	Red	E-M
	Restrict entry into the foodchain (inc FEPA order) (7)	Red	Green	Green	Green	E-M-L
	Select alternative land use (8)	Red	Red	Red	Amber	L
Milk-specific	Addition of AFCF to concentrate ration (16)	Red	Red	Green	Green	E-M-L
	Addition of calcium to concentrate ration (17)	Red	Red	Green	Green	E-M-L
	Addition of clay minerals to feed (18)	Red	Red	Amber	Amber	E-M-L
	Clean feeding (20)	Red	Green	Green	Amber	E-M-L
	Selective grazing (23)	Red	Red	Green	Green	E-M-L
	Slaughtering (culling) of livestock (24)	Red	Dark red	Dark red	Dark red	M-L
	Suppression of lactation before slaughter (25)	Red	Dark red	Dark red	Dark red	M-L
Waste disposal	Biological treatment (digestion) of milk (32)	Red	Amber	Amber	Amber	E-M-L
	Burial of carcasses (33)	Red	Amber	Amber	Amber	E-M-L
	Disposal of contaminated milk to sea (35)	Red	Dark red	Dark red	Dark red	E-M-L
	Incineration (36)	Red	Amber	Amber	Amber	E-M-L
	Landfill (37)	Red	Amber	Amber	Amber	E-M-L
	Landspreading milk/slurry (38)	Red	Green	Green	Green	E-M-L
	Processing and storage of milk products for disposal (40)	Red	Amber	Amber	Amber	E-M-L
	Rendering (41)	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.

Table 6.4 Step 3 - Applicability of management options for ^{131}I, based on physical, chemical or environmental factors

Management options*		
Pre-deposition options	Close air intake systems at food processing plants (1)	✓
	Short-term sheltering of animals (4)	✓
General applicability	Natural attenuation (with monitoring) (5)	✓
	Product recall (6)	✓
	Restrict entry into the foodchain (incl FEPA order) (7)	✓
	Select alternative land use (8)	c
Milk-specific	Addition of AFCF to concentrate ration (16)	a
	Addition of calcium to concentrate ration (17)	b
	Addition of clay minerals to feed (18)	a
	Clean feeding (20)	✓
	Selective grazing (23)	c
	Slaughtering (culling) of livestock 24)	c
	Suppression of lactation before slaughter (25)	c

Key:

✓: Selected as target radionuclide (ie 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

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

Table 6.5 Step 3 - Applicability of waste disposal options for ^{131}I, based on physical, chemical or environmental factors

Waste disposal options*	
Biological treatment (digestion) of milk (32)	✓
Burial of carcasses (33)	b
Disposal of contaminated milk to sea (35)	✓
Incineration (1100 ^{0}C)# (36)	a, c
Landfill (37)	b, c
Landspreading of milk and/or slurry (38)	✓
Processing and storage of milk products for disposal (40)	✓
Rendering (41)	c

Key:

✓: Selected as target radionuclide (ie known or probable applicability, see Section 5.3)

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

b. 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

c. Not recommended due to comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option

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

#: Maximum temperature at which option is carried out. Operating temperature is typically between 850 and 1100°C but is usually 900°C.

Go to greyscale table

Table 6.6 Step 3 - Selection table showing remaining management options for 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
Pre-deposition options	Close air intake systems at processing plants (1)	Green	Amber	Red	Red	P
	Short-term sheltering of animals (4)	Green	Green	Red	Red	P
General applicability	Natural attenuation (with monitoring) (5)	Red	Amber	Amber	Dark red	E-M-L
	Product recall (6)	Red	Green	Green	Red	E-M
	Restrict entry into the foodchain (inc FEPA order) (7)	Red	Green	Green	Green	E-M-L
Milk-specific	Clean feeding (20)	Red	Green	Green	Amber	E-M-L
Waste disposal	Biological treatment (digestion) of milk (32)	Red	Amber	Amber	Amber	E-M-L
	Disposal of contaminated milk to sea (35)	Red	Dark red	Dark red	Dark red	E-M-L
	Landspreading of milk and/or slurry (38)	Red	Green	Green	Green	E-M-L
	Processing and storage of milk products for disposal (40)	Red	Amber	Amber	Amber	E-M-L

Key:		
	Green	Recommended: few constraints.
	Amber	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 6.7 Step 4 - Checklist of major constraints to consider for the remaining management options

Remaining management options	Major constraints
Pre-deposition options	
Close air intake systems at food processing plants (1)	**Time:** a decision needs to be made quickly as this option would need to be implemented as soon as the possibility of a release is identified. Time between notification and release of contamination occurring
Short-term sheltering of animals (4)	**Time:** a decision needs to be made quickly as this option would need to be implemented as soon as the possibility of a release is identified. Time between notification and release of contamination occurring possible exposure of farm workers while moving animals
	Technical: availability of suitable housing with water supply
General applicability	
Natural attenuation (with monitoring) (5)	**Time:** it may take a prolonged period of time for the radionuclides to undergo radioactive decay and weathering from land surfaces.
	Technical: monitoring equipment and skilled personnel are required to take measurements and samples this option may be more feasible for semi-natural areas than in areas used for intensive agricultural production
Product recall (6)	**Waste:** there may be significant amounts of contaminated recalled food products (ie milk, meat, eggs and crops) that will require a suitable disposal route
Restrict entry into the foodchain (incl FEPA order) (7)	**Waste:** there may be significant amounts of contaminated food products (ie milk, meat, eggs and crops) that will require a suitable disposal route long term restrictions (eg FEPA order) may also lead to culling and disposal of livestock
Milk-specific	
Clean feeding (20)	**Technical:** availability of suitable housing with water, power supply, straw for bedding and ventilation availability of alternative clean feed
Waste disposal	
Biological treatment (digestion) of milk (32)	**Technical:** capacity of biological treatment facilities for milk which has a very high biological oxygen demand is limited
Disposal of contaminated milk to sea (35)	**Technical:** identification of long sea outfalls with capacity to discharge milk, authorisation to discharge milk to sea and transportation and offloading at discharge points
Landspreading of milk and/or slurry (38)	**Technical:** availability of land for land spreading (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 (40)	**Social:** availability of processing plant willing to accept contaminated milk.
	Technical:availability of storage facility

Go to greyscale table

Table 6.8 Step 4 - Selection table showing remaining management options for 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
Pre-deposition options	Close air intake systems at processing plants (1)	Green	Amber	Red	Red	P
	Short-term sheltering of animals (4)	Green	Green	Red	Red	P
General applicability	Product recall (6)	Red	Green	Green	Red	E-M
	Restrict entry into the foodchain (inc FEPA order) (7)	Red	Green	Green	Green	E-M-L
Milk-specific	Clean feeding (20)	Red	Green	Green	Amber	E-M-L
Waste disposal	Disposal of contaminated milk to sea (35)	Red	Dark red	Dark red	Dark red	E-M-L
	Landspreading of milk and/or slurry (38)	Red	Green	Green	Green	E-M-L
	Processing and storage of milk products for disposal (40)	Red	Amber	Amber	Amber	E-M-L

Key:		
	Green	Recommended: few constraints.
	Amber	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 6.9 Step 5 - Effectiveness of management options for reducing activity concentrations of ^{131}I in milk

Management option	Effectiveness* (%)
Pre-deposition options	
Close air intake systems at food processing plants (1)	~ 100
Short-term sheltering of animals (4)	Up to 100
General applicability	
Product recall (6)	Up to 100
Restrict entry into the foodchain (incl FEPA order) (7)	100
Milk-specific	
Clean feeding (20)	Up to 100

Table 6.10 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
Pre-deposition options			
Close air intake systems at food processing plants (1)	×	×	×
Short-term sheltering of animals (4)	×	×	×
General applicability			
Product recall (6)	×	✓	✓
Restrict entry into the foodchain (incl FEPA order) (7)	×	✓	✓
Milk-specific			
Clean feeding (20)	✓	✓	✓

Key:
✓ Yes
X No

Table 6.11 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	Secondary waste
Disposal of contaminated milk to sea (35)	✓	✓	×
Landspreading of milk/slurry (38)	✓	✓	×
Processing and storage of milk products for disposal (40)	✓	×	×

Key:
✓ Yes
X No

6.3 Greyscale tables

Table 6.3 Step 2 - Selection table of management options for milk (commercial)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
Pre-deposition options	Close air intake systems at processing plant (1)					P
	Short-term sheltering of animals (4)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA order) (7)					E-M-L
	Select alternative land use (8)					L
Milk	Addition of AFCF to concentrate ration (16)					E-M-L
	Addition of calcium to concentrate ration (17)					E-M-L
	Addition of clay minerals to feed (18)					E-M-L
	Clean feeding (20)					E-M-L
	Selective grazing (23)					E-M-L
	Slaughtering (culling) of livestock (24)					M-L
	Suppression of lactation before slaughter (25)					M-L
Waste disposal	Biological treatment (digestion) of milk (32)					E-M-L
	Burial of carcasses (33)					E-M-L
	Disposal of contaminated milk to sea (35)					E-M-L
	Incineration (36)					E-M-L
	Landfill (37)					E-M-L
	Landspreading milk/slurry (38)					E-M-L
	Processing and storage of milk products for disposal (40)					E-M-L
	Rendering (41)					E-M-L

Table 6.3 Step 2 - Selection table of management options for milk (commercial)

When to apply		Pre-deposition (P)	Early (E) (hours-days)	Medium (M) (weeks-months)	Late (L) (more than a year)	When to decide
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 6.6 Step 3 - Selection table showing remaining management options for 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
Pre-deposition options	Close air intake systems at processing plants (1)					P
	Short-term sheltering of animals (4)					P
General applicability	Natural attenuation (with monitoring) (5)					E-M-L
	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA order) (7)					E-M-L
Milk	Clean feeding (20)					E-M-L
Waste disposal	Biological treatment (digestion) of milk (32)					E-M-L
	Disposal of contaminated milk to sea (35)					E-M-L
	Landspreading of milk and/or slurry (38)					E-M-L
	Processing and storage of milk products for disposal (40)					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 6.8 Step 4 - Selection table showing remaining management options for 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
Pre-deposition options	Close air intake systems at processing plants (1)					P
	Short-term sheltering of animals (4)					P
General applicability	Product recall (6)					E-M
	Restrict entry into the foodchain (inc FEPA order) (7)					E-M-L
Milk	Clean feeding (20)					E-M-L
Waste disposal	Disposal of contaminated milk to sea (35)					E-M-L
	Landspreading of milk and/or slurry (38)					E-M-L
	Processing and storage of milk products for disposal (40)					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.

6.4 References

Crick MJ and Linsley GS (1982). Assessment of the radiological impact of the Windscale fire, October 1957. Chilton, NRPB-R135.

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. Health Protection Agency, Chilton, RPD-EA-4. Available at http://www.strategy-ec.org.uk.

Loutit JF, Marley WG and Russell RS (1960). The nuclear reactor at Windscale, October 1957: environmental aspects. The hazards to man of nuclear and allied radiations: A second report to the Medical Research Council. London, HMSO. **Cmnd 1225:** 129-139.

Wilkins BT, Woodman RFM, Nisbet AF and Mansfield PA (2001). Management options for food production systems affected by a nuclear accident: Task 5: Disposal of waste milk to sea. National Radiological Protection Board, Chilton, NRPB-R323.

7 Datasheets of Management Options

7.1 Datasheet template

This handbook considers 42 management options that may be implemented in food production systems in the event of a nuclear accident or incident. 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 7.1 presents the template with a brief summary of the information that appears under each heading.

Table 7.1 Datasheet template (adapted from Nisbet et al, 2004)*

	Name of management option
Objective	Primary aim of the option (eg 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 or to which the option is to be applied (eg soil, crop, animal).
Targeted radionuclides	Radionuclide(s) that the option is aimed at. Radionuclides 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 (eg 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 (eg inhalation, ingestion, external exposure).
Time of application	Time relative to the accident or incident when the option is applied. Can be pre-deposition (ie 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 (eg annually).
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 (eg crop or animal product or surface in the environment).
Factors influencing effectiveness of procedure	Technical (eg climate, soil fertility, fat content of milk) and social factors (eg 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 (eg monitoring equipment, tankers).
Required utilities and infrastructure	Utilities (eg water and power supplies) and infrastructure (eg building and manufacturing plants) which may be required to implement the option.
Required consumables	Consumables which may be required to implement the option (eg 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 (eg capacity).

Table 7.1 Datasheet template (adapted from Nisbet et al, 2004)*

	Name of management option
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 (eg 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 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 (eg public acceptability and legal feasibility of the waste treatment or 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 (eg operators, members of the public). This dose is influenced by procedures 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 costs	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 (eg 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 (eg 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 (eg 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 (eg maintain farm income, help communities affected by overproduction by encouraging diversification, promotion of self-help, distribution of costs and benefits).
UK stakeholder opinion	Stakeholder opinion from the UK node (AFCWG) of the FARMING network.
Practical experience	State-of-the-art experience in carrying out the management option. Some options have only been tested on a limited scale, while 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.
Document history	History of previous publications that have led to the formulation of the datasheet.

* Location of hyperlinks to more detailed documentation are highlighted by underlined text.

7.2 Datasheets

The datasheets are comprehensive, concise and specific to the UK. The format and content of the datasheets are based largely on similar documents developed initially in the STRATEGY project (Nisbet et al, 2004), and adopted in version 1 of the UK Recovery Handbook for Radiation Incidents (Health Protection Agency, 2005). Further work within the EURANOS project (Beresford et al, 2006) considered management options that would be applicable to the pre-deposition and early phases and as a consequence several new datasheets were developed. Those relevant to the UK are included here ('Closure of air intake systems', 'Prevention of contamination of greenhouse crops', 'Protection of harvested crops from deposition', 'Short-term sheltering of dairy animals'). An additional update to the datasheets was made during development of version 3 of the UK Recovery Handbook (Health Protection Agency, 2009). These updates focused on changes in UK legislation and provided additional information on social and ethical factors affecting implementation of options. Stakeholder opinion from members of the AFCWG was also included.

7.2.1 Exclusion of datasheets for some management options

As stated at the start of Section 3, not all of the management options developed for use in agricultural, domestic and semi-natural ecosystems are applicable for implementation in the UK. Extensive discussion and debate within the AFCWG since 1997 has enabled a subset of options to be selected for inclusion in this handbook. Appendix B presents a list of the management options that have been excluded and reasons are given for their exclusion.

7.2.2 Key updates to the datasheets

The datasheets presented in this section are based on those published in the UK Recovery Handbook for Radiation Incidents (Health Protection Agency, 2009) but have been updated to reflect new data from recovery work in Japan following the accident at Fukushima Daiichi. Several new management options have also been included (natural attenuation with monitoring, product recall, and soil washing).

7.3 References

Beresford NA, Barnett CL, Howard BJ, Rantavaara A, Rissanen K, Reales N, Gallay F, Papachristodoulou C, Ioannides K, Nisbet AF, Brown J, Hesketh N, Hammond D, Oatway WB, Oughton D, Bay I and Smith JT (2006). *Compendium of countermeasures for the management of food production systems, drinking waters and forests.*

Health Protection Agency (2005). *UK Recovery Handbook for Radiation Incidents.* Chilton, UK, HPA-RPD-002.

Health Protection Agency (2009). *UK Recovery Handbook for Radiation Incidents 2009 Version 3.* Chilton, HPA-RPD-064.

Nisbet AF, Mercer JA, Hesketh N, Liland A, Thørring H, Bergan T, Beresford NA, Howard BJ, Hunt J and Oughton DH (2004). Datasheets on countermeasures and waste disposal options for the management of food production systems contaminated following a nuclear accident. National Radiological Protection Board, Chilton, NRPB-W58.

Table 7.2 Index of all management options, with hyperlinks to datasheets

Table 7.2 Index of all management options, with hyperlinks to datasheets

Back to list of options

1 Close air intake systems at food processing plant

Objective	To reduce: contamination of foodstuffs from unfiltered air used in processing (1); contamination of food processing facilities (2). 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 (eg 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	Industrial food processes: milling, roasting, drying, dairy or meat plants, bakery and catering industries etc. Predominantly targeted at food processes involving powdered foodstuffs. Beneficial in processing of cereals, fruit and vegetables, milk, meat, eggs, honey and fish products (1). All facilities of food processing industry (2).
Targeted radionuclides	All radionuclides.
Scale of application	Potentially large scale.
Contamination pathway	Deposition from air to foodstuffs.
Exposure pathway pre-intervention	ingestion of contaminated foodstuffs (1,2) external and inhalation doses from contaminated facilities (2)
Time of application	This option is only effective if implemented in the pre-deposition phase, before the passage of the radioactive plume, and should therefore be implemented as soon as risk becomes apparent.
Constraints	
Legal constraints	Requirement to consider radiation protection if there is a risk of operators being exposed to contaminated air-masses (ie 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; eg willingness to enter the affected area to collect products.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	For batch processes that are completed and stopped before passage of the plume the effectiveness should be close to 100% assuming that processing is not restarted until air concentrations are reduced to close to background levels (1). 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% (2).
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 or 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

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1 Close air intake systems at food processing plant

	evacuation. Changes of wind direction after the time of the incident may deem this operation unnecessary. Although the effectiveness of this measure is otherwise 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.
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, especially if they must go outside in order to close air vents. An effective system of communication must be in place, with protective clothing supplied if required. 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 protocols for implementing this measure are 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 significant quantities of waste will be generated from the measure. (1) Or a reduction in the amount of unfit food to be disposed of. Filters in air ventilation systems will require disposal.
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 disposal of contaminated air filters.
Intervention costs	
Equipment	None.
Consumables	Air filters have to be changed.
Operator time	Additional staff, extra work or 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 costs	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.

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1 Close air intake systems at food processing plant

	Clear and readily available instructions should be provided in the identified 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 (eg advisory centre, leaflets, internet and social media). Responsibilities regarding compensation may need to be defined.
Side effect evaluation	
Ethical considerations	As this measure is precautionary authorities are unlikely to lose 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 or owners. Informed consent, as 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.
UK stakeholder opinion	Use as part of emergency planning, identify plants around nuclear sites (beyond DEPZ) and issue guidance. Avoids contamination of the plant as well as products. Closure of air intake systems could lead to lost production and it is not clear who would pay compensation for the close down if it was a false alarm. Re-assurance monitoring would be required on food products subsequently processed at the plant for public confidence. Notification to close air intake systems would need to coincide with public announcement about the incident.
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 (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). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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2 Prevent contamination of greenhouse crops

Objective	To stop contaminated air or water entering greenhouse and/or polytunnels thus preventing or minimising the contamination of crops and growing media within them.
Other benefits	Reduces the amount of potentially 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. Plants should be watered with clean water, not contaminated by the incident.
Target	Greenhouse and/or polytunnel crops.
Targeted radionuclides	All radionuclides.
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. This measure should be implemented as soon as the risk becomes apparent.
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 or operators to carry out procedure.
Environmental constraints	None.
Effectiveness	
Management option effectiveness	Potentially 100% depending upon radionuclide. Radionuclides in gaseous form (eg 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 or 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 or 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 or reduced amount of food to be disposed of if measure effective. However, potentially contaminated rainwater collected during deposition should not subsequently be used to irrigate greenhouse crops and should be disposed of.
Possible transport, treatment and storage routes	Potential need for transport and disposal of rainwater.
Factors influencing waste issues	Timing of the measures as crop disposal may be required if ineffective or if crops spoilt as a consequence of the measure.

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2 Prevent contamination of greenhouse crops

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 costs	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 (eg gardeners and commercial producers); multiple channels may be necessary (eg media broadcasts, advisory centre, leaflets, internet and social media). 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. While 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 lose 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 or 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.
UK stakeholder opinion	Use as part of emergency planning, identify commercial greenhouses around nuclear sites (beyond DEPZ) and issue guidance. Avoids contamination of the greenhouse as well as the products inside. Closure of ventilation systems could lead to lost production if sustained for a lengthy period of time. It is not clear who would pay compensation for the close down if it was a false alarm. Re-assurance monitoring would be required for crops entering the foodchain for public confidence. Notification to switch off ventilation systems would need to coincide with public announcement about the incident.
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 (Nisbet AF) and STUK (A Rantavaara) provided general comments. **EURANOS peer reviewer(s)**: Vandecasteele C (Federal Agency for Nuclear Control,

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2 Prevent contamination of greenhouse crops

	Belgium). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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3 Protect harvested crops from contamination

Objective	To prevent the contamination of crops which have been harvested prior to deposition and those stored outside waiting processing (eg sugar beet).
Other benefits	Public confidence in food products.
Management option description	Covering of hay, silage (stored in clamps) and fodder crops (eg 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 (cereals, fruit and vegetables) where appropriate.
Targeted radionuclides	All radionuclides.
Scale of application	Potentially large scale but depends on the time available between notification and arrival of the plume and availability of resources or materials.
Contamination pathway	Direct deposition.
Exposure pathway pre-intervention	Ingestion of contaminated foodstuffs - animal products and possibly crops.
Time of application	This option is only effective if implemented in the pre-deposition phase, before the passage of the radioactive plume, and should therefore be implemented as soon as threat becomes apparent.
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 or resistance of farmers or 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 or waterproof tarpaulin and method of securing (eg pegs, ropes, rocks).
Required skills	Skills are present in agricultural community.
Required safety precautions	Ensure operators are removed from field prior to deposition or 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	See 36 Incineration or 37 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.

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3 Protect harvested crops from contamination

	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	Plastic sheeting or waterproof tarpaulin.
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 (eg fodder likely to be under cover with one or more open walls).
Compensation costs	Potential if crops damaged by prolonged coverage.
Waste costs	Transport and disposal of covering materials. Crops may require disposal if damaged. May be reduction in amount of food to be disposed of.
Assumptions	N/A
Communication needs	Cost of communicating the management option and its objectives to farmers; multiple channels may be necessary (eg media broadcasts, advisory centre, leaflets, internet and social media). 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. While 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 lose 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 or 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.
UK stakeholder opinion	Use as part of emergency planning, identify farms around nuclear sites (beyond DEPZ) and issue guidance to farmers. Hay bales may be covered already or in Dutch barns. Similarly, silage may be in clamps. If harvested crops have not been gathered this would need to be done before covering and therefore require additional time. There would be a secondary waste issue from covering material. Re-assurance monitoring would be required for harvested crops entering the foodchain for public confidence.
Practical experience	Farmers will have experience of covering crops after harvest (eg silage clamps) or to protect from weather.

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3 Protect harvested crops from contamination

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 (Nisbet AF) and STUK (A Rantavaara) provided general comments. **EURANOS peer reviewer(s)**: Vandecasteele C (Federal Agency for Nuclear Control, Belgium). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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4 Short-term sheltering of animals	
Objective	To avoid or limit contamination of food products derived from outdoor 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 may increase.
Management option description	Short-term housing of grazing animals prior to deposition and feeding with stored feedstuffs. The long-term clean feeding or housing of livestock is dealt with in a separate datasheet (20 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 24 Slaughtering (culling) of livestock). For extreme emergency situations requiring the immediate evacuation of the public, this management option will not be possible.
Target	All milk, meat or egg producing animals outdoors at the time of the passage of the radioactive plume
Targeted radionuclides	All radionuclides.
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, meat and egg products.
Time of application	Pre-deposition phase (not long-term). This option has to be implemented as soon as the risk becomes apparent.
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; eg 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 or 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 or 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 (eg from nitrates). Storage capacity on farm for manure and/or slurry.
Effectiveness	
Management option effectiveness	Up to 100% dependent 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 or 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 (eg some housing, especially 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 3 Protect harvested crops from contamination). Unlikely to be sufficient local housing and conserved foodstuffs in systems using

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4 Short-term sheltering of animals

	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 or 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 or 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 or passage of contaminated air mass (effective system of communication must be in place). If carried out with evacuation of population, health physics advice or 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. Reduced amount of food waste.
Possible transport, treatment and storage routes	Use of normal slurry or 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 or 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 or labour.
Waste costs	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.

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4 Short-term sheltering of animals

	Cost of communicating the management option and its objectives to farmers, other operators and the food industry (eg milk collectors); multiple channels may be necessary (eg media broadcasts, advisory centre, leaflets, internet and social media). The short time available may preclude extensive consultation, thus making it difficult to satisfy conditions of informed consent from operators. While 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 lose 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 or 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 (while 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 (ie may not be as well prepared as when normally housed) and if housed in summer when ventilation or temperature may be a problem.
Social impact	May impact on public confidence eg: loss of confidence that farm produce and derivative products (eg 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; lack of confidence if no management option applied. Disruption or adjustment of farming and related industrial activities, and people's image or perception of 'countryside'. Stigma associated with the area affected.
Other side effects	None.
UK stakeholder opinion	Use as part of emergency planning, identify farms around nuclear sites (beyond DEPZ) and issue guidance to farmers. Farmers should be able to gather dairy animals relatively quickly (in about 1 hour) as the cows would be grazing close to the milking parlour. There could be animal welfare issues as animals have to adapt to stored feeds very quickly. The availability of alternative feed will depend on the time of year with the period from March-May likely to have fewest options for alternative feedstuffs.
Practical experience	Potential efficiency demonstrated in those countries where animals were still housed at time of Chernobyl accident (eg 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 while 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 (eg 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

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4 Short-term sheltering of animals

	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 (Nisbet AF) and STUK (A Rantavaara) provided general comments. **EURANOS peer reviewer(s)**: Vandecasteele C (Federal Agency for Nuclear Control, Belgium). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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5 Natural attenuation (with monitoring)

Objective	To allow contamination to return to acceptable or background level with no active intervention.
Other benefits	No active implementation required.
Management option description	Natural decay of radionuclides will occur with time. When the contamination involves a radionuclide that has short half-life, then simply allowing sufficient time for the contamination to decay with time can be sufficient. Natural weathering via rain may lead to in increased leaching of certain radionuclides from soil and therefore lower uptake by crops or exposure to animals. Need to consider weather conditions, may be of less of benefit in hot/dry periods.
Target	Cereals, fruit and vegetable crops, milk, meat, eggs, honey and fish.
Targeted radionuclides	Probable applicability: Short-lived radionuclides such as ^{131}I. Not applicable: Long-lived radionuclides where no significant reduction in activity level will be seen before a prolonged period of time has passed.
Scale of application	Any.
Contamination pathway	N/A
Exposure pathway pre-intervention	Ingestion of contaminated milk, meat, eggs and crops
Time of application	Time relative to the accident or incident when the option is applied. Can be pre-deposition (ie 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 (eg annually).
Constraints	
Legal constraints	Need to consider potential contamination of waterways.
Social constraints	Contamination may remain a hazard until it has reduced to a safe level. Risk of contamination leaching into ground water and contaminating water courses. May be unacceptable to public to 'do nothing'
Environmental constraints	The procedure imposes environmental risk ie could bring contamination closer to ground water with leaching which may lead to transfer of radionuclides to other areas and affect other populations. Biodiversity could be affected, particularly for soil dwelling organisms.
Effectiveness	
Management option effectiveness	This recovery option does not remove the radionuclide from the affected area; decay will occur but this may take a prolonged period of time.
Factors influencing effectiveness of procedure	Properties of radionuclide Soil type Weather conditions (season) Vicinity of waterways
Feasibility	
Required specific equipment	Monitoring equipment. This option cannot be used without checks of its effectiveness and the land may not be suitable again for food production until contamination is shown to have reduced to a 'safe' level. Monitoring of any 'at risk' water courses would also be necessary.
Required ancillary equipment	None.
Required utilities and infrastructure	None.
Required consumables	Any consumables required for sampling, monitoring and analysis work. May require fencing / signs to prevent access to land.
Required skills	Skilled personnel to sample, analyse and interpret monitoring data.
Required safety precautions	None
Other limitations	Size of area. Nature of contamination
Waste	
Amount and type	This recovery option does not directly generate any waste. Wastes may arise in the first year following the incident but management strategies in subsequent years would be designed to avoid production of waste.

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5 Natural attenuation (with monitoring)

Possible transport, treatment and storage routes	N/A
Factors influencing waste issues	N/A.
Doses	
Incremental dose	N/A
Intervention costs	
Equipment	Cost of monitoring equipment.
Consumables	Cost of the consumables for sampling, monitoring and analysis work.
Operator time	That associated with sampling, monitoring and analysis. That associated with fencing / signs to prevent access to land, if required.
Factors influencing costs	Time and distances involved with travelling to areas to collect samples.
Compensation costs	There may be requests for compensation for loss of earnings from farmers or food producers if they are unable to use the land. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Waste costs	N/A
Assumptions	None.
Communication needs	It is essential that prior to, during and after the response to a radiation incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Require dialogue between farmers, ecologists and public because of potential for ground water or surface water contamination. It is important to foster confidence in the data and how it is interpreted.
Side effect evaluation	
Ethical considerations	Potential redistribution of exposure from individuals ingesting food products to new populations.
Environmental impact	The procedure imposes environmental risk ie could bring contamination closer to ground water with leaching which may lead to transfer of radionuclides to other areas and affect other populations. Biodiversity could be affected, particularly for soil dwelling organisms.
Agricultural impact	May result in agricultural land being unusable for a prolonged period of time.
Social impact	Potential for public mistrust in authorities over decision to 'do nothing' Monitoring may increase confidence of consumers and encourage people to start farming land again
Other side effects	None
UK stakeholder opinion	
Practical experience	
Key references	IAEA (2011) Final Report of the International mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Dai-ichi NPP 7-15 October 2011, Japan, IAEA NE/NEFW/2011, 15/11/2011 IAEA (2014) The follow-up IAEA International Mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Daiichi Nuclear Power Plant. Tokyo and Fukushima Prefecture, Japan. 14-21 October 2013. Final report 23/01/2014
Comments	
Document history	Adapted in 2014 from UK Recovery Handbook for Chemical Incidents Version 1.

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6 Product recall

Objective	To prevent consumers from eating contaminated food that they have already purchased.
Other benefits	Maintenance of confidence in food businesses and brands.
Management option description	Recall involves advice to the public not to consume specific products but to dispose of them or return them to the retail outlet where they were purchased (normally for a refund). Food business operators must recall products when risk assessment indicates a public health concern and withdrawal alone does not provide sufficient level of protection. Product recall would normally be carried out in conjunction with other restrictions on the food chain (7 Restrict entry into the foodchain (including FEPA orders)) Food businesses and retailers may also choose to initiate a recall when they consider this necessary to maintain public confidence. Consumers should be informed effectively and accurately of the reason for the recall of the product and consideration given to those who may already have consumed affected products (ie to avoid unnecessary anxiety and whether or not they should seek medical advice).
Target	Food retailers and people who have purchased the affected products.
Targeted radionuclides	All
Scale of application	Any.
Contamination pathway	N/A
Exposure pathway pre-intervention	Ingestion of contaminated food products.
Time of application	This recovery option has to be implemented as soon as risk becomes apparent. The time between contamination and recall is important and this may limit the feasibility of this option.
Constraints	
Legal constraints	Under general food law Regulation (EC) 178/2002 Article 19.1 places the obligation on food businesses to recall products where necessary to protect public health. Article 18.3 obliges food business operators to maintain records of the businesses to whom they supply their products. The basis for enforcement under 178/2002 is risk to health. As risk assessments tend to be subjective by nature, it is possible that the need for a recall may be challenged by the food business operator. There will be legal constraints on the fate of the recalled foodstuffs.
Social constraints	Individuals complying with instruction to return food. Issue may be trust (or lack of) in the institutions or experts advising against consumption. Effects to consumers eg price increases and food shortages in extreme incidents and potential panic buying. If extensive, recall of food products could lead to market shortages and disruption of farming and the food processing industry particularly in early phase of Implementation and where there had been panic buying. However, this is unlikely. There may be public anxiety for those who have already consumed recalled products. Perceived contamination of all food products (and loss of confidence). Operators could be put out of business with knock-on effects on other businesses. 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.
Environmental constraints	None, although there may be indirect environmental impacts depending on disposal route selected for recalled food products.
Effectiveness	
Management option effectiveness	Compliance with the recommendation not to eat certain foodstuffs and returning/ disposing of contaminated food products very unlikely to be 100% effective at reducing exposure, and will never be possible to verify in practice. Some implicated food may already have been consumed. Additionally there would be no certainty that the message reaches all purchasers of affected batches.
Factors influencing effectiveness of procedure	Selection of suitable communication channels and clarity of information. Difficulties tracing contaminated food that has been significantly distributed (eg

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6 Product recall

	abroad), though the established mechanisms of the European Rapid Alert System for Food and Feed (RASFF) should help minimise such problems. The extent to which advice is followed (possible language and literacy issues). There may be negative consequences for food producing companies, who may therefore challenge the basis for the recall. When the population has trust in the institutions or experts advising against consumption, the recovery option is likely to have more positive than negative social consequences (eg trust, personal control and informed choice).
Feasibility	
Required specific equipment	No specialist equipment is required to implement this option; however containers and temporary storage facilities may be needed for recalled food.
Required ancillary equipment	None.
Required utilities and infrastructure	For a large scale recall, specific facilities (ie temporary storage prior to waste disposal) may be required. Appropriate lines of communication are of paramount importance in implementing this option. However, as food recalls are relatively common, appropraite communication plans should be available for implementation.
Required consumables	Dependent on communication method.
Required skills	Communication skills.
Required safety precautions	None.
Other limitations	None.
Waste	
Amount and type	Milk, meat, eggs and crops. Depending on scale of the recall, it is possible that significant quantities of contaminated food products may require disposal.
Possible transport, treatment and storage routes	Milk may be landspread (38 Landspreading of milk and/or slurry) processed (40 Processing and storage of milk products for disposal) , biologically treated (32 Biological treatment (digestion) of milk) or disposed of to sea (35 Disposal of contaminated milk to sea). Meat products may be disposed of by incineration (36 Incineration) or burial (33 Burial of carcasses). Ash would require disposal (37 Landfill). Crops may be composted (34 Composting), landfilled (37 Landfill) or incinerated (36 Incineration). Waste products may be fed to fur producing animals (subject to animal welfare considerations) since transfer to fur is negligible (although contaminated carcasses and excreta may require disposal from fur farms).
Factors influencing waste issues	Disposal route selected for recalled foodstuffs and quantities of waste produced. Acceptability of, and compliance with, waste disposal practice. Local availability of suitable disposal routes. Legal constraints on the fate of recalled 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	Containers and temporary storage facilities if required.
Consumables	Dependent on communication method.
Operator time	That associated with communication - dependent on communication method.
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	There may be requests for compensation; Food industry For difference in costs compared to normal practices. Refund or replacement costs. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.

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6 Product recall

Waste costs	Dependent on subsequent disposal route selected for recalled foodstuffs and quantities of waste produced.
Assumptions	None.
Communication needs	Implementation of this recovery option is likely to meet resistance from some production or retail companies, so good stakeholder dialogue will be essential. Dissemination of information about the recovery option, its rationale and possible alternatives ie information explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels will be required to all of the food businesses concerned. Good communication with members of public is essential to prevent alarm within communities, with consistent information about the recall and the reasons for it. All possible means of communication to consumers should be considered. These may include food business, Local Authority and Food Standards Agency websites, special interest groups (eg for contaminated infant formula or baby food, organisations such as NCT, Royal College of Midwives), point-of-sale notices, newspaper and magazine adverts, television and radio (local and/or national), direct mailing (where possible and relevant).
Side effect evaluation	
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). For complete and detailed guidance, see the Human Rights Act. As this measure is precautionary authorities are unlikely to lose public trust even if with hindsight measures are proved to have been unnecessary.
Environmental impact	None, although there may be indirect environmental impacts depending on disposal route selected for recalled food products.
Agricultural impact	None.
Social impact	Public trust (or lack of) in the institutions or experts advising against consumption may be affected. 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
UK stakeholder opinion	
Practical experience	Product recalls are very common (see the Alerts section of the Food Standards Agency website at http://www.food.gov.uk/enforcement/alerts/
Key references	
Comments	
Document history	Adapted in 2014 from UK Recovery Handbook for Chemical Incidents Version 1.

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7 Restrict entry into the foodchain (including FEPA orders)

Objective	To remove food that is unsafe, for example where contaminated above Maximum Permitted Levels (MPLs), 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 withheld or withdrawn from sale. Condemnation completely removes contaminated food from the market but can leave large quantities of waste needing disposal.
Target	Predominantly milk, meat and crops (cereals, fruit and vegetables) but may also be applicable to eggs, honey, freshwater or marine fish. Also derived products from processing of these foodstuffs.
Targeted radionuclides	All radionuclides.
Scale of application	Large scale.
Contamination pathway	N/A
Exposure pathway pre-intervention	Ingestion of contaminated milk, meat, crops and other foodstuffs.
Time of application	Predominantly early but possibly to long term. This option should be considered as soon as a risk is recognised.
Constraints	
Legal constraints	MPLs are legally binding for marketed foodstuffs. There will be legal constraints on the fate of unfit foodstuffs (see waste disposal datasheets below).
Social constraints	Retail trade or producers resistance to management option.
Environmental constraints	The fate of unfit foodstuffs must be considered when food restrictions are introduced. Subsequent disposal of unfit 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. Timing and mode of implementation of the management option.
Feasibility	
Required specific equipment	The equipment required would depend upon the radionuclide. Food restrictions, which could be applied on any food where contamination is suspected, would be accompanied by measurement of 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. Personnel will be required to enforce this management option.
Required safety precautions	Radiological advice to workers (eg drivers bringing uncontaminated food into affected areas, monitoring personnel).
Other limitations	None.
Waste	
Amount and type	Foodstuffs eg 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 (38 Landspreading of milk and/or slurry) processed (40 Processing and storage of milk products for disposal) , biologically treated (32 Biological treatment (digestion) of milk) or disposed of to sea (35 Disposal of contaminated milk to sea). Livestock carcasses may be disposed of directly by rendering (41 Rendering) , incineration (36 Incineration) or burial (33 Burial of carcasses). Alternatively, the carcass

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	may be rendered and the meat and bone meal subsequently buried or incinerated at a later date. Ash would require disposal (37 Landfill). Crops may be ploughed in (39 Ploughing in of a standing crop), composted (34 Composting), landfilled (37 Landfill) or incinerated (36 Incineration). Waste products may be fed to fur producing animals (subject to animal welfare considerations) 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 unfit 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, if this requires them to drive through a contaminated area to make the delivery.
Intervention costs	
Equipment	Appropriate monitoring equipment to determine multiple radionuclides. Vehicles and equipment for collecting contaminated foodstuffs and for extending distribution networks of uncontaminated foodstuffs.
Consumables	Fuel and parts for vehicles.
Operator time	That associated 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 restricted products Food industry: for difference in costs compared to normal practices. As an example, following the accident in Fukushima, the prices of beef, peach and cucumber in 2012 were 20 to 30% lower than before the accident.
Waste cost	Dependent on subsequent disposal route selected for unfit 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 ie information explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels. Following food restrictions communication regarding the comparative safety of foodstuffs below intervention levels will be required, but this is likely to provide only partial reassurance. Good communication with members of public is essential to prevent alarm within communities 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 restrictions, whereas other areas benefit. The protection offered to the people would not necessarily compensate for this. Effects to consumers eg 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.

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7 Restrict entry into the foodchain (including FEPA orders)

Environmental impact	None, although likely to be indirect environmental impacts depending on disposal route chosen for unfit foodstuffs.
Agricultural impact	If predominant reason for food restrictions 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, restrictions on 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. Only likely to occur if panic buying ensues. 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). There may be reluctance to eat food crops even without any restrictions. 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. Pressure from consumers and retailers to apply even stricter acceptable levels of contamination. Retailers may unilaterally apply their own maximum levels and monitoring regimes.
Other side effects	None.
UK stakeholder opinion	Generally accepted that there has to be agreed limits above which food is considered unfit. It is important to harmonise these limits between member states. There must be recognition that food restrictions have associated waste disposal problems.
Practical experience	Over a period of approximately eight weeks following the 1957 Windscale accident, $3x10^6$ 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 former Soviet Union and Norway following the Chernobyl accident. In Norway condemned meat has been used as feed for fur animals. Following the Fukushima accident, the Japanese government stopped the distribution and sale of contaminated food from Fukushima prefecture and surrounding areas.
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. J Env Radioact 41 (3), 233-255. IAEA (2014) The follow-up IAEA International Mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Daiichi Nuclear Power Plant. Tokyo and Fukushima Prefecture, Japan. 14-21 October 2013. Final report 23/01/2014 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. Hamada et al, 2012 - Hamada N, Ogino H and Fujimicji Y (2012) Safety regulations of food and water implemented in the first year following the Fukushima nuclear accident. Journal of Radiation Research 53(5) pp 641-671, September 2012 Sugiman T (2014) Lessons learned from the 2011 debacle of the Fukushima nuclear power plant, Public Understanding of Science April 2014 23:254-267, first published September 12, 2013
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 restrictions do not fully protect the foodchain. However, any restrictions would be accompanied by advice relating to non-commercial foods.
Document history	**STRATEGY originator**: Nisbet AF (HPA). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA); Hunt J (ULANC), Oughton DH (UMB).

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7 Restrict entry into the foodchain (including FEPA orders)

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 (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

Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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8 Select alternative land use	
Objective	To allow agricultural land to be used for productive activities by selecting 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 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, or given over to recreational use (eg golf courses).
Target	Farmland used for crops (eg cereals, fruit and vegetables) and livestock (milk, meat and egg production).
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	Change in land use may not be allowed at farms participating in Environmental Stewardship Schemes in England, Agri-Environment Schemes in Scotland, and Environmentally Sensitive Areas (ESAs) and Countryside Stewardship Schemes (CSS) in Northern Ireland. However, grants will be available for the creation of new woodland on agricultural land and farms under the English Woodland Grant Scheme, the Better Woodlands for Wales Scheme, Land Management Contracts in Scotland, and the Environmentally Sensitive Areas Scheme and Countryside Management Scheme in Northern Ireland. In England grants for introducing short rotation coppicing under the Energy Crops Scheme closed in 2007, but will likely be re-opened in 2007 under the next Rural Development Plan. Change in land use may also be restricted in areas designated within Nitrate Vulnerable Zones (NVZs). The Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999, implementing EC Nitrate Directive 91/676/EEC, has classified areas of land in the UK as NVZs. The areas of land classified NVZs in England, Scotland, Wales and Northern Ireland are 55%, 13%, 3% and 0.1% respectively. Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. The Codes of Good Agricultural Practice should also be followed. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if a change in land use is to be carried out in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs is made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation. Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European

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8 Select alternative land use

	context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995.
Social constraints	Farmers, food industry or consumers resistance to management option. Perception that land remains contaminated.
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	This management option does not remove contamination but the 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 or 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 or harvesting equipment for alternative crop type.
Required ancillary equipment	None.
Required utilities and infrastructure	Processing facilities for chosen crop or 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 or 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, datasheets 36 Incineration or 37 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.

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8 Select alternative land use	
Intervention costs	
Equipment	Sowing or harvesting equipment for alternative crop type may not be available on farm and have to be hired.
Consumables	Seed. Livestock.
Operator time	Sowing or 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 or operators require information on choice of crop. Dissemination of information to farmers about replacing food crops with non-food crop or 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 or disruption to peoples' image or perception of 'countryside'. Possible loss of confidence in products. Disruption or adjustment of farming and related industrial activities or maintenance of farming and associated communities. Alternative practices may not be as economically viable (eg wool and leather production versus normal animal production regimes). May impact on public confidence *eg*: loss of confidence that farm produce and derivative products (eg 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 or animal products. Maintains income to the farmer. In communities affected by overproduction, diversification may be advantageous.
UK stakeholder opinion	Unlikely to be an option applicable to the short and medium term after an accident. Nevertheless, it could be considered as a longer-term option for land that must be taken out of food production due to high levels of contamination over a prolonged period. The adoption of alternative land uses requires the development of markets and processing capacity as well as training of farmers in new types of husbandry. Production of wool and leather would not be economically viable.

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8 Select alternative land use

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. *Sci Tot Env* 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. B*iomass 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 (39 Ploughing in of a standing crop), composted (34 Composting) or sent for disposal (37 Landfill). 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 (eg ploughing).
Document history	**STRATEGY originator**: Nisbet AF (HPA). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA); 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 (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). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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9 Application of lime to soils

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 hence crops such as cereals, fruit and vegetables, and grassland (which may be used in production of milk or meat producing animals)
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	Lime addition and subsequent ploughing will be restricted at farms participating in Environmental Stewardship Schemes in England, Agri-Environment Schemes in Scotland, and in Northern Ireland, Environmentally Sensitive Areas, Countryside Stewardship Scheme and Organic Farming Scheme. Restrictions will also apply in areas designated within Nitrate Vulnerable Zones (NVZs). The Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999, implementing EC Nitrate Directive 91/676/EEC, has classified areas of land in the UK as NVZs. The areas of land classified NVZs in England, Scotland, Wales and Northern Ireland are 55%, 13%, 3% and 0.1% respectively. Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. The Codes of Good Agricultural Practice should be followed. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if liming and ploughing are to be carried out in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs is made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981.In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation. Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic

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9 Application of lime to soils

	Monuments and Archaeological Objects (Northern Ireland) Order 1995.
Social constraints	Public or farmers resistance to management option (depends on usual farm practice and the potential for ecosystem change or 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 or 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 or 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	This management option does not remove contamination from the environment but can be an effective method of reducing levels in crops to be consumed or milk and meat following application to grassland. 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 (Alexakhin, 2009). These data are from studies at Kyshtym. 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}). 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 (eg $CaCO_3$ 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 or 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.

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9 Application of lime to soils

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 h 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 costs	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 or 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 or 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 (eg 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 (eg organic farming). Appropriate selection of priority areas for application of this management option.
Other side effects	Possible improvement of soil fertility.
UK stakeholder opinion	This standard agricultural practice is acceptable to farmers, provided the incremental doses to tractor drivers from the deposited activity are trivial. It should be carried out on land that is normally fertilised to minimise loss of biodiversity. Reassurance, via monitoring programmes, that crops/grass subsequently grown on treated land have radionuclide concentrations less than intervention limits.
Practical experience	Standard agricultural practice. Used widely in conjunction with NPK fertilisers in former Soviet Union following Chernobyl accident.
Key references	ALEXAKHIN, R.M., 'Remediation of areas contaminated after radiation accidents and incidents', Remediation of Contaminated Environments (VOIGT, G., FESENKO, S., Eds), Elsevier, Amsterdam (2009) 177-222. 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. *Sci Tot Env* 137, 173-182. Woodman RFM and Nisbet AF (1999). Deep ploughing, potassium and lime

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9 Application of lime to soils

	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). **STRATEGY Contributors**: Nisbet AF, Mercer JA and Hesketh N (HPA); 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 (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 Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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10 Application of potassium fertilisers to soils

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. It can also be applied as a top dressing to grassland.
Target	Arable soils and hence crops such as cereals, fruit and vegetables, and grassland (which may be used in production of milk or meat producing animals).
Targeted radionuclides	**Known applicability**: ^{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	Fertiliser addition and subsequent ploughing will be restricted at farms participating in Environmental Stewardship Schemes in England, Agri-Environment Schemes in Scotland, and in Northern Ireland, Environmentally Sensitive Areas, Countryside Stewardship Scheme and Organic Farming Scheme. The amounts of fertiliser used will be limited by the quantity of nitrogen in the fertiliser. Under the Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999, implementing EC Nitrate Directive 91/676/EEC, the total amount of nitrogen in manufactured fertiliser should not exceed crop requirement. This applies to arable soils and grasslands in England, Wales, Scotland and Northern Ireland. There are also closed periods of use. The areas of land classified as NVZs in England, Scotland, Wales and Northern Ireland are 55%, 13%, 3% and 0.1% respectively. Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. The Codes of Good Agricultural Practice should also be followed. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if fertilising and ploughing are to be carried out in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs is made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation. Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic

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10 Application of potassium fertilisers to soils

	Monuments and Archaeological Objects (Northern Ireland) Order 1995.
Social constraints	Public or farmers resistance to management option. This depends on usual farm practice and the potential for ecosystem change or 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 or 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 or stoniness of some land may make it unsuitable for a tractor and spreader.
Effectiveness	
Management option effectiveness	This management option does not remove contamination from the environment but can be an effective method of reducing levels in crops and grassland/grass-based products fed to milk and meat producing livestock. Potassium is most effective when exchangeable potassium status is less than 0.5 meq 100 g^{-1} soil. Under these conditions reduction factors of up to 5 (~80%) have been reported in the literature based on field experiments. Recent studies in Japan suggest that potassium will be effective when the soil solution potassium concentration is below about 1 mmol per litre (Smolders and Tsukada (2011). 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 or soil solution. Farmers' compliance to management option, ie 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 or 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 h ha^{-1}) excluding transport and loading of potassium.
Factors influencing costs	Repeated application may be required.

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10 Application of potassium fertilisers to soils	
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 costs	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 or 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 (eg 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	
UK stakeholder opinion	This standard agricultural practice is acceptable to farmers, provided the incremental doses to tractor drivers from the deposited activity are trivial. It should be carried out on land that is normally fertilised to minimise loss of biodiversity. Reassurance, via monitoring programmes, that crops/grass subsequently grown on treated land have radionuclide concentrations less than intervention limits.
Practical experience	Routinely applied in agriculture to optimise crop yields. Used widely in conjunction with other fertilisers and lime in former Soviet Union following Chernobyl accident. Used successfully in Japan following the Fukushima accident, with the result that only 71 out of 10 million rice bags exceeded activity reference levels.
Key references	IAEA (2014) The follow-up IAEA International Mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Daiichi Nuclear Power Plant. Tokyo and Fukushima Prefecture, Japan. 14-21 October 2013. Final report 23/01/2014 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. *Sci Tot Env* **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. *Env Sc and Tech* **31**(12), 3432-3438. Smolders E and Tsukada H (2011). The Transfer of Radiocesium from Soil to Plants: Mechanisms, Data, and Perspectives for Potential Countermeasures in Japan, Integrated Environmental Assessment and Management, Vol 7, Number 3, pp379-38 Woodman RFM and Nisbet AF (1999). Deep ploughing, potassium and lime applications to arable land, Chilton, NRPB-M1072.
Comments	Potassium would normally be applied in conjunction with nitrogen (not ammonium) and

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10 Application of potassium fertilisers to soils

	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). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA); 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 datasheets. HPA (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 Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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11 Deep ploughing

Objective	To reduce radionuclide uptake by crops, including pasture.
Other benefits	Reduction in external doses from contaminated land. Does not produce any waste.
Management option description	If no crop is present an ordinary single-furrow mouldboard plough can be used to invert the top 45cm (or other required reversal depth as determined by the distribution of radioactivity within the soil, or by presence of pebbles or other items in the soil) 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 (with subsequent plant to animal transfer if pasture land)
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 will be restricted at farms participating in Environmental Stewardship Schemes in England, Agri-Environment Schemes in Scotland, and Environmentally Sensitive Areas and the Countryside Stewardship Scheme in Northern Ireland. Restrictions will also apply in areas designated within Nitrate Vulnerable Zones (NVZs). The Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999, implementing EC Nitrate Directive 91/676/EEC, has classified areas of land in the UK as NVZs. The areas of land classified NVZs in England, Scotland, Wales and Northern Ireland are 55%, 13%, 3% and 0.1% respectively. Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. The Codes of Good Agricultural Practice should also be followed. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if ploughing is to be carried out in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs are made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation.

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11 Deep ploughing

	Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995.
Social constraints	Resistance to management option eg: 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. The depth of the water table must be taken into account. 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. The measure would not be acceptable in regions with thin top-soils as soil fertility and structure would be detrimentally affected. The risks of implementing this option would need to be assessed, for example this option may bring contamination closer to ground water sources, which could lead to the transfer of radionuclides to other areas and affect other populations.
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). External dose reduced by 50-95% (factors of 2-20), the highest reduction factors are for complete inversion of soil. Remediation in Japan following the Fukushima accident (IAEA, 2011) reduced dose rates by up to 57% (factor of 2.3). While 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	Ploughing depth. 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. Fixation of caesium is linked to the ground water level and saturation of the soil.
Feasibility	
Required specific equipment	Plough (with minimum furrow width of 0.75 m). Only depths of up to 45cm can be ploughed by normal agricultural machinery
Required ancillary equipment	Tractor (Deep ploughing requires powerful tractors eg 76-90 kW).
Required utilities and infrastructure	None.
Required consumables	Fuel.
Required skills	Farmers or agricultural workers are likely to possess the necessary skills but must be

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	instructed carefully about the objectives.
Required safety precautions	Consider respiratory protection if very dry conditions. Increased atmospheric concentration of radioactive contamination found to be mainly associated with larger soil particles, so workers could be protected by wearing a mask to reduce inhalation of such particles.
Other limitations	High ground water level. Dose limits for farmers or 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}, ie 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 costs	N/A.
Assumptions	None.
Communication needs	Farmers or 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 and to clarify the costs and benefits to farmers before decisions on implementation are made. Need dialogue between farmers, ecologists and public because of potential for ground water contamination. Provision of information to operators on correct application of procedure including radiological hazards.
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 ie brings contamination closer to the ground water 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 eg enhanced mineralisation of organic matter, change of nutrient loading and soil erosion. Changes in landscape.

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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 (eg tourism). Stigma associated with food products where the management option has been applied. May impact on public confidence eg: 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	None
UK stakeholder opinion	This standard agricultural practice is acceptable to farmers, provided the incremental doses to tractor drivers from the deposited activity are trivial. It should be carried out on land that is normally ploughed to minimise environmental impact both in terms of run-off and loss of biodiversity. Reassurance, via monitoring programmes, that crops subsequently grown on this land have radionuclide concentrations less than intervention limits. Long term control over such land is necessary for radionuclides with long physical half-lives as future management of the land may return 'buried' contamination to the surface.
Practical experience	Used widely in former Soviet Union as a management option following the Chernobyl accident. Tested on a limited scale in Denmark. Used in Japan following the Fukushima accident, where typically a ploughing depth of 30 cm was used.
Key references	IAEA, 2011 - Final Report of the International mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Dai-ichi NPP 7-15 October 2011, Japan, IAEA NE/NEFW/2011, 15/11/2011 Maubert H, Vovk I, Roed J, Arapis G and Jouve A (1993). Reduction of soil-plant transfer factors: mechanical aspects. Sci Total Env 137, 163-167. Ministry of the Environment, Japan (2013) Decontamination Guidelines, 2nd Edition. Vovk IF, Blagoyev VV, Lyashenko AN and Kovalev IS (1993). Technical approaches to decontamination of terrestrial environments in the CIS (former USSR). Sci Total Env 137, 49-63. Yasutaka T, Naito W, Nakanishi J (2013) Cost and effectiveness of decontamination strategies in radiation contaminated areas in Fukushima in regard to external radiation dose. PLoS One 2013; 8(9):e75308
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). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, 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 (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;

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UMB (Oughton DH 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

Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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Objective	To reduce activity concentrations of radionuclides in animals grazing unimproved pasture.
Other benefits	Reduction in external dose from contaminated land.
Management option description	Land improvement involves ploughing, rolling, reseeding and the application of NPK fertilisers and lime. Improvement of poorer quality pasture reduces uptake of radiocaesium and radiostrontium. 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 and subsequent plant to animal transfer
Exposure pathway pre-intervention	Ingestion of contaminated animal products.
Time of application	Medium to long term.
Constraints	
Legal constraints	Ploughing and subsequent fertiliser or lime addition will be restricted at farms participating in Environmental Stewardship Schemes in England, Agri-Environment Schemes in Scotland, and in Northern Ireland, Environmentally Sensitive Areas, Countryside Stewardship Scheme, Organic Farming Scheme. Restrictions will also apply in areas designated within Nitrate Vulnerable Zones (NVZs). The Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999, implementing EC Nitrate Directive 91/676/EEC, has classified areas of land in the UK as NVZs. The areas of land classified NVZs in England, Scotland, Wales and Northern Ireland are 55%, 13%, 3% and 0.1% respectively. Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. The Codes of Good Agricultural Practice should also be followed. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if ploughing with fertiliser or lime addition is to be carried out in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs are made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation. Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of

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	Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995.
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 < 0.3 m: unsuitable for ploughing Depth 0.3-0.5 m: shallow ploughing only Depth > 0.5 m: skim and burial or 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 former Soviet Union 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 former Soviet Union. 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.

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Feasibility	
Required specific equipment	Tractor, plough, sprayer, fertiliser spreader, seeder, roller.
Required ancillary equipment	Fencing and drainage equipment (eg digger) may be required.
Required utilities and infrastructure	Fertiliser or lime production facilities. Access to road network in remote areas. Spare land on the farm (or alternative eg on neighbouring farm or common land) to graze livestock while improvements are carried out.
Required consumables	Fuel, NPK fertilisers, lime, grass seed, herbicide (eg Glyphosate) if required. May also require consumables associated with fencing and drainage operations.
Required skills	Agricultural workers or 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 (eg 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 while 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 costs	N/A.
Assumptions	All infrastructure listed in feasibility is available.
Communication needs	Need for dialogue regarding selection of areas for treatment, between land owners or farmers, ecologists and public.

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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 or 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 (eg 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 eg: loss of confidence that farm produce and derivative products is 'safe' (may ie 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.
Other side effects	Availability of additional improved grazing can reduce wintering costs and result in higher prices for improved stock.
UK stakeholder opinion	Limited applicability in the uplands due to terrain. Unacceptable to environmentalists if carried out on a large scale due to loss of biodiversity.
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. *J Env Radioact* **56** 139-156. Nisbet AF and Woodman RFM (1999). Options for the Management of Chernobyl-restricted areas in England and Wales. Chilton, 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. Chilton, 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**: AF Nisbet (HPA, UK). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA); 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

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	extents within the EURANOS project. CEH (Beresford NA, Barnett CL and Howard BJ) revised and critically evaluated all data sheets. HPA (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). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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13 Removal of topsoil

Objective	To reduce radionuclide uptake by crops, including pasture, allotment or kitchen garden produce.
Other benefits	Reduction in external dose from contaminated land. Reduction in resuspension doses.
Management option description	**On agricultural scale:** Much of the contamination can be removed by removal of the top 2-5 cm soil. On pasture land turf is removed with the soil. On arable land any crops/plants that are present need to be removed first. Optionally, a soil hardener may be used before removal of soil. The removal may be carried out using road construction equipment such as a bobcat, mini-bulldozer, hammer-knife equipment, backhoe, or mechanical digger. The scale of equipment used will depend on the size of the area. If very thin layers of topsoil (1 cm or less) are removed, repeated runs may be necessary until the required depth is stripped. Lime (see 9 Application of lime to soils) may optionally be added to the remaining topsoil. Optionally, the soil can be replaced and can be reseeded or re-turfed depending on the size of the area. Uneven surfaces may result in some patches not being stripped - these will need to be stripped manually. Additionally, manual collection of soil and roots may be required, depending on the equipment used (eg hammer knife mower). **On allotment/kitchen garden scale:** In kitchen gardens topsoil can be removed by spade and relocated to an area of the garden not used for food production eg flower bed. Occasionally topsoil could be removed from gardens and disposed of to landfill sites or purpose-built repositories. Topsoil may also be removed from sections of allotments if non-food production area is available.
Target	Pasture or fallow arable land, areas used for domestic production such as gardens and allotments.
Targeted radionuclides	**Known applicability**: ^{60}Co, ^{75}Se, ^{89}Sr (on kitchen garden/allotment scale) , ^{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 **Not applicable**: The relatively short physical half-lives (1-2 months) of the following radionuclides may preclude this management option on an agricultural scale: ^{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 on agricultural scale. Early to long term on allotment/kitchen garden scale. Should be carried out as soon as possible, but significant reductions are still possible in the longer 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	Topsoil removal will be restricted at farms participating in Environmental Stewardship Schemes in England, Agri-Environment Schemes in Scotland, and Environmentally Sensitive Areas and Countryside Stewardship Schemes in Northern Ireland. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if topsoil removal is to be carried out in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs are made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation.

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	Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995. The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of 'radioactive waste' as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If the soil is defined as 'radioactive waste' then authorisation would be required for its storage and disposal. Disposal of waste classified 'Very Low Level Waste' (VLLW) by the EA can be disposed of with household rubbish and is subject to standard authorisation conditions. Low Level Waste (LLW) is normally disposed of at Drigg, but some may go to landfill under a controlled burial authorisation. Intermediate Level Waste (ILW) and High Level Waste (HLW) are usually stored in containers encased in concrete or glass. If the activity concentration, type of waste, and radionuclides present meet the criteria specified in Schedule 1 of RSA93, the Radioactive Substances (Phosphatic Substances, Rare Earths etc) Exemption Order 1962 and the Radioactive Substances (Substances of Low Activity) Exemption Order 1986, as amended 1992, the waste can then be sent directly to landfill and authorisation is not required. If wastes are defined as 'radioactive waste' then for road transportation the Radioactive Material (Road Transport) Regulations 2002 as amended, apply to England, Scotland and Wales. For Northern Ireland the Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1992 apply. These regulations are implemented by the Radioactive Material (Road Transport) Act 1991 and the Radioactive Material (Road Transport) (Northern Ireland) Order 1992. The Radioactive Material (Road Transport) (Definition of Radioactive Material) Order 2002 also applies in England, Scotland and Wales. For rail transportation the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 apply in England, Scotland and Wales. In Northern Ireland the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 apply, and also cover class 7 road vehicles. During 2007 the road and rail regulations for England, Scotland and Wales will be combined to form the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 made under the Health and Safety at Work etc Act 1974. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
Social constraints	Resistance to: topsoil removal (together with associated flora and fauna). aesthetic consequences of amenity or 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 unstructured soils cannot be removed effectively as a thin layer. It may not be possible to strip off frozen soil. Fields need to have compact soil with sufficient weight bearing capacity for the equipment used. Heavy equipment may break furrows. Large negative consequences for the environment when implemented on larger scale.

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Effectiveness	
Management option effectiveness	90-97% of the activity is removed. Thin-layer soil stripping using hammer knife equipment gave about 70% reduction rate. Stripping to 5cm with a mechanical digger gave 65-95% reduction. Removal of between 2 and 4 cm topsoil was found to be the most efficient countermeasure for reducing radioactive caesium in soil, with reported efficiencies of between 75 and 97% (IAEA, 2011)
Factors influencing effectiveness of procedure	Optimisation of thickness of removed layer. It is noted that the thickness removed may not match the aimed thickness. For example in Japanese trials, typically 5 to 7 cm was removed rather than the planned 3 to 5 cm. Identification of hotspots where removal of greater soil depths may be required. 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	**On agricultural scale:** Bobcat mini bulldozer or bulldozer, hammer-knife mower, backhoe, or mechanical digger **On allotment/kitchen garden scale:** Typical garden equipment (eg spade, wheelbarrow)
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	On agricultural scale: Can be carried out by already skilled operators such as municipal workers and additional operators could be instructed within a day. On allotment/kitchen garden scale: None - can be implemented as ‘self help’ measure Possible need for radiation protection training of workers.
Required safety precautions	Consider respiratory protection if very dry or dusty conditions.
Other limitations	Dose limits for workers (when implementing on agricultural scale) or public (when implementing on allotment/kitchen garden scale).
Waste	
Amount and type	If soil is relocated to other areas of garden not used for food production, no waste is produced. Otherwise, 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). The volume of removed soil to be handled (waste) will be considerably higher due to a reduction in its density during the excavation process. The volume corresponding to the removal of 5 cm layer from land surface is 50,000 m^3 per km^2 but the volume of removed soil to be handled as waste will be considerably higher.
Possible transport, treatment and storage routes	**On agricultural scale:** Disposal to landfill sites or purpose built repositories. **On allotment/kitchen garden scale:** Local authority may transport contaminated topsoil to landfill sites but due to volumes that would be involved, this would not be common practice. Removed topsoil may be treated with soil washing (42 Soil washing) to reduce the volume of contaminated soil that requires disposal.
Factors influencing waste issues	Contamination level of waste. Volume of waste. Acceptability of waste disposal options.

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	Location of disposal site especially if outside affected area. Whether topsoil is relocated within the garden or allotment or completely removed for disposal.
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	**On agricultural scale:** Bobcat or bulldoze, hammer-mower or mechanical digger shared between a number of farms. Vehicle to transport waste. **On allotment/kitchen garden scale:** Typical garden equipment (eg spade, wheelbarrow)
Consumables	Fuel for bobcat or other equipment (ca 40 l ha^{-1}). Transporters.
Operator time	Typically up to 50-100 h ha^{-1}, including loading to waste transport truck, but excluding waste transport and work at repository. If soil hardener is used there will be a delay to let topsoil harden prior to removal. Hammer-knife mower method reported to work at rate of 700 m^2/day.
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. Possible need for temporary storage as well as final disposal of removed soil
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. **Allotment holders:** Costs of new topsoil
Waste costs	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 timing and selection of areas considered suitable for treatment with this management option. Clarification of the costs and benefits before decisions on implementation are made. Provision of information on correct application of procedure including radiological hazards.
Side effect evaluation	
Ethical considerations	Potential redistribution of dose to workers/gardeners/members of the public, as well as inequity due to redistribution of dose to populations living close to waste disposal areas. Free informed consent of workers/gardeners/members of the public.
Environmental impact	Risk of soil erosion. Soil biota affected. Loss of biodiversity. Changes in landscape. Large volumes of waste generated if implemented on a larger scale.
Agricultural impact	Soil fertility may be affected by the loss of top 5 cm of soil. Fertilisation may be required. The underlying soil may be compacted with implications for subsequent cultivation.

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	Vegetation needs to be re-established.
Social impact	Stigma associated with affected areas. Disruption to farming and other related activities (eg 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.
UK stakeholder opinion	**On agricultural scale:** Unlikely to be an option considered in the UK, except for very localised contamination because of the volumes of waste generated. **On allotment/kitchen garden scale:** Thought to be acceptable option for kitchen gardens and for allotments where non food production is carried out.
Practical experience	Used in former Soviet Union as a management option following the Chernobyl accident. It was also used on a small scale after the Goiania, Palomares and Mayak accidents. Used in Japan following the Fukushima accident.
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. *J Env Radioact* **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 Phys* **76** (4), 421-430. IAEA (2011) Final Report of the International mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Dai-ichi NPP 7-15 October 2011, Japan, IAEA NE/NEFW/2011, 15/11/2011 Ministry of the Environment, Japan (2013) Decontamination Guidelines, 2nd Edition. Miyahara K., Tokizawa T., Nakayama S (2012). Decontamination pilot projects: building a knowledge base for Fukushima environmental remediation. Mater Res Soc Symp Proc 2012; 1518:245-256. Nakano M. and Yong RN (2013). Overview of rehabilitation schemes for farmlands contaminated with radioactive cesium released from Fukushima power plant. Engineering Geol 2013; 155:87-93. 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. Vovk IF, Blagoyev VV, Lyashenko AN and Kovalev IS (1993). Technical approaches to decontamination of terrestrial environments in the CIS (former USSR). *Sci Tot Env* **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). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, 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 (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F), UOI

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(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

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.

Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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14 Shallow ploughing

Objective	To reduce radionuclide uptake by crops, including pasture.
Other benefits	Reduction in external dose from contaminated land. Does not produce any waste.
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 (with subsequent plant to animal transfer if pasture land)
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 and prior to sowing a new arable crop. However, if practical, a delay after deposition will reduce external doses from short-lived radionuclides to operators.
Constraints	
Legal constraints	Ploughing may be restricted under some environmental protection schemes.
Social constraints	Acceptability of making contamination less retrievable, rather than removing it. Potential resistance where ploughing is not standard practice. Resistance to aesthetic consequences of any subsequent landscape or 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^{o}. While steep slopes and shallow soils cannot be ploughed these are unlikely to be found within areas of arable land. The measure may not be acceptable in regions with thin top-soils as soil fertility and structure would be detrimentally affected. The risks of implementing this option would need to be assessed, for example this option may bring contamination closer to ground water sources, which could lead to the transfer of radionuclides to other areas and affect other populations.
Effectiveness	
Management option effectiveness	This management option does not remove contamination from the environment but can be an effective method of removing the source or weakening the exposure pathway. 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). While 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.

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	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 and parts for equipment.
Required skills	Farmers or 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. Increased atmospheric concentration of radioactive contamination found to be mainly associated with larger soil particles, so workers could be protected by wearing a mask to reduce inhalation of such particles.
Other limitations	Very high ground water table. Dose limits for farmers or 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 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 costs	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.

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Environmental impact	The procedure brings contamination closer to the ground water. 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 eg: loss of confidence that farm produce and derivative products (eg 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 (eg tourism). Contamination of the soil may restrict subsequent uses. Aesthetic consequences of any subsequent landscape or 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.
UK stakeholder opinion	This standard agricultural practice is acceptable to farmers, provided the incremental doses to tractor drivers from the deposited activity are trivial. It should be carried out on land that is normally ploughed to minimise environmental impact both in terms of run-off and loss of biodiversity. Reassurance, via monitoring programmes, that crops subsequently grown on this land have radionuclide concentrations less than intervention limits. Long term control over such land is necessary for radionuclides with long physical half-lives.
Practical experience	Tested widely in former Soviet Union following the Chernobyl accident. Tested on a limited scale in Denmark. Used in Japan following the Fukushima accident, where ploughing twice to about 30 cm was carried out.
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. *J Env Radioact* **56**, 77-98. Maubert H, Vovk I, Roed J, Arapis G and Jouve A (1993). Reduction of soil-plant transfer factors:mechanical aspects. *Sci Tot Env* **137**, 163-167. Ministry of the Environment, Japan (2013) Decontamination Guidelines, 2nd Edition. Salt CA and Rafferty B (2001). Assessing potential secondary effects of countermeasures in agricultural systems: a review. *J Env Radioact* **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. *Sci Tot Env* **278**,199-214. Vovk IF, Blagoyev VV, Lyashenko AN and Kovalev I S (1993). Technical approaches to decontamination of terrestrial environments in the CIS. *Sci Tot Env* **137**, 49-63.
Comments	Ploughing is more effective when carried out in conjunction with fertiliser and lime application (see 12 Land improvement) Potassium and calcium reduce uptake of radiocaesium and radiostrontium.
Document history	**STRATEGY originat**or: Nisbet AF (HPA). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA); Beresford NA and Howard BJ (CEH); Hunt J (ULANC); Oughton DH (UMB).

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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 (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

Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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15 Skim and burial ploughing

Objective	To reduce radionuclide uptake by crops, including pasture.
Other benefits	Reduction in external doses from contaminated land. Does not produce any waste.
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 (with subsequent plant to animal transfer if pasture land)
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	Ploughing will be restricted at farms participating in Environmental Stewardship Schemes in England, Agri-Environment Schemes in Scotland, and Environmentally Sensitive Areas and the Countryside Stewardship Scheme in Northern Ireland. Restrictions will also apply in areas designated within Nitrate Vulnerable Zones (NVZs). The Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999, implementing EC Nitrate Directive 91/676/EEC, has classified areas of land in the UK as NVZs. Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. The Codes of Good Agricultural Practice should also be followed. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if ploughing is to be carried out in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs is made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation.

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	Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995.
Social constraints	Farmers' resistance to management option. Topsoil burial with associated removal of flora and fauna raises wildlife issues that are likely to be contested. Resistance to aesthetic consequences of any subsequent landscape or amenity changes. Perception that contamination is not being removed and is just being 'buried'.
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. The risks of implementing this option would need to be assessed, for example this option may bring contamination closer to ground water sources, which could lead to the transfer of radionuclides to other areas and affect other populations.
Effectiveness	
Management option effectiveness	Reduction of contamination by about 83-92% (factor of 6-12.5), 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% (factor of 16.7). While 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	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, ie 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, eg 90 kW, which are not necessarily widely available).
Required utilities and infrastructure	Road network for transporting plough.
Required consumables	Fuel and parts for equipment.
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.

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Required safety precautions	Consider respiratory protection if very dry conditions. Increased atmospheric concentration of radioactive contamination found to be mainly associated with larger soil particles, so workers could be protected by wearing a mask to reduce inhalation of such particles.
Other limitations	Shallow soils. High ground water table. Dose limits for farmers or 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	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}, ie (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 costs	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 to clarify the costs and benefits to farmers before decisions on implementation are made. Need dialogue between farmers, ecologists and public because of potential for ground water contamination. Provision of information to operators on correct application of procedure including radiological hazards.
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 ground water and there is a risk that radionuclides will be transferred to other areas and affect other populations. Long term changes in physical characteristics and structure of the surface horizon, eg enhanced mineralisation of organic matter, change of nutrient loading and soil erosion. Biodiversity could be affected, particularly for soil dwelling organisms. Future restriction on land use: must not be deep tilled. Changes in landscape.

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	Potential for ecosystem change or damage. Severely complicates subsequent removal of the contamination.
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. Pasture land will require reseeding.
Social impact	Stigma associated with food products where the management option has been applied. May impact on public confidence eg: 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 or 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 (eg 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	None
UK stakeholder opinion	Skim and burial ploughing is acceptable to farmers, provided the incremental doses to tractor drivers from the deposited activity are trivial. It should be carried out on land that is normally ploughed to minimise environmental impact both in terms of run-off and loss of biodiversity. Reassurance, via monitoring programmes, that crops subsequently grown on this land have radionuclide concentrations less than intervention limits. Long term control over such land is necessary for radionuclides with long physical half-lives as future management of the land may return 'buried' contamination to the surface.
Practical experience	Used in former Soviet Union 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. *J Env Radioact* **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). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, 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 (Hesketh N and Nisbet AF) took the lead for generating additional radionuclide lists; IRSN (Reales N and Gallay F),

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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

Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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16 Addition of AFCF to concentrate ration

Objective	To reduce activity concentrations of radiocaesium in meat, milk and eggs to below intervention levels.
Other benefits	Reduction in quantities of animal produce that will need to be disposed of. Normal animal management or 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 or egg 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, milk and egg 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}Cs, ^{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	On 14 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. After administration of AFCF, milk and meat will be subject to Maximum Permitted Levels (MPLs). The use of AFCF may not be permitted under some organic production regimes. The welfare of on-farm livestock is protected by the Protection of Animals Act 1911, as amended, in England and Wales, the Protection of Animals (Scotland) Act 1912 and the Welfare of Animals Act (Northern Ireland) 1972. They are further protected in England, Scotland and Wales by the Agriculture (Miscellaneous Provisions) Act 1968. This Act provides for ‘welfare codes’ of recommendations to be drawn up. Although ‘welfare codes’ do not lay down statutory requirements, livestock farmers and employers are required by law to ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes. The Welfare of Farmed Animals (England) Regulations 2000 cover all farmed animals and contain specific requirements regarding activities such as inspections and feeding and watering of animals. Equivalent UK legislation is Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000. These regulations implement EU General Directive 98/58/EC, EU Laying Hens Directive 99/74/EC, EU Calves Directive 91/629/EEC as amended and EU Pigs Directive 91/630/EEC as amended. The Animal Welfare Act 2006 has brought together and modernised welfare legislation, particularly the Protection of Animals Act 1911 and equivalent acts, for farmed and non-farmed animals.
Social constraints	Acceptability to farmers or herders, food industry and consumers of using an additional feed additive to remove contamination from the gut of livestock.
Environmental constraints	Minor considerations are the presence of AFCF and enhanced levels of radiocaesium in slurry.

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Effectiveness	
Management option effectiveness	For cows receiving 3 g 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. For pigs and calves receiving 2 g AFCF per day a 90% reduction in radiocaesium contamination in meat (Giese, 1988 and 1989). Hexacyanoferrate compounds can achieve reduction factors in animal products of up to ten (90% reduction) (IAEA, 2006) Application of Prussian blue gave a reduction factor of 3 (67% reduction) for ^{137}Cs in milk, and a reduction factor of 2 (50% reduction) for ^{137}Cs in beef. (Jacob et al, 2001) The maximum effectiveness of AFCF application in terms of ^{137}Cs activity concentration reduction in animal products is up to 10-fold, but typically in field conditions it is 3 to 5-fold (IAEA, 2012)
Factors influencing effectiveness of procedure	Effective administration of the concentrate. Amount of AFCF ingested to animal daily. Greater effectiveness when farmer or 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 or 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. Current production facilities for AFCF may be rate limiting if large quantities required. Application of this measure may be limited by costs. In Ukraine no local source of Prussian blue was available and the cost of purchasing it from western Europe was considered to be too high (IAEA, 2006).
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 was € 0.27 EUR per kg feed (*c*. 2003). Estimated annual cost of application of Prussian blue was about €25 per cow. (Jacob et al, 2001)
Operator time	Farmer may need to mix the AFCF in the feed.
Factors influencing costs	Production cost for the concentrates with AFCF. Transportation costs.

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Compensation costs	To the farmer or herder to compensate for the extra costs associated with buying concentrates with AFCF.
Waste costs	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	None
Environmental impact	While 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 eg: loss of confidence that farm produce and derivative products (eg cheese) from affected areas are 'safe' (may ie 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.
UK stakeholder opinion	Farmers consider AFCF supplementation of feed to be acceptable, as this will help to ensure that milk and meat can still enter the foodchain. There would be reluctance by organic farmers to administer AFCF because it could be perceived as an unnecessary additive. The National Farmers' Union would support this option provided they were satisfied that there were no long-term effects or animal suffering. Reassurance, via monitoring programmes, would be necessary to show that treated livestock have radionuclide concentrations less than intervention limits. Public reassurance would also be required to show that milk and meat did not contain AFCF or its breakdown products. If the alternative to this option is mass slaughter of livestock, the public would probably favour the administration of additives to the diet.
Practical experience	Used frequently after the Chernobyl accident in Norway with good results for cows and goats and reindeer; in the former Soviet Union 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. Sci Tot Env 85, 317-327. Hove K (1993). Chemical methods for reduction of the transfer of radionuclides to farm animals in semi-natural environments. Sci Tot Env 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. J Env Radioact 56, 115-137. IAEA (1994). Handbook of parameter values for the prediction of radionuclide transfer in temperate environments. IAEA Technical Report Series No. 364, Vienna IAEA. IAEA (2012)Guidelines for remediation strategies to reduce the radiological consequences of environmental contamination. IAEA Technical Report Series No. 475, Vienna IAEA. Pearce J (1994). Studies on any toxicological effects of Prussian Blue compounds in mammals - a review. Food Chem. Toxicol 32, 577-582.

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	Salt CA and Rafferty B (2001). Assessing potential secondary effects of countermeasures in agricultural systems: a review. J Env Radioact 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. J Env Radioact 41 (3), 233-255. IAEA (2006) Environmental Consequence of the Chernobyl Accident and Their Remediation: Twenty Years of Experience. Report of the Chernobyl Forum Expert Group ‘Environment’. International Atomic Energy Authority, Vienna. Jacob et al, 2001 - Jacob P, Fesenko S, Firsakova SK, Likhtarev IA, Schotola C, Alexakhin RM, Zhuchenko YM, Kovgan L, Sanzharova NI and Ageyets V (2001) Remediation strategies for rural territories contaminated by the Chernobyl accident, Journal of Environmental Radioactivity, 56(2001) 51-76
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 or 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 or flock.
Document history	**STRATEGY originator**: Liland A (NRPA) **STRATEGY contributors**: Nisbet AF, Mercer JA and Hesketh N (HPA); 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 (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 Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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17 Addition of calcium to concentrate ration

Objective	To reduce the activity concentration of radiostrontium in milk and other animal produce to below intervention levels.
Other benefits	Reduction in quantity of milk that will need to be disposed of. Normal animal management or 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	Primarily aimed at milk producing animals, but may also benefit animals used for meat or egg production.
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 and other animal products (meat and eggs).
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 Maximum Permitted Levels (MPLs). 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. The welfare of on-farm livestock is protected by the Protection of Animals Act 1911, as amended, in England and Wales, the Protection of Animals (Scotland) Act 1912 and the Welfare of Animals Act (Northern Ireland) 1972. They are further protected in England, Scotland and Wales by the Agriculture (Miscellaneous Provisions) Act 1968. This Act provides for 'welfare codes' of recommendations to be drawn up. Although 'welfare codes' do not lay down statutory requirements livestock farmers and employers are required by law to ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes. The Welfare of Farmed Animals (England) Regulations 2000 cover all farmed animals and contain specific requirements regarding activities such as inspections and feeding and watering of animals. Equivalent UK legislation is Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000. These regulations implement EU General Directive 98/58/EC, EU Laying Hens Directive 99/74/EC, EU Calves Directive 91/629/EEC as amended and EU Pigs Directive 91/630/EEC as amended. The Animal Welfare Act 2006 has brought together and modernised welfare legislation, particularly the Protection of Animals Act 1911 and equivalent acts, for farmed and non-farmed animals.
Social constraints	Acceptability of the management option to farmers or herders, food industry and consumers.
Environmental constraints	Need to consider increased contamination in slurry.
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. While 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). Use of calcium rich fodder resulted in a 10-fold decline (90% reduction) in ^{90}Sr concentrations in milk (Alexakin, 2009)

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Factors influencing effectiveness of procedure	Effective administration of the calcium in concentrate. Animal's dietary intake prior to calcium supplementation and its calcium requirements. While 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 or 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 costs	N/A.
Assumptions	None.
Communication needs	Possible cost of labelling.
Side effect evaluation	
Ethical considerations	None.
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 eg: loss of confidence that farm produce and derivative products (eg cheese) from affected areas is 'safe' (may ie 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.

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Other side effects	Can maintain milk production without disrupting the normal farming practices.
UK stakeholder opinion	Farmers consider calcium supplementation of feed to be acceptable, as this will help to ensure that milk can still enter the foodchain. Reassurance, via monitoring programmes, that livestock have radionuclide concentrations less than intervention limits would be necessary. If the alternative to this option is mass slaughter of livestock, the public would probably favour the administration of additives to the diet. The administration of more 'natural' components (in this case calcium) to feed would be more acceptable to consumers.
Practical experience	Was used following the Kyshtym accident.
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. Rad and Env 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. J Env Radioact 51, 321-342. Alexakhin R (2009) Remediation of Areas Contaminated after Radiation Accidents, in Remediation of Contaminated Environments, ed G Voigt and S Fesenko, Radioactivity in The Environment Volume 14, Elsevier
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 or effective to incorporate enhanced Ca into pelleted feeds during manufacture.
Document history	**STRATEGY originator**: Nisbet AF (HPA). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, UK); 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). **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 (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 Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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18 Addition of clay minerals to feed

Objective	To reduce activity concentrations of radiocaesium in meat, milk or eggs 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 or grazing regimes can be used.
Management option description	Clay minerals (ie bentonites, vermiculites, zeolites) can be added to fodder to reduce gut uptake of radiocaesium by farmed livestock.
Target	Meat and milk or egg 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}Cs, ^{137}Cs **Probable applicability**: - **Not applicable**: -
Scale of application	Large.
Contamination pathway	Plant to animal.
Exposure pathway pre-intervention	Ingestion of contaminated meat, milk or eggs
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 Maximum Permitted Levels (MPLs). Bentonite is a legal feed additive in some countries to prevent scouring. The welfare of on-farm livestock is protected by the Protection of Animals Act 1911, as amended, in England and Wales, the Protection of Animals (Scotland) Act 1912 and the Welfare of Animals Act (Northern Ireland) 1972. They are further protected in England, Scotland and Wales by the Agriculture (Miscellaneous Provisions) Act 1968. This Act provides for 'welfare codes' of recommendations to be drawn up. Although 'welfare codes' do not lay down statutory requirements livestock farmers and employers are required by law to ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes. The Welfare of Farmed Animals (England) Regulations 2000 cover all farmed animals and contain specific requirements regarding activities such as inspections and feeding and watering of animals. Equivalent UK legislation is Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000. These regulations implement EU General Directive 98/58/EC, EU Laying Hens Directive 99/74/EC, EU Calves Directive 91/629/EEC as amended and EU Pigs Directive 91/630/EEC as amended. The Animal Welfare Act 2006 has brought together and modernised welfare legislation, particularly the Protection of Animals Act 1911 and equivalent acts, for farmed and non-farmed animals.
Social constraints	Public or farmers resistance to management option. Acceptability of method with respect to animal welfare issues.
Environmental constraints	Need to consider increased contamination in slurry.
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 1-2 g kg^{-1} body weight per day. A reduction factor of 2-3 (50 - 67% reduction) is seen for ^{137}Cs from administration of clay minerals to animals (IAEA, 2012)
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 has been observed if 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.

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	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 or 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 or herder already incorporated in feed, the farmer or 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 costs	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 eg zeolite are spread to land with slurry or manure.
Agricultural impact	May be necessary to provide additional water.

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	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 eg: loss of confidence that farm produce and derivative products (eg cheese) from affected areas is 'safe' (may ie 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.
UK stakeholder opinion	Farmers consider supplementation of feed with clay minerals to be acceptable, as this will help to ensure that milk can still enter the foodchain. Reassurance, via monitoring programmes, that livestock have radionuclide concentrations less than intervention limits would be necessary. If the alternative to this option is mass slaughter of livestock, the public would probably favour the administration of additives to the diet. The administration of more 'natural' components (in this case clay minerals) to feed would be more acceptable to consumers.
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. *Sci Tot Env* **85**, 339-347. Voigt G (1993). Chemical methods to reduce the radioactive contamination of animals and their products in agricultural ecosystems. *Sci Tot Env* **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. *J Env Radioact* **31**, 29-50. IAEA (2012) International Atomic Energy Authority Technical Report Series No 475, Guidelines for Remediation Strategies to Reduce the Radiological Consequences of Environmental Contamination. IAEA, Vienna, 2012.
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 or 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).

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18 Addition of clay minerals to feed

STRATEGY contributors: Mercer JA and Hesketh N (HPA, UK); 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 (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

Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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19 Administer AFCF boli to ruminants

Objective	To reduce activity concentrations of radiocaesium in meat to below intervention levels.
Other benefits	Reduction in quantities of animal produce that will need to be disposed of. Normal animal management or grazing regimes can be maintained. Potential for additional reduction of radiocaesium uptake from soil to grass and other crops through using manure (from housed animals) containing AFCF for fertilisation (see Howard et al*,* 2001).
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. 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. There is potential for applying this management option to milk producing animals, though it is more likely that 16 Addition of AFCF to concentrate ration would be used.
Target	Primarily meat producing ruminants, though potential for application to milk producing animals.
Targeted radionuclides	**Known applicability**: ^{134}Cs, ^{137}Cs **Probable applicability**: - **Not applicable**: Specific to radiocaesium
Scale of application	Distributed to all ruminants eating contaminated feed - especially suitable for free-grazing or 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 or stockpiles means that is not a potential management option for application in the early-phase).
Constraints	
Legal constraints	On 14 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. After administration of boli, milk and meat will be subject to Maximum permitted Levels (MPLs). AFCF boli may not be permitted under some organic production regimes. The welfare of on-farm livestock is protected by the Protection of Animals Act 1911, as amended, in England and Wales, the Protection of Animals (Scotland) Act 1912 and the Welfare of Animals Act (Northern Ireland) 1972. They are further protected in England, Scotland and Wales by the Agriculture (Miscellaneous Provisions) Act 1968. This Act provides for 'welfare codes' of recommendations to be drawn up. Although 'welfare codes' do not lay down statutory requirements livestock farmers and employers are required by law to ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes. The Welfare of Farmed Animals (England) Regulations 2000 cover all farmed animals and contain specific requirements regarding activities such as inspections and feeding and watering of animals. Equivalent UK legislation is Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000. These regulations implement EU General Directive 98/58/EC, EU Laying Hens Directive 99/74/EC, EU Calves Directive 91/629/EEC as amended and EU Pigs Directive 91/630/EEC as amended. The Animal Welfare Act 2006 has brought together and modernised welfare legislation, particularly the Protection of Animals Act 1911 and equivalent acts, for farmed and non-farmed animals.
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 former Soviet Union and sheep farmers in the UK.
Environmental constraints	Minor considerations are the presence of AFCF and enhanced levels of radiocaesium in

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	slurry.
Effectiveness	
Management option effectiveness	Up to 80% reduction in lamb meat and goat milk, and up to 70% reduction in cows' 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 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 (eg 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.
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. 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 per applicator for reindeer (Norwegian example *c*. 2003).
Consumables	Approximately € 2 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. 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. Hence

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	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 or 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 costs	None.
Assumptions	None.
Communication needs	Requirement for labelling products.
Side effect evaluation	
Ethical considerations	Animal welfare when administering boli.
Environmental impact	While 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. Change in agricultural production status (especially organic).
Social impact	May impact on public confidence eg: loss of confidence that farm produce and derivative products (eg 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.
UK stakeholder opinion	There would be reluctance by organic farmers to administer AFCF because it could be perceived as an unnecessary additive. Farmers generally consider administration of AFCF boli to be acceptable, as this will help to ensure that meat can still enter the foodchain. The National Farmers' Union would support this option provided they were satisfied that there were no long-term effects or animal suffering. Reassurance, via monitoring programmes, would be necessary to show that treated livestock have radionuclide concentrations less than intervention limits. Public reassurance would also be required to show that milk and meat did not contain AFCF or any of its breakdown products. If the alternative to this option is mass slaughter of livestock, the public would probably favour the administration of additives to the diet.
Practical experience	Used in production systems in Norway and the former Soviet Union after the Chernobyl accident. In former Soviet Union 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. *J Env Radioact* **56**, 115-137. Nisbet AF and Woodman RFM (2000). Options for the Management of Chernobyl-restricted areas in England and Wales. *J Env Radioact* **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*

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	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 Phys* **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. *Sci Tot Env* **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**: Mercer JA and Hesketh N (HPA, UK); 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 (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). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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Objective	To reduce activity concentrations of radionuclides in milk, meat and eggs to below intervention levels.
Other benefits	Reduces amount of milk, meat and eggs 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. Clean feeding can be used to prevent animals becoming contaminated in the first place, or to minimise the time need for metabolism and excretion to reduce the contamination to an acceptable level. 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 Maximum Permitted Levels (MPLs). For milk or egg producing animals clean feeding will need to be continuous while pasture/food activity concentrations would result in milk or eggs exceeding MPLs. 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). This could be achieved by moving animals onto uncontaminated pasture prior to slaughter, a practice which is already common in some areas (eg fattening of hill-bred sheep on lowland pasture prior to slaughter).
Target	All livestock (milk, meat and egg producing animals, especially grazing animals) that are destined for the foodchain.
Targeted radionuclides	All radionuclides
Scale of application	Large scale application, although dependent on supply of suitable clean feed at a reasonable price. For domestic scale application see datasheet 26 Clean feeding (domestic livestock).
Contamination pathway	Plant to animal.
Exposure pathway pre-intervention	Ingestion of contaminated milk, meat and eggs.
Time of application	Early to long term.
Constraints	
Legal constraints	The sale of milk and meat intended for human consumption is subject Maximum Permitted Levels (MPLs). Standards of animal husbandry and welfare and regulations governing feed storage would need to be observed. Some certification schemes may be contravened. For example, in the case of organic milk production, there is a limit on the proportion of concentrate in the diet of dairy cattle. Free range schemes may also be restricted following an accident, if animals have to be housed. The welfare of on-farm livestock is protected by the Protection of Animals Act 1911, as amended, in England and Wales, the Protection of Animals (Scotland) Act 1912 and the Welfare of Animals Act (Northern Ireland) 1972. They are further protected in England, Scotland and Wales by the Agriculture (Miscellaneous Provisions) Act 1968. This Act provides for ‘welfare codes’ of recommendations to be drawn up. Although ‘welfare codes’ do not lay down statutory requirements livestock farmers and employers are required by law to ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes. The Welfare of Farmed Animals (England) Regulations 2000 cover all farmed animals and contain specific requirements regarding activities such as inspections and feeding and watering of animals. Equivalent UK legislation is Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000. These regulations implement EU General Directive 98/58/EC, EU Laying Hens Directive 99/74/EC, EU Calves Directive 91/629/EEC as amended and EU Pigs Directive 91/630/EEC as amended. The Animal Welfare Act 2006 has brought together and modernised welfare legislation, particularly the Protection of Animals Act 1911 and equivalent acts, for farmed and non-farmed animals. Local regulations on the use and siting of buildings must be consulted. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if a programme of grassland management (mowing) with fertiliser or lime addition is to be carried out in an

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	area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs is made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation. Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Consents will also be required if structures such as temporary buildings and fences are to be erected. Grassland management and erecting temporary buildings and fences may also be restricted in archaeological areas and areas containing ancient monuments. These areas are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995.
Social constraints	Resistance of farmer or herder to management option. Acceptability to food industry or consumers of changes in the quality of the food product (eg 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 or manure. This must be stored and disposed of to land at times when ‘conventional’ pollution (from manure or slurry) would not occur (eg suitable weather conditions). There may be restrictions on where temporary fences can be erected eg in National Parks and Environmentally Sensitive Areas.
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%. A reduction factor of 2-5 (50 - 80% reduction) is seen for ^{137}Cs and ^{90}Sr from clean feeding (IAEA, 2012) Clean feeding of pigs for two months before slaughter gave a reduction factor of 3 (67% reduction) for ^{137}Cs in pork meat (Jacob et al, 2001) Clean feeding resulted in ^{90}Sr concentrations 2-7 (50 - 85% reduction) times lower in meat and 3-4 times lower (67 - 75% reduction) in milk (Alexakin, 2009)
Factors influencing effectiveness of procedure	Farmers or 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.

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	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 or 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. Straw for bedding.
Required skills	Farmers would possess the necessary skills as housing animals is an existing practice.
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. There may be limitations due to the availability of clean feed. For example, with the Fukushima accident occurring in late spring, there was a problem that the availability of stored feed was limited.(Beresford and Howard, 2011)
Waste	
Amount and type	A programme of grassland management must be implemented while livestock are fenced or housed to ensure that intervention levels are not exceeded when the animals are reintroduced to pasture and that pasture quality is maintained. This involves cutting and disposing of contaminated grass before animals are returned to pasture. Slurry or manure produced while livestock are fenced in or housed.
Possible transport, treatment and storage routes	The cut grass may be composted (34 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 or 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

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	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 or 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 or manure. In summer, slurry or 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 or manure either by composting (34 Composting) or landspreading (38 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 while 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 or feed transport.
Operator time	**Farmer/herder**: obtaining uncontaminated feed (and harvesting grass pre-deposition); looking after animals not normally housed or fenced; implementation of the alternative feeding regime; collection, storage and disposal of slurry/manure; cutting and disposal (eg 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 costs	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 21 Live monitoring).
Communication needs	Explaining management option to farmers or herders. Ensuring communication re harvesting of grass in pre-deposition phase.
Side effect evaluation	
Ethical considerations	Self-help for farmers or herders. Animal welfare issues if animals are housed in the summer when temperature and

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	ventilation could be a problem (eg humidity, high levels of ammonia in buildings). Animal welfare issues may also arise when enclosures are used (eg parasite burden, general animal hygiene).
Environmental impact	Inappropriate disposal of additional slurry or 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 high stocking rate surface vegetation will be destroyed. Greater volumes of manure or slurry.
Social impact	Disruption to people's image or perception of 'countryside' eg if there are no animals in the fields, with potential impacts on tourism etc. May impact on public confidence eg: loss of confidence that farm produce and derivative products (eg 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	None.
UK stakeholder opinion	Acceptable to all major stakeholders but can be expensive depending on time of year. Reassurance, via monitoring programmes, that livestock have radionuclide concentrations less than intervention limits.
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. Clean feeding was also used following the Fukushima and Kyshtym accidents.
Key references	Åhman B (1999). Transfer of radiocaesium via reindeer meat to man - effect of countermeasures applied in Sweden following the Chernobyl accident. *J Env Radioact* **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 Phy* **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. Chilton, 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. Chilton, 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. *J Env Radioact* **41** (3), 233-255. IAEA (2012) International Atomic Energy Authority Technical Report Series No 475, Guidelines for Remediation Strategies to Reduce the Radiological Consequences of Environmental Contamination. IAEA, Vienna, 2012. Jacob P, Fesenko S, Firsakova SK, Likhtarev IA, Schotola C, Alexakhin RM, Zhuchenko YM, Kovgan L, Sanzharova NI and Ageyets V (2001) Remediation strategies for rural territories contaminated by the Chernobyl accident, Journal of Environmental Radioactivity, 56(2001) 51-76)

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	Alexakhin R (2009) Remediation of Areas Contaminated after Radiation Accidents, in Remediation of Contaminated Environments, ed G Voigt and S Fesenko, Radioactivity in The Environment Volume 14, Elsevier Beresford N and Howard B (2011) An overview of the Transfer of Radionuclides to Farm Animals and Potential Countermeasures of Relevance to Fukushima Releases, Integrated Environmental Assessment and Management, volume 7 number 3 pp 382-384.
Comments	Sheltering of animals prior to and during deposition is dealt with in a separate datasheet (4 Short-term sheltering of 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 (eg large bale silage making generally requires two 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). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, 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) 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 (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). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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21 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 20 Clean feeding, or 16 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 (eg cattle, sheep, goats)
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 (ie beta and alpha emitters) and radionuclides with low photon energies (eg ^{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 Maximum Permitted Levels (MPLs). The welfare of on-farm livestock is protected by the Protection of Animals Act 1911, as amended, in England and Wales, the Protection of Animals (Scotland) Act 1912 and the Welfare of Animals Act (Northern Ireland) 1972. They are further protected in England, Scotland and Wales by the Agriculture (Miscellaneous Provisions) Act 1968. This Act provides for ‘welfare codes’ of recommendations to be drawn up. Although ‘welfare codes’ do not lay down statutory requirements, livestock farmers and employers are required by law to ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes. The Welfare of Farmed Animals (England) Regulations 2000 cover all farmed animals and contain specific requirements regarding activities such as inspections and feeding and watering of animals. Equivalent UK legislation is Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000. These regulations implement EU General Directive 98/58/EC, EU Laying Hens Directive 99/74/EC, EU Calves Directive 91/629/EEC as amended and EU Pigs Directive 91/630/EEC as amended. The Animal Welfare Act 2006 has brought together and modernised welfare legislation, particularly the Protection of Animals Act 1911 and equivalent acts, for farmed and non-farmed animals.
Social constraints	Resistance by farmer or 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

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	foodchain (see radiocaesium below). **Radiocaesium** Accuracy of calibration and detector type; uncertainty on measurement may mean that a rejection level much below the intervention limit is used (eg in the UK where the post Chernobyl intervention level for radiocaesium is 1000 Bq kg^{-1} sheep with a lower estimated activity concentration, based on the type and age of the monitor used (for example 645 Bq ^{137}Cs kg^{-1}) were 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. Consideration of the monitoring environment (for example, proximity of stone walls). Duration of counting time. Weather conditions - equipment needs to be weatherproof (ie resistant to low temperatures (potentially to -20°C), snow etc under field conditions); rapid temperature shocks to the detector should be avoided. **Other radionuclides** While 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 or 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 (eg ^{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. variation in the size of animals monitored due to the age and breed. difficulty in keeping animals still during monitoring can lead to erroneous readings.
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 (eg cattle crush) will be required while monitoring some animals.
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, or alternative identification method.
Required skills	Monitoring would be carried out by trained personnel. Animal handling experience or 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 (eg cattle, horses).
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 or 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.

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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 or 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 or 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 costs	None.
Assumptions	None.
Communication needs	Dialogue with farmer or herders. Farmer or 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 or 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 (eg 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 or 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 or herder. Stigma associated to affected area. May impact on public confidence eg: 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.

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UK stakeholder opinion	Acceptable to all the major stakeholders as it provides reassurance to consumers that contaminated meat is not entering the foodchain. The technique is currently limited to gamma emitting radionuclides so to provide total reassurance, other forms of monitoring need to be developed. Consistency in measurement techniques and calibration throughout the UK would increase public reassurance.
Practical experience	Combined with 20 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 until present, 2014) and the UK (from 1986 until 2012) 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 (2014) to monitor reindeer from Chernobyl restricted areas. Used in Ireland and Sweden to monitor carcasses at slaughterhouses, following Chernobyl accident. Used in Spain after the incident at Palomares, involving a collision with an American B-52 carrying four thermonuclear bombs.
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. p 159-162. Risø National Laboratory, Roskilde. 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. Firsakova SK (1993). Effectiveness of countermeasures applied in Belarus to produce milk and meat with acceptable levels of radiocaesium after the Chernobyl accident. *Sci Tot Env* **137**, 199-203. Meredith RCK, Mondon KJ, Sherlock JC (1988). A rapid method for the in vivo monitoring of radiocaesium activity in sheep. *J Env Radioact* **7**, 209-214. Nisbet AF, Woodman RFM (1999). Options for the management of Chernobyl restricted areas in England and Wales. Chilton, NRPB-R305. NCRP (2014) Decision Making for Late-Phase Recovery from Nuclear or Radiological Incidents, NCRP Report No 175
Comments	Can be used to confirm or optimise effectiveness of other management options.
Document history	**STRATEGY originator**: Nisbet AF (HPA). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, UK); Beresford NA and Howard BJ (CEH); 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 (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). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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22 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: minimise the entry of radionuclides into animal derived food products by slaughtering soon after deposition before the livestock have eaten sufficient contaminated feed that meat concentrations exceed the intervention levels 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 (ie slaughtering occurring at a time of year when the contamination levels are low). For animals assessed to be contaminated above a monitoring screening level, this option can be accompanied with clean feeding (20 Clean feeding)
Target	Meat producing livestock including farmed animals, free grazing sheep.
Targeted radionuclides	**Known applicability**: All (in long-term predominantly ^{134}Cs, ^{137}Cs) **Probable applicability**: - **Not applicable**: -
Scale of application	Small to large scale depending upon recommended implementation (ie 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 Maximum Permitted Levels (MPLs). The welfare of on-farm livestock is protected by the Protection of Animals Act 1911, as amended, in England and Wales, the Protection of Animals (Scotland) Act 1912 and the Welfare of Animals Act (Northern Ireland) 1972. They are further protected in England, Scotland and Wales by the Agriculture (Miscellaneous Provisions) Act 1968. This Act provides for 'welfare codes' of recommendations to be drawn up. Although 'welfare codes' do not lay down statutory requirements livestock farmers and employers are required by law to ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes. The Welfare of Farmed Animals (England) Regulations 2000 cover all farmed animals and contain specific requirements regarding activities such as inspections and feeding and watering of animals. Equivalent UK legislation is Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000. These regulations implement EU General Directive 98/58/EC, EU Laying Hens Directive 99/74/EC, EU Calves Directive 91/629/EEC as amended and EU Pigs Directive 91/630/EEC as amended. The Animal Welfare Act 2006 has brought together and modernised welfare legislation, particularly the Protection of Animals Act 1911 and equivalent acts, for farmed and non-farmed animals. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required for any change of grazing regime in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs is made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the

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	Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation. Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995.
Social constraints	Farmer or herder resistance to the management option.
Environmental constraints	None
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. **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.
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 or 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).
Required consumables	Feed for prolonged fattening period.
Required skills	Slaughtering would be carried out by licensed slaughtermen with necessary skills. Herders or farmers would possess other skills required.
Required safety precautions	General precautions for animal handling.
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; for some drugs there may be a waiting periods of up to 60 days post administration before animals can enter the foodchain.

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	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 or herd size agreements.
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 or 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 (eg 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, eg 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 or 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 costs	None.
Assumptions	None.
Communication needs	Dialogue with farmers or 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

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	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 (eg 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 or herding activity eg with respect to availability of manpower, provision of feed over longer periods etc. Markets may be prone to seasonal gluts and shortages, although due to long shelf life of many products, unlikely to be a major issue. Freezing is a simple method to effectively mitigate this impact.
Social impact	Altering slaughtering periods can have profound consequences for annual cycles of farming or herding activity eg availability of manpower, provision of feed over longer periods etc. May impact on public confidence eg: loss of confidence that farm produce and derivative products from affected areas is 'safe' (may ie 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 or adjustment of farming and related industrial activities, eg the supply of meat to food industry and potential market shortages. Disruption to people's image or perception of 'countryside' with potential impacts on tourism etc.
Other side effects	Possible positive impact on biodiversity if grazing period is shortened. Possible negative impact if grazing too intense.
UK stakeholder opinion	Reassurance, via monitoring programmes, would be necessary to show that livestock have radionuclide concentrations less than intervention limits.
Practical experience	Used in Norway after the Chernobyl accident for sheep, but other management options like the use of saltlicks or boli with AFCF (16 Addition of AFCF to concentrate ration and 19 Administer AFCF boli to ruminants and 20 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. *J Env Radioact* **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. *Sci Tot Env* **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. *Sci Tot Env* **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

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	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 (ie porkers, cutters, baconers and heavy hogs). Thus bringing forward or prolonging the age of slaughter may simply mean changing the slaughter weight category.
Document history	**STRATEGY originator**: Nisbet AF (HPA). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA); 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) 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 (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). Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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Objective	To reduce activity concentrations of radionuclides in meat, milk and eggs 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 or activity concentrations in vegetation.
Target	Meat, milk and egg 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, milk and eggs.
Time of application	Medium to long term.
Constraints	
Legal constraints	Depends on land status (ie conservation areas, National Parks, Areas of Outstanding Natural Beauty). Grazing may be restricted at farms participating Environmental Stewardship Schemes in England, Agri-Environment Schemes in Scotland, and Environmentally Sensitive Areas and Countryside Stewardship Scheme in Northern Ireland. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if temporary fencing is to be erected in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs are made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation. Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Archaeological areas and ancient monuments are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995.
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 eg in National Parks and Environmentally Sensitive Areas.

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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 costs	None.
Assumptions	None.
Communication needs	Information or 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.

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Agricultural impact	Undergrazing of fenced areas of pasture.
Social impact	Stigma associated to affected areas. May impact on public confidence eg: 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 (eg 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).
UK stakeholder opinion	Acceptable to all stakeholders.
Practical experience	Used widely in the former Soviet Union and also employed in Norway. Used in the uplands of UK, in combination with 21 Live monitoring, to produce lamb with activity concentrations <MPL.
Key references	Crout NMJ, Beresford NA and Howard BJ (1991). The radioecological consequences for lowland pastures used to fatten upland sheep contaminated with radiocaesium. Sci Tot Env 103, 73-87. Nisbet AF and Woodman RFM (2000). Options for the Management of Chernobyl-restricted areas in England and Wales. J Env Radioact 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. Sci Tot Env 137, 183-198.
Comments	
Document history	**STRATEGY originator**: Nisbet AF (HPA). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, UK); 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 (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 Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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24 Slaughtering (culling) of livestock	
Objective	To remove the source of contaminated milk/meat from the foodchain.
Other benefits	Maintains consumer confidence in food products.
Management option description	Slaughtering could be considered for those animals whose milk/meat 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. It is possible that following a large scale accident, killing by free bullet (that is by a marksman in the field using rifle, shotgun or humane killer) or chemical euthanasia would be the primary method of culling considered initially (on farm or abattoir). Other options would include culling an animal on the farm or at a knacker's yard using a bullet and gun. Condemnation completely removes contaminated food from the market but can leave large quantities of animal waste needing disposal.
Target	Dairy, egg or meat producing 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	Animal welfare guidelines must be followed. The transportation of livestock to slaughterhouses is covered by the Welfare of Animals (Transport) (England) Order 2006 and Welfare of Animals (Transport) (Scotgland) Order 2006. Parallel legislation is being prepared in Wales to replace the Welfare of Animals (Transport) Order 1997 ('WATO') as amended, and in Northern Ireland to replace the Welfare of Animals (Transport) Order (Northern Ireland) 1997. These transpose the EU rules governing animal welfare in transit (Regulation (EC) No 1/2005 into UK legislation. At the slaughterhouses the Welfare of Animals (Slaughter or Killing) Regulations 1995 as amended apply in England, Scotland and Wales. In Northern Ireland the Welfare of Animals (Slaughter or Killing) Regulations (Northern Ireland) 1996 as amended apply. These regulations implement the EU Directive 93/119/EC.
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 or of rare breeds. Disruption of farming and associated communities. Disruption to people's image/perception of the countryside (ie no animals in the fields, impact on tourism). Market shortage of animal products.
Environmental constraints	Slaughter sites outside of controlled premises may require an environmental impact assessment.
Effectiveness	
Management option effectiveness	Highly effective (ie 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.

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24 Slaughtering (culling) of livestock

	In large scale incidents movement of animals may be infeasible and risk spread of contamination.
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 eg incinerators, rendering plants, burning and burial sites.
Required consumables	Fuel for transport to abattoir if necessary. Cartridges for captive bolts etc. Disinfectants may be required to prevent disease if carcasses cannot be moved quickly.
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 or monitoring and protective clothing will be required.
Other limitations	Capacity of disposal routes.
Waste	
Amount and type	Condemned livestock carcasses. Disinfectants, if used. Animal bodily fluids and faeces will need to be managed at the place of slaughter.
Possible transport, treatment and storage routes	Disposal by: incineration (36 Incineration), burial (33 Burial of carcasses) and rendering (41 Rendering).
Factors influencing waste issues	Acceptability of and compliance with waste disposal practice. Legislative issues, eg 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**: for milk unable to be sold, for loss of dairy animals and for maintaining pastures if all stock is removed. **Abattoir**: for decontamination of slaughtering equipment if necessary.
Waste costs	Transportation of carcasses to rendering or incineration plant or burial or 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 (eg advisory centre, leaflets, internet, social media), preferably as part of emergency management planning; requirement for updating as situation develops.

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24 Slaughtering (culling) of livestock

	Implementation of this management option is likely to meet resistance from some farmers so good stakeholder dialogue will be essential. Dialogue with farmers or herders is necessary to ensure understanding of the reasons and conduct of slaughter, and to identify means of ameliorating negative consequences of the option on other farming and related activities.
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. Potential for contamination of surface waters due to run off from carcasses.
Agricultural impact	If the entire herd or flock is slaughtered, under-grazing of pasture will occur.
Social impact	May impact on public confidence eg: loss of confidence that farm produce and derivative products from affected areas is 'safe' (may ie 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 or perception of 'countryside' eg 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.
UK stakeholder opinion	The farming industry considers this an unacceptable and radical option that could potentially destroy pedigree dairy herds. Breeding stock could be preserved and even moved to uncontaminated areas. Support for wide scale slaughtering comes from the food and drink industry and retail trade on the premise that it would maintain contaminated milk from the foodchain. Given the public reaction to mass slaughter during Foot and Mouth disease, disposal of carcasses must be carefully considered.
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 or 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. Cattle (95,500) and pigs (23,000) were slaughtered between May and July 1986, following the Chernobyl accident. Many carcasses were buried and some were stored in refrigerators, but this produced great hygiene, practical and economic difficulties. (IAEA, 2006)
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. Chilton, 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. *J Env Radioact* **41** (3), 233-255. International Atomic Energy Authority (2006) Environmental Consequence of the Chernobyl Accident and Their Remediation: Twenty Years of Experience. Report of the Chernobyl Forum Expert Group 'Environment'. International Atomic Energy Authority, Vienna.
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

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24 Slaughtering (culling) of livestock

	to sustainable restoration.
Document history	**STRATEGY originator**: Nisbet AF (HPA). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, 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 (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 Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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25 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 unless a decision has been made to slaughter the 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. The welfare of on-farm livestock is protected by the Protection of Animals Act 1911, as amended, in England and Wales, the Protection of Animals (Scotland) Act 1912 and the Welfare of Animals Act (Northern Ireland) 1972. They are further protected in England, Scotland and Wales by the Agriculture (Miscellaneous Provisions) Act 1968. This Act provides for ‘welfare codes’ of recommendations to be drawn up. Although ‘welfare codes’ do not lay down statutory requirements, livestock farmers and employers are required by law to ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes. The Welfare of Farmed Animals (England) Regulations 2000 cover all farmed animals and contain specific requirements regarding activities such as inspections and feeding and watering of animals. Equivalent UK legislation is Welfare of Farmed Animals (Scotland) Regulations 2000, Welfare of Farmed Animals (Wales) Regulations 2001 and Welfare of Farmed Animals (Northern Ireland) Regulations 2000. These regulations implement EU General Directive 98/58/EC, EU Laying Hens Directive 99/74/EC, EU Calves Directive 91/629/EEC as amended and EU Pigs Directive 91/630/EEC as amended. The Animal Welfare Act 2006 has brought together and modernised welfare legislation, particularly the Protection of Animals Act 1911 and equivalent acts, for farmed and non-farmed animals.
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

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25 Suppression of lactation before slaughter

	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 or 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 or 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 MPL 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 (38 Landspreading of milk and/or slurry), biological treatment (32 Biological treatment (digestion) of milk), processing into a milk product suitable for storage prior to disposal (40 Processing and storage of milk products for disposal) and disposal to sea (35 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 costs	Dependent on disposal route for milk chosen.
Assumptions	Availability of synthetic oestrogens, progestogens or prostaglandins.
Communication needs	Dialogue with farmers or 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.

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25 Suppression of lactation before slaughter

Side effect evaluation	
Ethical considerations	Animal welfare issues. The process of drying-off in a situation other than for preparation for calving, lambing or 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 or benefits between rural and urban population.
Environmental impact	Pollution issues related to hormone treatments eg 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 eg: 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 market); 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 or perception of 'countryside' as natural. Negative psychological impact.
Other side effects	None.
UK stakeholder opinion	Drying off without the use of synthetic hormones would be unacceptable to farmers with high yielding cows because of animal welfare concerns. Similarly there may be public reaction on animal welfare grounds. Generally felt that capacity for immediate slaughter would be sufficient to negate the need for drying off.
Practical experience	None
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. Chilton, NRPB-W8.
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). **STRATEGY contributors**: Mercer JA and Hesketh N (HPA, 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 (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. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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26 Clean feeding (domestic livestock)

Objective	To reduce activity concentrations of radionuclides in milk, meat, eggs and honey to below intervention levels.
Other benefits	Reduce amount of produce requiring disposal.
Management option description	Domestic livestock (including hens) may be fenced in or housed to prevent grazing of contaminated pasture. The animals are then given nutritionally balanced diets comprising uncontaminated or less contaminated feed. Bee hives may be moved to an uncontaminated area.
Target	Domestic livestock including honey bees.
Targeted radionuclides	All.
Scale of application	Large scale application possible, although dependent on supply of clean feed at a reasonable price.
Contamination pathway	Plant to animal.
Exposure pathway pre-intervention	Ingestion of contaminated milk, meat, eggs and honey.
Time of application	Early to long term.
Constraints	
Legal constraints	The sale of milk and meat intended for human consumption is subject to Maximum Permitted Levels (MPLs). Standards of animal husbandry and welfare and regulations governing feed storage would need to be observed. Some certification schemes may be contravened. For example, in the case of organic milk production, there is a limit on the proportion of concentrate in the diet of dairy cattle. Free range schemes may also be restricted following an accident, if animals have to be housed. The welfare of domestic animals is regulated by the Animal Welfare Act 2006 in England and Wales and the Animal Health and Welfare Act 2006 in Scotland. The principal law governing domestic animal welfare in Northern Ireland is the Protection of Animals Act 1911. Local regulations on the use and siting of buildings must be consulted. A consent from Natural England, Scottish Natural Heritage, the Countryside Council for Wales or the Environment and Heritage Service Northern Ireland will be required if a programme of grassland management (mowing) with fertiliser or lime addition is to be carried out in an area designated a Site of Special Scientific Interest (SSSIs) in England, Scotland and Wales or a Area of Special Scientific Interest (ASSIs) in Northern Ireland. The notification of SSSIs are made under the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000 in England and Wales). A small number of improvements to the SSSI regime have been made by the Natural Environment and Rural Communities (NERC) Act 2006 which amends the Wildlife and Countryside Act 1981. In Northern Ireland ASSIs are made under the Environment (Northern Ireland) Order 2002. They implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), the EC Wild Birds Directive 79/409/EEC and the EC Habits Directive 92/43/EEC into UK legislation. Land designated as National Nature Reserves (NNRs) under the National Parks and Access to the Countryside Act 1949, as amended by NERC, can within a European context be designated as Special Protection Areas (SPAs) or Special Areas of Conservation (SACs). These are made under 79/409/EEC and 92/43/EEC respectively, as part of Natura 2000. For these sites a Special Nature Conservation Order under Regulation 22 of the Conservation (Natural Habits, &c) Regulations 1994 can be made to prohibit any operation likely to cause damage or destruction. Consents will also be required if structures such as temporary buildings and fences are to be erected. Grassland management and erecting temporary buildings and fences may also be restricted in archaeological areas and areas containing ancient monuments. These areas are protected by the Ancient Monuments and Archaeological Areas Act 1979 in England, Scotland and Wales, and the Historic Monuments and Archaeological Objects (Northern Ireland) Order 1995.
Social constraints	Resistance of animal owners to management option.
Environmental constraints	Housing of livestock would mean that slurry would have to be collected and disposed of. This may be stored and disposed of to land.
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. Reductions in waste milk and meat arising of

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26 Clean feeding (domestic livestock)

	up to 100%. 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. Moving the bee hives to an uncontaminated area would reduce the contamination of the honey.
Factors influencing effectiveness of procedure	Livestock: availability and level of contamination of alternative feeds; rate at which alternative diet is introduced and duration of feeding regime; radionuclides involved; biological half-life of specific radionuclide-livestock species combination; willingness and ability of livestock to adapt to new regime. Bees: the distance that the bees need to be moved should be considered and the availability of nectar around the new site. If the bees need to be moved less than 3 km to the uncontaminated site but further than can comfortably be moved in short steps (a few metres) then first move the colony more than 3 km for 5-6 weeks, then back to their new site. If the new site is more than 3 km then the bees will realise that their surroundings have completely changed and reorient to their new hive position without any problem. However, in the middle of winter when the bees do not fly far from the hive entrance the hive may be moved any distance without concern. Timing of blocking the bees in the hive for transportation to new site, following deposition.
Feasibility	
Required specific equipment	Fencing or housing suitable for livestock. For honey bees: in the evening block the entrance to the hive with a piece of foam and secure by using a ratchet tie down strap around the floor, body and crown board. If the transit time is more than 15 minutes then use a ventilated travelling board or screen in place of the crown board.
Required ancillary equipment	Feeding and drinking troughs
Required utilities and infrastructure	Collection and disposal mechanism for slurry.
Required consumables	Alternative feeds. Straw for bedding.
Required skills	General animal husbandry and bee keeping knowledge.
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	If livestock are housed slurry or faeces will require disposal.
Possible transport, treatment and storage routes	Slurry or faeces could be used as a fertiliser.
Factors influencing waste issues	Amounts produced.
Doses	
Incremental dose	Trivial
Intervention costs	
Equipment	Modification to housing for livestock. Temporary fences. Transportation of hive to new site.
Consumables	Cost of purchasing uncontaminated feed. Additional concentrates may be required to nutritionally balance the alternative diets.
Operator time	Extra work required by the house holder to obtain clean feed and looking after housed or fenced animals. Collection and disposal of slurry or faeces. Finding suitable uncontaminated site for hive(s) to be placed.
Factors influencing costs	Availability of housing and fenced areas in the garden or allotment.
Compensation costs	Compensation may be available to cover cost of obtaining clean feed.
Waste costs	Time spent cutting and composting contaminated grass and landspreading additional slurry or manure.

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26 Clean feeding (domestic livestock)

Assumptions	Monitoring of animals is carried out following periods of clean feeding - these costs need to be added to this management option (see 21 Live monitoring)
Communication needs	Explaining management option to animal owners. Ensuring communication re harvesting of grass in pre-deposition phase.
Side effect evaluation	
Ethical considerations	Self-help for animal owners. Animal welfare issues if animals are housed in the summer when temperature and ventilation could be a problem (eg humidity or high levels of ammonia in buildings). Animal welfare issues may also arise when enclosures are used (eg parasite burden, general animal hygiene).
Environmental impact	Inappropriate disposal of additional slurry or manure could lead to pollution of water courses. Possible changes in landscape due to citing of new buildings.
Agricultural impact	N/A
Social impact	May impact on public confidence eg: loss of confidence that local farm produce and derivative products (eg 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	None.
UK stakeholder opinion (Domestic Produce and Free Foods (DPFF) subgroup of AFCWG)	The DPFF subgroup classed this option as being acceptable for livestock and honey bees. It is likely that livestock owners would favour this option rather than having to slaughter their livestock (eg pet goat).
Practical experience	Housing of livestock is a normal agricultural practice during winter months.
Key references	
Comments	See datasheet 20 Clean feeding
Document history	Mercer JA and Nisbet AF. Domestic food production and the gathering of free foods. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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27 Dietary advice (domestic)

Objective	To reduce dose to consumers of domestic produce and free food by providing food safety advice on contamination levels in the produce and information on the risks
Other Benefits	Help people maintain their way of life. Reduces the need for disposal. Enables informed choice.
Management option description	Provision of advice and information to allotment holders, kitchen garden producers and wild or free food gatherers on the risks associated with the consumption of contaminated produce and ways to restrict their dietary intake of radionuclides. This would include: The provision of information on activity concentrations in a range of domestically grown products and free foods (Green et al, 1999, Prosser et al, 1999) The provision of information on activity concentrations in private water supplies and water butts. The issuing of guidance on which foodstuffs can be eaten without restrictions, those which should only be consumed occasionally, and those which should be avoided completely. The provision of advice on additional management options that can be carried out to either reduce contamination levels in produce or provide reassurance that produce is safe to eat. Standard preparation techniques such as washing, removing outer leaves, peeling, isolating edible section of foodstuff etc, can achieve reduction of up to 100% of the surface contamination, depending on type of foodstuff, radionuclide and time since deposition. This method is suitable for fruits, berries, vegetables, herbs and nuts following contamination via direct deposition (provided that peel and foliage are discarded and not re-used in another part of the cooking process). (Green and Wilkins, 1995) The provision of advice on delaying the slaughter of animals reared for meat Much of the information, advice and guidance would come from FSA and be communicated via local associations cascading information down to members (eg National Society of Allotment and Leisure Gardeners, (NSALG)), as well as local media, leaflets, association magazines, internet and social media. The management option might need to be supplemented with monitoring (see 29 Provision of monitoring equipment (domestic produce))
Target	Consumers of domestic produce and gatherers of free foods. Critical groups who may have higher radionuclide intake as a consequence of dietary habits. Anyone who wants to reduce their dose.
Targeted radionuclides	All radionuclides.
Scale of application	Generally applicable to all population groups although may be most appropriate to critical groups (eg 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	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	The Food and Environment Protection Act, 1985 could be used to protect the public from exposure to potentially contaminated food by restricting the movement, supply or sale of certain foods, or food products from within a designated area. However, a FEPA Order cannot prevent the public from eating their own produce from their allotment or garden. The sale of these foodstuffs and their movement out of the affected area can come under the Order.
Social constraints	For socially isolated or independent rural populations, eg crofting communities, a key issue may be trust (or lack of) in the institutions or experts advising dietary restrictions.
Environmental constraints	N/A
Effectiveness	

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27 Dietary advice (domestic)

Management option effectiveness	Compliance with the recommendation of avoidance of certain foodstuffs would be 100% effective. Washing has been 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%). 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 Filleting and washing fish, and washing and shelling mussels and shrimps, are very effective in reducing levels of ^{226}Ra (c. 80% reduction). While 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 (eg 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. Availability of replacement foods.
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	There would be waste arising in situations where the advice given was to avoid eating a foodstuff.
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	Dependent on communication method, eg printing and distributing leaflets.
Operator time	The time used for providing information, advice and guidance will depend on the communication method (press releases, television interviews, public meetings, magazine

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27 Dietary advice (domestic)

	articles, letters, leaflets, internet and social media, telephone, fax etc)
Factors influencing costs	Scale of accident.
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. Possible liability issues in the case of unforeseen health effects.
Waste costs	N/A
Assumptions	None.
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 or experts advising dietary restrictions, the management option is likely to have more positive than negative social consequences (eg trust, personal control and informed choice).
Environmental impact	Possible ecological effect from increase in game population if hunting or fishing declines, or cessation of large-scale fungi or berry collection. Could be positive (eg conservation of habitats and increased nutrient availability resulting from increased decomposition) or negative (eg change in ecological equilibrium, lack of animal foodstuffs due to increased competition).
Agricultural impact	None.
Social impact	Changed perception of natural resources because of feeling that they are damaged or polluted. Loss of traditional activities eg 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	Self-help measure. Improves personal control and ability to make informed choices. Replacement foods may be required. Loss of traditional activities eg gathering free food.
UK stakeholder opinion (Domestic Produce and Free Foods (DPFF) subgroup of AFCWG)	The DPFF subgroup was of the opinion that although the FSA would provide food safety advice to consumers, it is likely that allotment holders within a ‘FEPA’ restricted area would also seek advice from the NSALG. It is thought that members would take notice of clear, quality advice and information. It is unlikely that they would want to grow produce that they were unable to consume.
Practical experience	Used in western Europe (especially Scandinavia) and the former Soviet Union after the Chernobyl accident. Proven to be a cheap and effective management option, if people are willing to follow the advice.
Key references	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 (2000). Self-help countermeasure strategies for populations living within contaminated areas of Belarus, Russia and the Ukraine. J Env Radioact 56, 215-239. Brynildsen LI et al (1996). Countermeasures for radiocaesium in animal products in Norway after the Chernobyl accident - techniques, effectiveness and costs. Health Phys 70, 665-672. Bryne AR, Dermelj M and Vakselj T (1979). Silver accumulation by fungi. Chemosphere, 10, 815-821. IAEA Technical Report Series (1994). Handbook of parameter values for the prediction of radionuclide transfer in temperate environments, No. 364. IAEA, Vienna. Petäjä E, Rantavaara A, Paakkola O, Puolanne E (1992). Reduction of radioactive caesium in meat and fish by soaking. J Env Radioact 16, 273-285. 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.

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27 Dietary advice (domestic)

	Health Phys 63, 4, 385-392. 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? Rad Prot Dosim 68, 261-266.
Comments	Consider this option in conjunction with others including 13 Removal of topsoil, 28 Processing or storage of domestic food products, 29 Provision of monitoring equipment (domestic produce), 30 Restrictions on foraging (gathering wild foods) and 31 Restrictions during hunting and fishing seasons
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. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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28 Processing or storage of domestic food products

Objective	To process and/or store foodstuffs until the activity concentrations have declined to acceptable levels.
Other benefits	Provides allotment holders and kitchen gardeners with the choice to consume home-grown produce. This reduces the amount of waste food requiring disposal.
Management option description	Processing to remove the radioactive contamination, or storage to allow for radioactive decay of short-lived radionuclides, may achieve reductions in activity concentrations to below intervention levels. At the domestic level, methods for processing and storing may include blanching, marinating, deep freezing, drying and making jams, chutneys and preserves. Implementation of this option in the UK beyond the domestic level would require an evaluation of economic considerations (eg major food shortage) and consultation with the food production industry, and may not be deemed acceptable.
Target	Potentially applicable to all contaminated food products that can be processed and/or stored, such as cereals, milk, meat, eggs, fruit, berries, vegetables, nuts, fish and honey. More applicable to home-grown produce.
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 Food and Environment Protection Act, 1985 may be used to protect the public from exposure to potentially contaminated food by restricting the movement, supply or sale of certain foods, or food products from within a designated area. However, a FEPA Order cannot prevent the public from eating their own produce from their allotment or garden; or 'free foods'. The sale of these foodstuffs can come under the Order, but there are no restrictions on the personal consumption of these foodstuffs.
Social constraints	Foodstuffs that may have been radioactively contaminated may not be acceptable to growers or consumers, when foodstuffs can be obtained from other sources.
Environmental constraints	None.

Effectiveness

Management option effectiveness

Blanching can remove activity incorporated within the food eg 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.

Reduction factors were seen in ^{90}Sr levels in produce as a result of food processing as follows (IAEA, 2012)

Process	Reduction factor for ^{90}Sr in product	
	Reduction factor	Equivalent % reduction
Milk to butter	10-20	90-95%
Grain to flour, groats	2-3	50-67%
Grain to alcohol	50-100	98-99%
Potato to starch	Up to 100	Up to 99%
Vegetables to oil	50-100	98-99%

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

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28 Processing or storage of domestic food products

	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 ground water 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	At the domestic level, this option can be implemented with 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	Possibly, contamination of kitchen utensils
Waste	
Amount and type	Boiling and blanching solutions, marinated fluids. Amount and type depend 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 29 Provision of monitoring equipment (domestic produce)).
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 costs	Dependent on nature and amount of waste arising and subsequent disposal route selected.
Assumptions	At the domestic level, 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

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28 Processing or storage of domestic food products

Social impact	Possible loss of confidence in products if normally sold.
Other side effects	Contamination of kitchen utensils.
UK stakeholder opinion (Domestic Produce and Free Foods (DPFF) subgroup of AFCWG)	Preliminary opinion from the DPFF subgroup is that this would be an acceptable option at the domestic level. It is 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. International Atomic Energy Authority (2012) Technical Report Series No 475, Guidelines for Remediation Strategies to Reduce the Radiological Consequences of Environmental Contamination. IAEA, Vienna.
Comments	Consider this option in conjunction with others including 27 Dietary advice (domestic) and 29 Provision of monitoring equipment (domestic produce).
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. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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29 Provision of monitoring equipment (domestic produce)

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	Consumers can make an informed choice about whether or not to eat a particular foodstuff. Also useful for reassurance purposes. Enhancing technical knowledge and skills among affected populations.
Management option description	With Government support local authorities could set up an independent accredited monitoring service so that the general public can check habitats or foodstuffs for radionuclide content (particularly home grown or self-gathered). In highly populated areas this might be based at local health centres. For sparsely populated rural areas a mobile facility could be deployed. Members of the public would be given the opportunity to provide samples of home produced or self-gathered foodstuffs to trained personnel who would be responsible for determining their radionuclide content. Other services may include whole body monitoring or general advice on radiation risks.
Target	Home grown and/or self-gathered foodstuffs such as milk, meat, eggs, vegetables, fruit, berries, nuts, honey, fish and mushrooms.
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 (ie beta and alpha emitters eg ^{90}Sr) and radionuclides with low photon energies (eg ^{141}Ce, ^{235}U, ^{238}Pu, ^{239}Pu and ^{241}Am).
Scale of application	Small or medium scale. Areas where food is home produced or self-gathered. Homes and gardens.
Contamination pathway	Plant to human; Animal to 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	Accreditation of all of the analytical methods used as well as logging of samples and recording of results. Members of the public may need to be asked whether they wanted the data logged and whether location should be included. Freedom of information necessary. Appropriately qualified personnel.
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. Numbers of samples to be analysed. Best used in conjunction with information provision. Need for trust in those providing equipment, information, monitoring results and interpretation of results. Acceptability and compliance of consumers to a) non-consumption of contaminated

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29 Provision of monitoring equipment (domestic produce)

	foodstuffs, and b) continued consumption of foodstuffs with low levels of contamination. May depend upon eg 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	NaI and HPGe spectrometry systems for the determination of gamma-ray emitting radionuclides in foodstuffs. Also consider provision of SAMs (small articles monitors) for gamma-ray emitters as a simple alternative or addition to spectrometry systems. Alpha or beta contamination monitors for estimation of activity of weakly penetrating nuclides in foodstuffs Radiochemical laboratories and equipment for beta and alpha measurement.
Required ancillary equipment	Data recording equipment.
Required utilities and infrastructure	Transport, distribution and co-ordination of monitoring equipment or service. Trained personnel to interpret and explain results to members of public.
Required consumables	Sample containers.
Required skills	Knowledge of radioanalytical and radiochemical methods; teaching for education and training of public (eg in use of counting equipment).
Required safety precautions	N/A
Other limitations	N/A
Waste	
Amount and type	Foodstuffs that are contaminated to unacceptable levels or that are not amenable to preparation and storage 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). It is possible that people may bring their contaminated produce to the monitoring station for disposal. 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 which radionuclides are present and the type of foodstuff to be measured. 'Mini Food Monitors' already exist for detecting radiocaesium and radioiodine in foodstuffs. HPA stores several monitors for measuring gamma-ray emitting radionuclides in milk. Specially produced equipment would cost ~£5,000 and could take up to a year for suitable stock to be produced.
Consumables	Chemicals: depends on monitoring type. Sample containers: depends monitoring type. Materials used to provide training and information.
Operator time	Time 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.

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29 Provision of monitoring equipment (domestic produce)

Waste costs	Variable.
Assumptions	None.
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 eg erosion, loss of soil fertility, changes in biodiversity, creation of wildlife habitats could occur. People may come to the monitoring stations to obtain compensation to cover food that is unsuitable for consumption.
UK stakeholder opinion (Domestic Produce and Free Foods (DPFF) subgroup of AFCWG)	There was consensus from the DPFF group that this option should be available to those who wanted to monitor their produce but people should not feel obliged to do so.
Practical experience	A similar scheme has worked successfully in the contaminated villages of Belarus where monitoring equipment was made available to householders for establishing levels of radioactive contamination in foodstuffs including milk and mushrooms. (see Hériard Dubreuil et al, 1999).
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 Phys* **77**, 361-372.
Comments	The management option should be carried out in conjunction with provision of dietary advice (27 Dietary advice (domestic)) Could also be used to monitor external doses if appropriate equipment was supplied (eg dose rate monitors) and suitable training provided. Even where this method is not used officially, members of the public are likely to self-monitor using unverified equipment purchased online - important to handle messaging about the applicability 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. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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30 Restrictions on foraging (gathering wild foods)

Objective	To reduce consumption of contaminated self gathered wild or free foods
Other benefits	
Management option description	Restrictions on gathering of wild or free food products such as game, nuts, mushrooms, honey, fruits and berries will reduce dose to those consuming these foodstuffs. The major foodstuffs contributing to dose will be those which have the highest concentrations of the radionuclides and/or which are eaten in large quantities. For example, although consumed in relatively small quantities, wild mushrooms and berries are known to most readily concentrate radioactivity (particularly ^{137}Cs). Certain groups may be exposed to higher doses than others due to their dietary, social and other habits.
Target	People who gather and/or consume wild foods. Foodstuffs such as fruits, berries, herbs, edible flowers, aquatic plants, nuts, mushrooms and game.
Targeted radionuclides	All (especially radiocaesium in long-term).
Scale of application	Large scale.
Contamination pathway	Soil to plant: plant to human; animal to human
Exposure pathway pre-intervention	Ingestion
Time of application	Early to long term.
Constraints	
Legal constraints	The Food and Environment Protection Act, 1985 may be used to protect the public from exposure to potentially contaminated food by restricting the movement, supply or sale of certain foods, or food products from within a designated area. A FEPA order typically applies to all forms of agricultural production, however, there are also provisions for prohibiting the gathering and picking of wild plants (eg fungi), and the gathering of wild game and fish. **Hunting**: The Wildlife and Countryside Act 1981, Wildlife and Countryside (Amendment) Act 1991, The Wildlife (Amendment) (Northern Ireland) Order 1995 and Wildlife and Countryside Act 1981 (Amendment) (Wales) Regulations 2004: protection of wildlife in the UK, including specific Wildfowl and Waterfowl species during closed season. The Game Act 1831 and Game Act 1970: protection of specific game birds during closed season in England and Wales. The Game (Scotland) Act 1832: protection of specific game birds during closed season in Scotland. Game Preservation (Amendment) Act (Northern Ireland) 2002: protection of specific game species during closed season. Ground Game Act 1880 and Ground Game (Amendment) Act 1906: rights of landowners to take game. Firearm and Game hunting licences are legal requirements for hunting. **Fishing**: Salmon and Freshwater Fisheries Act 1975: Salmon and Freshwater Fisheries (Consolidation)(Scotland) Act 2003 sets out coarse fish close season and makes provision for this to be altered or dispensed with through fisheries byelaws. Byelaws are the statutory rules and regulations put in place by the Environment Agency. They exist to prevent damage to fish stocks from insensitive fishing methods and to make sure that fisheries are sustainable for the enjoyment of current and future generations of anglers. The byelaws apply to all types of fisheries, be they owned by angling clubs, local authorities or private individuals. The coarse fish close season applies to all rivers and streams in England and Wales and all waters in the Specified Sites of Special Scientific Interest. It does not apply to most stillwaters and/or canals. Fishery owners and angling clubs are free to introduce a close season through club or fishery rules if they wish to. There is no legal close season for marine species caught in UK waters.
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.

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30 Restrictions on foraging (gathering wild foods)

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. Most effective if gatherers and locations of wild or free foods are known in community.
Factors influencing effectiveness of procedure	**Long-term (radiocaesium)** Success of communicating the restrictions to gatherers. Availability of contaminated foodstuffs for gathering, may vary by year, season and location. Individual willingness to submit to restrictions, particularly over long time periods. It is likely to be harder to 'police' occasional free food consumers than regular consumers who would be known amongst the local community. Type of mushrooms consumed in the contaminated region (eg 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. Availability of alternative sources of food.
Feasibility	
Required specific equipment	Signage, information boards, leaflets.
Required ancillary equipment	Monitoring equipment for authorities to regularly check level of contamination in wild or free foods.
Required utilities and infrastructure	Communication lines to inform those about restriction and 'policing' to ensure compliance.
Required consumables	Dependent on communication method (eg leaflets and signage).
Required skills	Communication skills.
Required safety precautions	N/A
Other limitations	None.
Waste	
Amount and type	N/A
Possible transport, treatment and storage routes	N/A
Factors influencing waste issues	N/A
Doses	
Incremental dose	Trivial external exposure to authorities erecting signs and information boards.
Intervention costs	
Equipment	Signage, information boards, leaflets. Monitoring equipment.
Consumables	Production of leaflets circulated to gatherers via local groups. Production and erection of signs in areas known to be used by gatherers (similar to Foot and Mouth Disease procedures). Information and advice distributed via specialist associations or societies ie ramblers.
Operator time	Time associated with policing the management option. Time associated with the erection of signs in areas known to be used by gatherers. Time 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 restrictions - collection of some wild foodstuffs is conducted at a commercial scale in many countries.
Waste costs	N/A
Assumptions	None.

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30 Restrictions on foraging (gathering wild foods)

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 eg increase in game population if hunting or fishing declines, or greater numbers or diversity if cessation of large-scale fungi or 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. Experience has shown that restrictions such as harvesting of wild foods can result in significant negative social consequences and consequently advice from the authorities to the general public may be ignored. The provision of suitable local educational programmes to emphasize the relevance of suggested changes is recommended
Other side effects	Replacement foods may be required.
UK stakeholder opinion (Domestic Produce and Free Foods (DPFF) subgroup of AFCWG)	Preliminary opinion from the DPFF subgroup is that this would be an acceptable option.
Practical experience	Restrictions enforced in Belarus following the Chernobyl accident. Restricted harvesting of food by the public in forest areas was successfully implemented in Japan following the Fukushima accident.
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 (2000). Self-help countermeasure strategies for populations living within contaminated areas of Belarus, Russia and the Ukraine. *J Env Radioact* **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. IAEA (2006) Environmental Consequence of the Chernobyl Accident and Their Remediation: Twenty Years of Experience. Report of the Chernobyl Forum Expert Group ‘Environment’. International Atomic Energy Authority, Vienna. IAEA (2011) Final Report of the International mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Dai-ichi NPP 7-15 October 2011, Japan, IAEA NE/NEFW/2011, 15/11/2011

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30 Restrictions on foraging (gathering wild foods)

Comments	See also 27 Dietary advice (domestic) and 31 Restrictions during hunting and fishing seasons.
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. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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31 Restrictions during hunting and fishing seasons

Objective	To reduce consumption of contaminated meat and fish by restricting hunting or fishing to certain times within the hunting or fishing season when activity concentrations in these foods are low.
Other benefits	Traditional hunting for game can be preserved; the amount of condemned meat will be reduced.
Management option description	Hunting and fishing (coarse or salmons species) are typically 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. It is possible that the length of the hunting or fishing season may be significantly reduced or completely excluded for one or more years.
Target	Farmers, land owners, gamekeepers, hunters (ie those involved in the hunting of waterfowl, wildfowl, game fowl, ground game, deer). Poachers are also at risk, but are less likely to observe restrictions. Hunting (as sport) could continue as long as the prey is kept out of the food chain. Anglers: Salmon family (eg salmon, trout) and Freshwater (ie Coarse) Fish (eg pike, perch, tench). However, competition anglers who comply with 'catch and return' are not at risk.
Targeted radionuclides	All (in long-term predominantly ^{134,137}Cs)
Scale of application	Large.
Contamination pathway	Plant to animal.
Exposure pathway pre-intervention	Ingestion of contaminated meat and fish.
Time of application	Annually from early to long term.
Constraints	
Legal constraints	The Food and Environment Protection Act, 1985 may be used to protect the public from exposure to potentially contaminated food by restricting the movement, supply or sale of certain foods, or food products from within a designated area. A FEPA order typically applies to all forms of agricultural production, however, there are also provisions for prohibiting the gathering and picking of wild plants (eg fungi), and the gathering of wild game and fish. **Hunting**: The Wildlife and Countryside Act 1981, Wildlife and Countryside (Amendment) Act 1991, The Wildlife (Amendment) (Northern Ireland) Order 1995 and Wildlife and Countryside Act 1981 (Amendment) (Wales) Regulations 2004: protection of wildlife in the UK, including specific Wildfowl and Waterfowl species during closed season. The Game Act 1831 and Game Act 1970: protection of specific game birds during closed season in England and Wales. The Game (Scotland) Act 1832: protection of specific game birds during closed season in Scotland. Game Preservation (Amendment) Act (Northern Ireland) 2002: protection of specific game species during closed season. Ground Game Act 1880 and Ground Game (Amendment) Act 1906: rights of landowners to take game. Firearm and Game hunting licences are legal requirements for hunting. **Fishing**: Salmon and Freshwater Fisheries Act 1975: Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003 sets out coarse fish close season and makes provision for this to be altered or dispensed with through fisheries byelaws. Byelaws are the statutory rules and regulations put in place by the Environment Agency. They exist to prevent damage to fish stocks from insensitive fishing methods and to make sure that fisheries are sustainable for the enjoyment of current and future generations of anglers.

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	The byelaws apply to all types of fisheries, be they owned by angling clubs, local authorities or private individuals. The coarse fish close season applies to all rivers and streams in England and Wales and all waters in the Specified Sites of Special Scientific Interest. It does not apply to most still waters and/or canals. Fishery owners and angling clubs are free to introduce a close season through club or fishery rules if they wish to. There is no legal close season for marine species caught in UK waters.
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	Close hunting seasons exist to allow time for breeding and for populations to recover from previous hunting or fishing seasons. **Hunting - close season**: varies with species and location but is typically 1 February to 31 Aug for game birds and wildfowl. **Fishing - close season**: varies with species and location but is typically 15 March to 15 June for coarse fish and salmon species in Rivers in England and Wales. If contamination levels in the species were such that the overall length of the hunting or fishing season was significantly reduced or completely excluded in a year, then a management programme would have to be introduced. For example; culling species normally hunted if over populated, removing fish from waters if over stocked and the meat or fish banned from the foodchain.
Effectiveness	
Management option effectiveness	Will effectively reduce consumption of contaminated meat of hunted species and freshwater fish. 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	Success of communicating information regarding the restrictions to hunters or anglers. Individual willingness to submit to restrictions. The hunting of rabbits, hares and pigeons is not restricted to seasonal hunting and may be hunted at any time of the year. Furthermore, there is no legal close season for marine species caught in UK waters. Thus, control over the hunting or fishing and subsequent consumption of meat or fish from these species may be more difficult. Availability of contaminated foodstuffs (ie mushrooms) to game before and during hunting (varies by year, time of hunting and location). Ability to predict times during the season when the contamination levels in the meat or fish would be below intervention levels.
Feasibility	
Required specific equipment	Monitoring equipment for authorities
Required ancillary equipment	Typical hunting and fishing equipment if management programme is required. Surveying equipment (electrofishing techniques) to establish fish populations.
Required utilities and infrastructure	Communication lines to inform those about restriction and 'policing' to ensure compliance
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	Could be none. However, waste in the form of contaminated carcasses would be produced if hunting or 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	For animal carcasses see 24 Slaughtering (culling) of livestock (waste).

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Factors influencing waste issues	None. See above
Doses	
Incremental dose	To those carrying out monitoring in the affected area. To those implementing the management programme if hunting or fishing is banned or significantly reduced for one or more years
Intervention costs	
Equipment	Monitoring equipment. Typical hunting equipment if management programme is required. Surveying equipment (electrofishing techniques) to establish fish populations.
Consumables	Production of leaflets to inform anglers, farmers, gamekeepers and hunters. For hunting: distribution of this information via associations or societies to their members or via firearms registration certificates from police, in associations or societies magazines, firearm dealers etc. For anglers: distribution of this information via associations or societies to their members or via those providing rod licences and fishing permits.
Operator time	Depends on communication method eg design and distribution of leaflets.
Factors influencing costs	Infrastructure available for communication and exchange of information during processing of information, decision-making and implementation of management option.
Compensation costs	The payments for unused hunting or fishing licences must be returned, if hunting or fishing season significantly reduced or excluded.
Waste costs	None.
Assumptions	None.
Communication needs	Guidance for hunters (possible requirement for rapid distribution).
Side effect evaluation	
Ethical considerations	If implemented successfully, low ethical impact. If unsuccessful (ie hunters simply avoiding the contaminated areas) possible negative consequences for the community or owner (for private hunting lands) or ecosystems.
Environmental impact	Impact on ecosystem (due to lack of game management), population dynamics, breeding, mortality or 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. The Environment Agency carries out regular surveys on principal rivers to determine fish populations. Thus, if the fishing season had to be reduced significantly or excluded then these checks will be an important method of establishing whether a management programme is required.
Agricultural impact	May cause an increase in the numbers of herbivores which may have impact on grassland, forestry and other environments. 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. Experience has shown that restrictions such altering hunting practices can result in significant negative social consequences and consequently advice from the authorities to the general public may be ignored. The provision of suitable local educational programmes to emphasize the relevance of suggested changes is recommended
Other side effects	Reduced financing of game management due to cancellation of hunting licences.
UK stakeholder opinion (Domestic Produce and Free Foods (DPFF) subgroup of AFCWG)	Opinion from the DPFF subgroup is delaying the start of the hunting season or cancelling the season altogether would be an acceptable option.
Practical experience	Has been tested or 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.

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	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. IAEA (2006) Environmental Consequence of the Chernobyl Accident and Their Remediation: Twenty Years of Experience. Report of the Chernobyl Forum Expert Group 'Environment'. International Atomic Energy Authority, Vienna.
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	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. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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32 Biological treatment (digestion) of milk

Objective	To reduce the mass of solids derived from contaminated milk requiring disposal.
Other benefits	Reduction in biochemical oxygen demand (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^{o}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 (> 300 μSv) if management option is carried out when activities in crops are at or above MPL: ^{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 Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of 'radioactive waste' as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). However, radioactively contaminated foodstuffs may not meet the strict legal definition of 'radioactive waste' as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. If defined as 'radioactive waste' then authorisation would be required for the storage and disposal of the foodstuffs. If they have activity concentrations in excess of the MPLs and are not considered 'radioactive waste' they will be regarded as agricultural waste and the following legislation will apply. The STWs and DEPs used to treat milk will be subject to the Urban Waste Water Treatment (England and Wales) Regulations 1994 as amended, the Urban Waste Water Treatment (Scotland) Regulations 1994 as amended or the Urban Waste Water Treatment Regulations (Northern Ireland) 1995 as amended which implement the Urban Waste Water Directive 91/271/EEC. The regulations ensure certain standards of wastewater treatment are attained but only apply to STWs serving a population equivalent of greater than 2000. If STWs have sludge treatment plants with capacities greater than 50 tonnes per day they will be subject to a permitting regime made under Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, Pollution Prevention and Control (Scotland) Regulations 2000 as amended or Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended, made under the Pollution Prevention and Control Act 1999 (PPC) and implementing the EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). Smaller facilities may come under the control of the Waste Management Licensing regime (WML). In England, Scotland and Wales the WML regime is made under Part II of the Environmental Protection Act 1990 (EPA90) and implements the EC Framework Directive on Waste (75/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). The EPA90 has been transposed into legislation via the Waste Management Licensing Regulations 1994 as amended (WMLR) in England, Scotland and Wales. For Northern Ireland the Waste Management Licensing Regulations (Northern Ireland) 2003 are used

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which are made under Part II of the Waste and Contaminated Land (NI) Order 1997 as amended, and partially implement the EC Framework Directive on Waste.

STWs are exempt from PPC and WML provided sewage sludge is recycled to agricultural land. They will also be exempt from WML if they have an effluent discharge consent made under the Water Resources Act 1991 and corresponding legislation. However, they may require a licence, under PPC or WML, to accept tankered waste. The PPC regime will also apply to DEPs treating and processing milk in quantities greater than 200 tonnes per day (average value on an annual basis). Smaller DEPs will be subject to the same legislation governing smaller STWs.

Discharges from STWs and DEPs to surface and ground waters are regulated in England and Wales by the Water Resources Act 1991. In Scotland they are regulated by the Control of Pollution Act 1974 and the Water Environment and Water Services (Scotland) Act 2003, and in Northern Ireland by the Water and Sewerage Services (NI) Order 1973 and the Water (Northern Ireland) Order 1999 as amended. They control the discharge of any poisonous, noxious or polluting matter, or any solid waste matter from entering any controlled waters, ie tidal and coastal waters (up to three miles from land), rivers, lakes, ponds and ground waters.

Any discharges of milk from DEPS to sewers are authorised by the Water Industry Act 1991 in England and Wales, the Sewerage (Scotland) Act 1968 and the Water and Sewerage Services (Northern Ireland) Order 1973.

Applying sewage sludge to agricultural land is regulated in the UK by the Sludge (Use in Agriculture) Regulations 1989 (as amended) and the Sludge (Use in Agriculture) Regulations (Northern Ireland) 1990 (as amended), which implements the Sewage Sludge Directive 86/278/EEC. The UK government has made a commitment to revise the regulations in line with the ‘Safe Sludge Matrix’, which is a voluntary agreement adopted by UK water companies for the safe spreading of sludge. Spreading sewage sludge on agricultural land used to grow commercial crops or to feed animals is exempt from WML provided it is done in accordance with the Sludge (Use in Agriculture) Regulations 1989, and up to 250 t ha^{-1} may be spread in any 12-month period. Spreading on non-agricultural land is also exempt from WML provided certain conditions are met. Sludge from DEPs is also exempt from WML provided it has been biologically treated and provides benefit to agriculture or ecological improvement. Again up to 250 t ha^{-1} may be spread in any 12 month period.

The amounts of sludge used will be limited by its nitrogen content if the land is in the boundaries of a Nitrate Vulnerable Zone (NVZ). Under the Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999, implementing EC Nitrate Directive 91/676/EEC, the total amount of nitrogen added to agricultural land is limited, depending on the form of nitrogen and land use. There are also closed periods of nitrogen use. The total nitrogen content of organic wastes applied to grassland is limited to 250 kg N ha^{-1} y^{-1} in England, Wales, Scotland and Northern Ireland. For non-grassland the limit is set at 210 kg N ha-1 y-1 reducing to 170 kg N ha^{-1} y^{-1} after the first four years in the Action Programme in England and Wales. In Scotland the limit is 170 kg N ha^{-1} y^{-1}. The limits in Northern Ireland are identical to England and Wales but depend on where the NVZ is situated. The areas of land classified as NVZs in England, Scotland, Wales and Northern Ireland are 55%, 13%, 3% and 0.1% respectively.

Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply.

If milk is defined as ‘radioactive waste’ then for road transportation the Radioactive Material (Road Transport) Regulations 2002 as amended, apply to England, Scotland and Wales. For Northern Ireland the Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1992 apply. These regulations are implemented by the Radioactive Material (Road Transport) Act 1991 and the

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32 Biological treatment (digestion) of milk

	Radioactive Material (Road Transport) (Northern Ireland) Order 1992. The Radioactive Material (Road Transport) (Definition of Radioactive Material) Order 2002 also applies in England, Scotland and Wales. For rail transportation the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 apply in England, Scotland and Wales. In Northern Ireland the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 apply, and also cover class 7 road vehicles. During 2007 the road and rail regulations for England, Scotland and Wales will be combined to form the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 made under the Health and Safety at Work etc Act 1974. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
Social constraints	Related to disposal option selected for waste eg willingness of farmers to accept sludge from biological treatment of milk. Resistance if the resulting sludge is applied to previously uncontaminated areas, or if the application restricts subsequent use, eg organic farming. 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 eg if contaminated sludge is disposed of in previously uncontaminated areas.
Environmental constraints	None for digestion of milk. Related 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 or 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^{-1}, pH should be between 6 and 9 and BOD between 300 and 600 mg l^{-1}. 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.

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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%. **Aerobic** Sludge is produced and the amounts depend on the micro-organisms present, BOD of milk, treatment method used etc. Excess sludge represents 1%-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, ie sludge, cake and liquid effluent. There are datasheets outlining the incremental dose pathways from the alternative disposal of sludge and cake to 37 Landfill and 36 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 (eg 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.

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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 costs	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 (eg organic farming) where sludge is spread on clean land. Stigma associated with areas and perceived contamination of food products where sludge has been applied.
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.
UK stakeholder opinion	The Dairy Industry and Environment Agency consider that it is preferable to use STWs rather than DEPs for treatment and disposal of contaminated milk. STWs are not connected with the supply of milk for human consumption and this separation of waste management from food production is thought to be important to public perception and the retail trade. Use of STWs is acceptable to the water industry provided the amounts of milk are kept to a minimum and personnel, assets and the environment are protected. The NFU raises concerns about the subsequent disposal of contaminated sludge to previously uncontaminated agricultural land, which may cause the land to be blighted.
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. Chilton, NRPB-W38.

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32 Biological treatment (digestion) of milk

	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 SE (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 JM (Ed). Aspen Publishers Inc. Maryland.
Document history	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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33 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 MPL: ^{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	The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of ‘radioactive waste’ as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If it is defined as ‘radioactive waste’ then authorisation would be required for the storage and disposal of the foodstuffs. However, radioactively contaminated foodstuffs may not meet the strict legal definition of ‘radioactive waste’ as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. If they have activity concentrations in excess of the MPLs and are not considered ‘radioactive waste’ they will be regarded as agricultural waste and the following legislation will apply. Under normal circumstances the burial of animal by-products is prohibited by the Animal By-Products Regulations 2005, the Animal By-Products (Scotland) Regulations 2003, the Animal By-Products (Wales) Regulations 2003 and the Animal By-Products Regulations (Northern Ireland) 2003, which enforce the EU Animal By-Products Regulation (EC) No. 1774/2002 (ABPR) made under the European Communities Act 1972. There are derogations from this prohibition permitting burial in remote areas, defined as Lundy and Isles of Scilly in England and a number of areas in Scotland, and in the event of a disease outbreak. Also, burial of cattle, sheep or goats which are known to be or are suspected of being infected with Specified Risk Material (SRM) will be prevented under the TSE (No.2) Regulations 2006 in England, TSE (Wales) Regulations 2002 as amended, TSE (Scotland) Regulations 2002 as amended, and TSE Regulations (Northern Ireland) 2006. They enforce the EU TSE Regulation EC 999/2001 into law. All SRM has to be removed from carcasses and disposed of in accordance with ABPR. In the UK waste disposal is regulated through the Waste Management Licensing regime (WML). In England, Scotland and Wales the WML regime is made under Part II of the Environmental Protection Act 1990 (EPA90) and implements the EC Framework Directive on Waste (75/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC) (WFD). The EPA90 has been transposed into legislation via the Waste Management Licensing Regulations 1994 (WMLR) as amended, in England, Scotland and Wales. For Northern Ireland the Waste Management Licensing Regulations (Northern Ireland) 2003 are used which are made under Part II of the Waste and Contaminated Land (NI) Order 1997 as amended, and partially implement the EC Framework Directive on Waste. These regulations have been amended further by the Waste Management (England and Wales) Regulations 2006, Waste (Scotland) Regulations 2005 and Waste Management Regulations (Northern Ireland) 2006, which define agricultural waste as industrial waste and are therefore classified as ‘controlled waste’ under Controlled Waste Regulations 1992. However, whole animal carcasses

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	are excluded from these regulations as they are covered by Animal By-Products Regulations. The development of burial sites will be limited by the Landfill (England and Wales) Regulations 2002 as amended, Landfill (Scotland) Regulations 2003 as amended and the Landfill Regulations (Northern Ireland) 2003 as amended, which implement the EC Landfill Directive 1999/31/EC into UK legislation. If a risk assessment showed carcasses to contain human or animal pathogens above naturally encountered levels, the EC Hazardous Waste Directive (91/689/EEC) would be enforced. Following the implementation of Waste Management (England and Wales) Regulations 2006 and parallel legislation, burial on farm will also be subject to Landfill Regulations, which is highly impractical and expensive for farmers. The burial of carcasses in the above circumstances is regulated by the Groundwater Regulations 1998 and Groundwater Regulations (Northern Ireland) 1998, which implement the EC Groundwater Directive 80/68/EEC. It requires member states to prevent List I substances from entering and List II substances from polluting ground water and requires prior investigation and authorisation where such substances are to be disposed of to land as well as 'requisite monitoring' post disposal. Since carcasses contain listed substances their disposal needs to be controlled. Large-scale burials of uninfected carcasses, and the development of mass burial sites require a risk assessment and Groundwater Authorisation (GWA) given by the EA before disposal. Burials above 2 tonnes, or involving infected carcasses, would need to be notified to the EA. All burials would need to comply with paragraph 276 of the 1998 Water Code. Neither the Groundwater Directive nor Regulations apply to any discharge of matter containing radioactive substances. Because of the large volumes of leachate produced by decomposing carcasses the Water Resources Act (England and Wales) 1991, the Control of Pollution Act 1974 and Water Environment and Water Services (Scotland) Act 2003 in Scotland, and the Water (Northern Ireland) Order 1999 as amended will also apply. They control the discharge of any poisonous, noxious or polluting matter, or any solid waste matter from entering any controlled waters, ie tidal and coastal waters (up to three miles from land), rivers, lakes, ponds and ground waters. For on-farm burial (where not prohibited by the ABPR) carcasses should never be buried near to watercourses, boreholes or springs, and the Code of Good Agricultural Practice for the Protection of Water should be followed. If wastes are defined as 'radioactive waste' then for road transportation the Radioactive Material (Road Transport) Regulations 2002 as amended, apply to England, Scotland and Wales. For Northern Ireland the Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1992 apply. These regulations are implemented by the Radioactive Material (Road Transport) Act 1991 and the Radioactive Material (Road Transport) (Northern Ireland) Order 1992. The Radioactive Material (Road Transport) (Definition of Radioactive Material) Order 2002 also applies in England, Scotland and Wales. For rail transportation the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 apply in England, Scotland and Wales. In Northern Ireland the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 apply, and also cover class 7 road vehicles. During 2007 the road and rail regulations for England, Scotland and Wales will be combined to form the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 made under the Health and Safety at Work etc Act 1974. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
Social constraints	Acceptability of changes to landscapes and of other environmental effects, to relevant populations. Local opposition to the selection of burial sites eg where contaminated carcasses are disposed of in previously uncontaminated areas. Aesthetic consequences of landscape or 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.

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Effectiveness	
Management option effectiveness	This management option does not remove the contamination, but removes contaminated livestock from the foodchain.
Factors influencing effectiveness of procedure	Engineering of burial pit, suitability and availability of land for burial pit (ie 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 is 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. 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 (eg clay lining) including burial of non-carcass material (eg sheep dip, paint diesel manure). There is a potential risk from carcasses awaiting disposal to contaminate private and public water supplies. The extent of the risk will depend on the state of decomposition of the carcasses and type of ground.
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 or 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 eg 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	**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;

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works (STW): the relevant dose pathways for this disposal route are given in the 37 Landfill datasheet.	transporting animal leachate to STWs.
Intervention costs	
Equipment	Civil engineering equipment required to dig pit (eg 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 monitoring ground water 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 costs	Treatment and disposal of animal leachate.
Assumptions	None.
Communication needs	Dissemination of information about carcass burial to the general public. Dialogue with land users. Media interest is likely to be high. Likely requirement to monitor area around burial pit and publish results.
Side effect evaluation	
Ethical considerations	Negative side effects on populations living close to burial sites. Possible environmental and aesthetic consequences. Loss of amenity or change in public perception of land used for burial. Liability for potential negative effects from disposal site (eg leakage).
Environmental impact	Minimal risk of contamination of surface and ground water 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 or 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, eg tourism. Policing the carcass burial and averting growth of a black market. Contamination of the soil may restrict subsequent uses (eg 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.
UK stakeholder opinion	Acceptable to the Environment Agency on a small scale only and then with suitable management. Unlikely to be acceptable for cattle due to potential contamination from BSE.
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. 24 April 2001.

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	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	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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34 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. Controlled methods of composting include mechanical mixing and aerating, ventilating the materials by dropping them through a series vertical of aerated chambers, or placing the compost in piles out in the open air and missing or turning it periodically. 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, including domestic produce.
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	The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of ‘radioactive waste’ as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If defined as ‘radioactive waste’ then authorisation would be required for the storage and disposal of the foodstuffs. However, radioactively contaminated foodstuffs may not meet the strict legal definition of ‘radioactive waste’ as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. If they have activity concentrations in excess of the MPLs and are not considered ‘radioactive waste’ they will be regarded as agricultural waste and the following legislation will apply. Following the transposition of Waste Management (England and Wales) Regulations 2006, Waste (Scotland) 2005 and Waste Management Regulations (Northern Ireland) 2006 into UK legislation, agricultural waste is classified as ‘controlled waste’ (under Controlled Waste Regulations 1992 as amended), and composting is therefore regulated either under the Pollution Prevention and Control regime (PPC) or the Waste Management Licensing regime (WML). Most composting sites will be exempt from PPC regulations in accordance with section 6.8 of Schedule 1. Only those where the composting operation is a subsidiary activity at, for example, a landfill site will be covered by PPC regulations. The PPC regime is made under the Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, Pollution Prevention and Control (Scotland) Regulations 2000 as amended or Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended. These are made under the Pollution Prevention and Control Act 1999 (PPC) and implement the EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). The Waste Management Licensing (WML) regime in England, Scotland and Wales is made under Part II of the Environmental Protection Act 1990 (EPA90) and implements the EC Framework Directive on Waste (75/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). The EPA90 has been transposed into legislation via the Waste Management Licensing Regulations 1994 as amended (WMLR) in England, Scotland and Wales. For Northern Ireland the Waste Management Licensing Regulations (Northern Ireland) 2003 are used which are made under Part II of the Waste and Contaminated Land (NI) Order 1997 as amended, and partially implement the EC Framework Directive on Waste.

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	Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. The Codes of Good Agricultural Practice should also be followed. If crops are defined as 'radioactive waste' then for road transportation the Radioactive Material (Road Transport) Regulations 2002 as amended, apply to England, Scotland and Wales. For Northern Ireland the Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1992 apply. These regulations are implemented by the Radioactive Material (Road Transport) Act 1991 and the Radioactive Material (Road Transport) (Northern Ireland) Order 1992. The Radioactive Material (Road Transport) (Definition of Radioactive Material) Order 2002 also applies in England, Scotland and Wales. For rail transportation the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 apply in England, Scotland and Wales. In Northern Ireland the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 apply, and also cover class 7 road vehicles. During 2007 the road and rail regulations for England, Scotland and Wales will be combined to form the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 made under the Health and Safety at Work etc Act 1974. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
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 or 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. Careful consideration needed in the case of *in situ* treatment.
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 eg Dutch barn. Vehicles for transport. Equipment for spreading compost.
Required utilities and infrastructure	Area of hard standing (eg concrete) on farm. Storage for compost. Roads for transport.
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. Farmers would have experience of spreading compost to land.
Required safety precautions	Consider protective clothing. Respiratory protection and protective clothing is

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	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	Leachate and 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 (ie 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 37 Landfill or 36 Incineration. There are separate datasheets for these disposal options 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 37 Landfill datasheet.	**Composting facility operative or farmer**: external exposure during daily inspection; inadvertent ingestion while turning compost; inhalation of dust while turning compost; dermal exposure while turning compost **Drivers (external exposure)**: 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 or 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 or 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 costs	Landfill charges and landfill tax. Leachate treatment.
Assumptions	None.
Communication needs	Need for dialogue regarding selection of areas for composting. Need for dialogue between land owners or farmers, environmentalists and public. Provision of information to farmers on rationale of this waste treatment option. Provision of information to farmers or 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

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	waste. If carried out on open ground the leachate might result in some contamination of land and ground water. 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 (eg 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.
UK stakeholder opinion	Acceptable to agricultural experts as a volume reduction technique, although the radionuclides become concentrated in the compost. The compost produced at commercial facilities is not likely to be accepted as fertiliser either for agricultural use or municipal purposes.
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. Chilton, NRPB-R328. Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. Chilton, NRPB-R295.
Document history	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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35 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 MPL 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 according to whether dairy cows were in fields consuming contaminated pasture at time of the accident.
Constraints	
Legal constraints	The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of 'radioactive waste' as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If it is defined as 'radioactive waste' then authorisation would be required for the storage and disposal of the foodstuffs. However, radioactively contaminated foodstuffs may not meet the strict legal definition of 'radioactive waste' as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. If they have activity concentrations in excess of the Maximum Permitted Levels (MPLs) and are not considered 'radioactive waste' they will be regarded as agricultural waste and the following legislation will apply. The Oslo-Paris Convention (OSPAR) protects the marine environment around Europe. However, in the view of the Government the requirements of the Convention relating to dumping would not necessarily apply in the event of an emergency, subject to the proviso that such dumping is conducted in such a way to minimise the likely impact. 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, after consultation with EA, milk containing radionuclides will not be classified as radioactive waste requiring authorisation for disposal under RSA93, and will therefore be classed as agricultural waste. Coastal sewage treatment works used to discharge milk to sea via long sea outfalls will be subject to the Urban Waste Water Treatment (England and Wales) Regulations 1994 as amended, the Urban Waste Water Treatment (Scotland) Regulations 1994 as amended, and the Urban Waste Water Treatment Regulations (Northern Ireland) 1995 as amended, which implement the Urban Waste Water Directive 91/271/EEC. The regulations ensure certain standards of wastewater treatment are attained but only apply to STWs serving a population greater than 2000. If STWs have sludge treatment plants with capacities greater than 50 tonnes per day they will be subject to a permitting regime (PPC) made under Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, Pollution Prevention and Control (Scotland) Regulations 2000 as amended or Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended, made under the Pollution Prevention and Control Act 1999 and implementing the EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC).

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	Smaller facilities may come under the control of the Waste Management Licensing regime (WML). In England, Scotland and Wales the WML regime is made under Part II of the Environmental Protection Act 1990 (EPA90) and implements the EC Framework Directive on Waste (75/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). The EPA90 has been transposed into legislation via the Waste Management Licensing Regulations 1994 as amended (WMLR) in England, Scotland and Wales. For Northern Ireland the Waste Management Licensing Regulations (Northern Ireland) 2003 are used which are made under Part II of the Waste and Contaminated Land (NI) Order 1997 as amended, and partially implement the EC Framework Directive on Waste. STWs are exempt from PPC and WML provided sewage sludge is recycled to agricultural land. They will also be exempt from WML if they have an effluent discharge consent made under the Water Resources Act 1991 and corresponding legislation. However, they may require a licence, under PPC or WML, to accept tankered waste. Discharges from coastal sewage treatment works are regulated by the Water Resources Act (England and Wales) 1991 (WRA91), the Control of Pollution Act 1974 and the Water Environment and Water Services (Scotland) Act 2003 in Scotland, and the Water (Northern Ireland) Order 1999 as amended. They control the discharge of any poisonous, noxious or polluting matter, or any solid waste matter from entering any controlled waters, ie tidal and coastal waters (up to three miles from land), rivers, lakes, ponds and ground waters. However, Section 89(1)(a) of WRA91 provides exemptions where such discharges are made 'in an emergency in order to avoid danger to life or health'. Disposal of untreated milk to sea is prohibited by the Animal By-Products Regulations (ABPR) 2005 in England, the Animal By-Products (Scotland) Regulations 2003, the Animal By-Products (Wales) Regulations 2003 and the Animal By-Products Regulations (Northern Ireland) 2003, which enforce Regulation (EC) No 1774/2002 made under the European Communities Act 1972. For disposal facilities located inside or outside the boundaries of a 'Natura 2000' site, as classified by the EC Wild Birds Directive 79/409/EEC, then an environmental impact assessment will have to be carried out in accordance with the Conservation (Natural Habitats & c) Regulations 1994 as amended, in England, Scotland and Wales, and the Conservation (Natural Habits etc) Regulations (Northern Ireland 1995 as amended. These implement the EC Habitats Directive 92/43/EEC into UK legislation.
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 biochemical oxygen demand (BOD) discharged by long sea outfalls. These vary according to the degree of mixing of water body receiving contaminated milk.
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. Acceptability of the implementation of the waste management option to operators, haulage companies and the public. Compliance or 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.

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	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. Distance from farms to sea outfalls.
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 costs	N/A.
Assumptions	None.
Communication needs	Need for widespread dialogue to ascertain the acceptability of discharge to sea both nationally and internationally. Dialogue with the operators and regulators need to be established well in advance. This will involve considerable time and effort. Public consultation can be a lengthy process that might not be achievable on the timescales required for disposing of large volumes of milk. Potential need to facilitate widespread debate regarding the ethics and practice of disposal at sea. Requirement to monitor water quality in surrounding water body.
Side effect evaluation	
Ethical considerations	Additional dose to tanker drivers, marine life and consumers of marine produce. Aesthetic or 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 of fish produce where milk has been disposed of to sea. Disruptions to people's image or perception of the 'seaside', eg milk flowing onto the beach from

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	outflow pipes, with potential impacts on tourism etc.
Other side effects	None.
UK stakeholder opinion	Acceptable in principle to the Environment Agency and water industry. A stakeholder group has been set up to identify suitable outfalls and to develop site-specific plans. Public reaction may be opposed to disposal of milk at sea even if proven to be acceptable scientifically.
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. Chilton, NRPB-R323.
Comments	Disposal of milk to sea will require pre-planning eg 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	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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36 Incineration

Objective	To reduce volume of contaminated food products prior to disposal and to produce a stable end product.
Other benefits	Volume reduction: The process reduces volume by a factor of about 20 (IAEA, 2014)
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. A major disadvantage of incinerators is a low tolerance for non-combustible material that can be present in the inflowing material mix. This can be resolved through sorting material before it is sent to the facility. Plasma gasification is an advanced technology that may be available to process organic wastes. This would produce gas and electricity for power together with a solid, vitrified waste product that is strong, inert and environmentally stable, with a number of end use applications, including use in the construction industry, therefore reducing the amount of incinerator ash being disposed of to landfill.
Target	Contaminated cereals, vegetables, fruit, fish, rendered meat, eggs, milk powder (milk would require dewatering prior to incineration.), 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. There may be limitations due to cost or capacity.
Contamination pathway	N/A.
Exposure pathway pre-intervention	N/A.
Time of application	Early to late.
Constraints	
Legal constraints	The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of 'radioactive waste' as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If defined as 'radioactive waste' then authorisation would be required to send the waste to an authorised incinerator (eg private incinerator) or if VLLW then may require authorisation to send to municipal incinerator. However, radioactively contaminated foodstuffs may not meet the strict legal definition of 'radioactive waste' as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. If they have activity concentrations in excess of the MPLs and are not considered 'radioactive waste' they will be regarded as agricultural waste and the following legislation will apply. The Waste Incineration (England and Wales) Regulations 2002, the Waste Incineration (Scotland) Regulations 2003 and the Waste Incineration Regulations (Northern Ireland) 2003 as amended, implement the EC Waste Incineration Directive 2000/76/EC (WID). The latter incorporates and extends the requirements of the 1989 Municipal Waste Incineration Directives (89/429/EEC and 89/369/EEC) and the Hazardous Waste Incineration Directive (94/67/EC) forming a single Directive on waste incineration. The Waste Incineration Regulations apply to incineration and co-incineration plants as defined by the WID. Exceptions to this are incinerators that burn only specified waste or specified waste with non-controlled waste. Specified wastes are defined in WID Article 2. Examples of specified waste incinerators include animal carcass incinerators regulated by the Animal Waste Directive 90/667/EC and implemented in the UK by either the Animal By-Products Regulations 2005 (ABPR) in England, the Animal By-Products (Scotland) Regulations 2003, the Animal By-Products (Wales) Regulations 2003 or the Animal By-Products Regulations (Northern Ireland) 2003, and radioactive waste incinerators which need a separate authority under RSA93. The Waste Incineration Regulations are implemented under the Pollution Prevention and

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	Control regime (PPC) which is made under the Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, the Pollution Prevention and Control (Scotland) Regulations 2000 as amended, and the Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended. The PPC Regulations are made under the Pollution Prevention and Control Act 1999 and implement the EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). Small units incapable of complying with the requirements of WID under any circumstances, such as small on-farm waste burners and small space heaters, will remain subject to control only under the provisions of EC Framework Directive on Waste (75/442/EEC as amended) (WFD), which is transposed in the UK by Part II of the Environmental Protection Act 1990 and the Waste Management Licensing Regulations 1994. If ash is defined as 'radioactive waste' then for road transportation the Radioactive Material (Road Transport) Regulations 2002 as amended, apply to England, Scotland and Wales. For Northern Ireland the Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1992 apply. These regulations are implemented by the Radioactive Material (Road Transport) Act 1991 and the Radioactive Material (Road Transport) (Northern Ireland) Order 1992. The Radioactive Material (Road Transport) (Definition of Radioactive Material) Order 2002 also applies in England, Scotland and Wales. For rail transportation the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 apply in England, Scotland and Wales. In Northern Ireland the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 apply, and also cover class 7 road vehicles. During 2007 the road and rail regulations for England, Scotland and Wales will be combined to form the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 made under the Health and Safety at Work etc Act 1974. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
Social constraints	Unlikely to be acceptable to the public if the crops or 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 or bringing in of mobile incinerators. However the European Parliament and Council Directive 2000/76/EC allows members of the 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.
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 (ie 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

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	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 or resistance to incineration. There is potential for a black market in slaughtered meat or 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 or 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 or 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 cannot 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. Ash may be fully immobilised by conditioning in cement or other suitable matrix prior to disposal.
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 37 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.*

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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 costs	Transportation of ash to disposal site. Cost of landfill - charges or 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. Operators require information on the incineration of contaminated material. Likely requirement to monitor air or water quality in area neighbouring the incinerator and publish results.
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.
UK stakeholder opinion	An acceptable option for small quantities of waste as incinerators are already licensed to accept very low level radioactive waste as well as food wastes. There could be local opposition near to an incineration plant due to public perception that contamination will be released to atmosphere.
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. IAEA (2011) Final Report of the International mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Dai-ichi NPP 7-15 October 2011, Japan, IAEA NE/NEFW/2011, 15/11/2011 IAEA (2014) The follow-up IAEA International Mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Daiichi Nuclear Power Plant. Tokyo and

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	Fukushima Prefecture, Japan. 14-21 October 2013. Final report 23/01/2014 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. Chilton, NRPB-R295.
Comments	A valuable option when landfill space is scarce.
Document history	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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37 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	The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of 'radioactive waste' as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If it is defined as 'radioactive waste' then authorisation would be required for the storage and disposal of the foodstuffs. However, radioactively contaminated foodstuffs may not meet the strict legal definition of 'radioactive waste' as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. Disposal of waste classified 'Very Low Level Waste' (VLLW) by the EA can be disposed of with household rubbish and is subject to standard authorisation conditions. Low Level Waste (LLW) is normally disposed of at Drigg, but some may go to landfill under a controlled burial authorisation. Intermediate Level Waste (ILW) and High Level Waste (HLW) are usually stored in containers encased in concrete or glass. If the activity concentration, type of waste, and radionuclides present meet the criteria specified in Schedule 1 of RSA93, the Radioactive Substances (Phosphatic Substances, Rare Earths etc) Exemption Order 1962 and the Radioactive Substances (Substances of Low Activity) Exemption Order 1986, as amended 1992, the waste can then be sent directly to landfill and authorisation is not required. If they have activity concentrations in excess of the MPLs and are not considered 'radioactive waste' they will be regarded as agricultural waste and the following legislation will apply. In the UK landfill sites currently fall under 2 regimes: all new landfills and landfills receiving over 10 tonnes a day or with a total capacity exceeding 25,000 tonnes (excluding inert waste) are regulated under the Pollution Prevention and Control regime (PPC); other sites, including inert sites, are regulated through the Waste Management Licensing regime (WML). By the end of 2007 (extended to 2009 in Scotland for landfills coming under the second regime given above) all landfills regulated by the Waste Management Licensing Regulations will be transferred to regulation under the Pollution Prevention and Control (PPC) regime which is made under the Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, Pollution Prevention and Control (Scotland) Regulations 2000 as amended or Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended, and the Landfill (England and Wales) Regulations 2002 as amended, Landfill (Scotland) Regulations 2003 as amended, Landfill Regulations (Northern Ireland) 2003 as amended, or closed. These regulations are made under the Pollution Prevention and Control Act 1999, except the Landfill Regulations (Northern Ireland) 2003 made under the Environment (NI) Order 2002 as amended, and implement the EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC) and EC Landfill Directive 1999/31/EC. The Landfill Regulations classify landfills as hazardous, non-hazardous or inert, setting a

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	strict criteria under which wastes may be deposited at each site: a ban on the disposal of all liquids to landfill, both hazardous and non-hazardous (excluding sludge); a ban on infectious hospital, clinical and veterinary wastes, and on wastes that might be corrosive, oxidising, flammable or explosive within a landfill; a requirement for waste to be treated prior to landfilling (other than for some inert wastes and where pre-treatment would not reduce hazard to human health or the environment. The Animal By-Products Regulations 2005 (ABPR) in England, the Animal By-Products (Scotland) Regulations 2003, the Animal By-Products (Wales) Regulations 2003 or the Animal By-Products Regulations (Northern Ireland) 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972, ban any animal by-products from directly being disposed of to landfill. However, products produced after processing may be sent to landfill. In England, Scotland and Wales the WML regime is made under Part II of the Environmental Protection Act 1990 (EPA90) and implements the EC Framework Directive on Waste (75/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). The EPA90 has been transposed into legislation via the Waste Management Licensing Regulations 1994 as amended (WMLR) in England, Scotland and Wales. For Northern Ireland the Waste Management Licensing Regulations (Northern Ireland) 2003 are used which are made under Part II of the Waste and Contaminated Land (NI) Order 1997 as amended, and partially implement the EC Framework Directive on Waste. For sites under the WML regime an authorisation under the Water Resources Act (England and Wales) 1991, the Control of Pollution Act 1974 and Water Environment and Water Services (Scotland) Act 2003 in Scotland, or the Water (Northern Ireland) Order 1999 as amended, must be obtained before any wastes can be discharged to controlled waters (surface and ground waters). This authorisation is not required for sites coming under control of the PPC regime. However, they must meet the conditions required by the Groundwater Regulations 1998 and Groundwater Regulations (Northern Ireland) 1998, that implement the EC Groundwater Directive (80/68/EEC) into UK legislation, to stop or limit the discharge of certain listed substances. Discharges of landfill leachate to sewers requires authorisation under the Water Industry Act 1991 in England and Wales, the Sewerage (Scotland) Act 1968 and the Water and Sewerage Services (Northern Ireland) Order 1973. If wastes are defined as 'radioactive waste' then for road transportation the Radioactive Material (Road Transport) Regulations 2002 as amended, apply to England, Scotland and Wales. For Northern Ireland the Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1992 apply. These regulations are implemented by the Radioactive Material (Road Transport) Act 1991 Radioactive Material (Road Transport) (Definition of Radioactive Material) Order 2002 also applies in England, Scotland and Wales. For rail transportation the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 apply in England, Scotland and Wales. In Northern Ireland the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 apply, and also cover class 7 road vehicles. During 2007 the road and rail regulations for England, Scotland and Wales will be combined to form the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 made under the Health and Safety at Work etc Act 1974. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
Social constraints	Local opposition to use of particular landfill sites eg where contaminated crops are disposed of in previously uncontaminated areas.
Environmental constraints	Shallow sea, lake and marshy areas should be avoided because of negative impact on environment. Otherwise, none provided landfill site is fully engineered.
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

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	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. 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 eg 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 (eg 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 inadver*tent ingestion while ploughing 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 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).

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37 Landfill

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 costs	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. Likely requirement to monitor area around landfill site and publish results.
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.
UK stakeholder opinion	An acceptable option because landfill sites are already licensed to accept very low level radioactive waste as well as food wastes. Public acceptance of landfilling large quantities of contaminated produce may be low.
Practical experience	Landfill is a current practice.
Key references	Nakano M. and Yong RN (2013). Overview of rehabilitation schemes for farmlands contaminated with radioactive cesium released from Fukushima power plant. Engineering Geol 2013; 155:87-93. Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. Chilton, NRPB-R295.
Document history	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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38 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	The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of 'radioactive waste' as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If it is defined as 'radioactive waste' then authorisation would be required for the storage and disposal of the foodstuffs. However, radioactively contaminated foodstuffs may not meet the strict legal definition of 'radioactive waste' as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. If they have activity concentrations in excess of the Maximum Permitted Levels (MPLs) and are not considered 'radioactive waste' they will be regarded as agricultural waste and the following legislation will apply. In the UK waste disposal is regulated through the Waste Management Licensing regime (WML). In England, Scotland and Wales the WML regime is made under Part II of the Environmental Protection Act 1990 (EPA90) and implements the EC Framework Directive on Waste (75/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). The EPA90 has been transposed into legislation via the Waste Management Licensing Regulations 1994 as amended (WMLR) in England, Scotland and Wales. For Northern Ireland the Waste Management Licensing Regulations (Northern Ireland) 2003 are used which are made under Part II of the Waste and Contaminated Land (NI) Order 19971994 as amended, and partially implement the EC Framework Directive on Waste. However, under the Waste Management (England and Wales) Regulations 2006, spreading milk on agricultural land is exempt from WML (under Exemption 47) provided the requirement is registered with the EA and certain conditions are met. These include the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, and parts of The Codes of Good Agricultural Practice. Equivalent legislation is Waste (Scotland) Regulations 2005 and Waste Management Regulations (Northern Ireland) 2006. The amounts of milk spread will be limited by its nitrogen content if the land is in the boundaries of a Nitrate Vulnerable Zone (NVZ). Under the Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended or the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999 as amended, implementing EC Nitrate Directive 91/676/EEC, the total amount of nitrogen added to agricultural land is limited, depending on the form of nitrogen and land use. There are also closed periods of nitrogen use. The total nitrogen content of organic

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38 Landspreading of milk and/or slurry

	wastes applied to grassland is limited to 250 kg N ha^{-1} y^{-1} in England, Wales, Scotland and Northern Ireland. For non-grassland the limit is set at 210 kg N ha^{-1} y^{-1} reducing to 170 kg N ha^{-1} y^{-1} after the first four years in the Action Programme in England and Wales. In Scotland the limit is 170 kg kg N ha^{-1} y^{-1}. The limits in Northern Ireland are identical to England and Wales but depend on where the NVZ is situated. The areas of land classified as NVZs in England, Scotland, Wales and Northern Ireland are 55%, 13%, 3% and 0.1% respectively. However, by the end of 2004 it is likely that either 85% or all of Northern Ireland will be classified as NVZ. Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. By the end of 2007 (extended to 2009 in Scotland for those still under WML control) all landfills regulated by the WMLR will be transferred to regulation under the Pollution Prevention and Control (PPC) regime which is made under the Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, the Pollution Prevention and Control (Scotland) Regulations 2000 as amended or the Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended, and the Landfill (England and Wales) Regulations 2002 as amended, the Landfill (Scotland) Regulations 2003 as amended or the Landfill Regulations (Northern Ireland) 2003 as amended. These regulations are made under the Pollution Prevention and Control Act 1999, except the Landfill Regulations (Northern Ireland) 2003 made under the Environment (NI) Order 2002, and implement the EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC) and EC Landfill Directive 1999/31/EC. The Landfill Regulations define landfill as land onto or into which waste is deposited to dispose of it and prohibits the disposal of any liquids (excluding sludge) from 30th October 2007. Therefore the spreading of milk for disposal (but not for recovery) will be prohibited. Sites coming under control of the PPC regime must meet any conditions required by the Groundwater Regulations 1998 to stop or limit the discharge of certain listed substances to ground water. The Groundwater Regulations 1998 and Groundwater Regulations (Northern Ireland) 1998 implement the EC Groundwater Directive (80/68/EEC) into UK legislation. Spreading of milk (and colostrum) on the farm of origin is excluded from the Animal By-Products Regulations 2005 (ABPR) in England, the Animal By-Products (Scotland) Regulations 2003, the Animal By-Products (Wales) Regulations 2003 and the Animal By-Products Regulations (Northern Ireland) 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
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 or slurry is spread on farmland. Acceptability to food industry or 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.
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).

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38 Landspreading of milk and/or slurry

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 cannot 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 costs	N/A.
Assumptions	None.
Communication needs	Need for dialogue regarding selection of areas for treatment. Need for dialogue between land owners or farmers, environmentalists and public. 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 (eg organic farming).
Other side effects	None.
UK stakeholder opinion	An acceptable option to both the Environment Agency and the National Farmers' Union with emphasis placed on appropriate planning to avoid water pollution. A stakeholder group has been set up to produce practical guidance to farmers. Public reaction may be opposed to disposal of milk on land even if proven to be acceptable scientifically.
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

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38 Landspreading of milk and/or slurry

	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. Chilton, NRPB-W11.
Document history	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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39 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.
Management option 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 eg 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 (cereals, pasture, fruit, vegetables).
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 MPL: ^{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. If herbicide pre-treatment is considered necessary this will cause a delay to the ploughing option.
Constraints	
Legal constraints	Farms in Environmental Stewardship Scemes in England, Agri-Environment Schemes in Scotland, and the Organic Farming Scheme in Northern Ireland, might find this option unacceptable due to its use of herbicides. Ploughing in may be restricted at farms designated within Nitrate Vulnerable Zones. The Nitrate Vulnerable Zones (NVZ) Action Programme, made under the Action Programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 as amended, the Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 1998 as amended, and the Action Programme for Nitrate Vulnerable Zones Regulations (Northern Ireland) 1999 as amended, implement the EC Nitrate Directive 91/676/EEC. This designates the areas of land in England, Scotland, Wales and Northern Ireland classified as NVZs to be 55%, 13%, 3% and 0.1% respectively. Following the implementation of the Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004 all of Northern Ireland will be classified as an NVZ (total territory). However, until a new Action Plan is established the previous regulations apply. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
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.
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

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39 Ploughing in of a standing crop

	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 or 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; 1 h ha^{-1} forage harvester; 2 h 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 costs	N/A.
Assumptions	None.
Communication needs	Need for dialogue regarding selection of areas 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 (ie 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.

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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.
UK stakeholder opinion	An acceptable option to the National Farmers' Union and other agricultural experts provided soil conditions are suitable and nitrate loss is controlled by appropriate husbandry.
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. Chilton, NRPB-R295.
Document history	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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40 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 MPL: ^{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	The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of 'radioactive waste' as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If it is defined as 'radioactive waste' then authorisation would be required for the storage and disposal of the foodstuffs. However, radioactively contaminated foodstuffs may not meet the strict legal definition of 'radioactive waste' as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. If they have activity concentrations in excess of the Maximum Permitted levels (MPLs) and are not considered 'radioactive waste' they will be regarded as agricultural waste and the following legislation will apply. Milk processing plants used to treat liquid wastes will be subject to the Urban Waste Water Treatment (England and Wales) Regulations 1994 as amended, the Urban Waste Water Treatment (Scotland) Regulations 1994 as amended, the Urban Waste Water Treatment Regulations (Northern Ireland) 1995 as amended, which implement the Urban Waste Water Directive 91/271/EEC. The regulations ensure certain standards of wastewater treatment are attained but only apply to STWs serving a population equivalent of greater than 2000. In England, Scotland and Wales milk processing plants have been controlled by the Integrated Pollution Control (IPC) regime made under the Environmental Protection (Prescribed Processes and Substances) Regulations 1991 as amended, as Part I of the Environmental Protection Act 1990 (EPA90). Equivalent legislation in Northern Ireland is the Industrial Pollution Control (Prescribed Process and Substances) Regulations (Northern Ireland) 1998 as amended, and the Industrial Pollution Control (Northern Ireland) Order 1997 as amended. By the end of 2007 all facilities treating and processing milk in quantities greater than 200 tonnes per day (average value on an annual basis) will be transferred to a permitting regime (PPC) made under Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, Pollution Prevention and Control (Scotland) Regulations 2000 as amended or Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended, made under the Pollution Prevention and Control Act 1999 and implementing the EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). Facilities processing less than 200 tonnes per day of milk are not controlled by the PPC regime and may come under the control of the Waste Management Licensing regime (WML). In England, Scotland and Wales the WML regime is made under Part II of EPA90 and implements the EC Framework Directive on Waste (75/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). The EPA 1990 has been transposed into legislation via the Waste Management Licensing Regulations 1994 as amended (WMLR) in England, Scotland and Wales. For Northern Ireland the Waste Management Licensing Regulations (Northern Ireland) 2003 are used which are made under Part II of the Waste and Contaminated Land (NI) Order 1997 as amended and partially implement the EC

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	Framework Directive on Waste. However, they will be exempt from WML if they have an effluent discharge consent made under the Water Resources Act 1991 and corresponding legislation (see below). Discharges from milk processing plants are regulated by the Water Resources Act (England and Wales) 1991, the Control of Pollution Act 1974 and Water Environment and Water Services (Scotland) Act 2003 in Scotland, and the Water (Northern Ireland) Order 1999 as amended. They control the discharge of any poisonous, noxious or polluting matter, or any solid waste matter from entering any controlled waters, ie tidal and coastal waters (up to three miles from land), rivers, lakes, ponds and ground waters. Discharges of milk to sewers requires authorisation under the Water Industry Act 1991 in England and Wales, the Sewerage (Scotland) Act 1968 and the Water and Sewerage Services (Northern Ireland) Order 1973. If milk is defined as 'radioactive waste' then for road transportation the Radioactive Material (Road Transport) Regulations 2002 as amended, apply to England, Scotland and Wales. For Northern Ireland the Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1992 apply. These regulations are implemented by the Radioactive Material (Road Transport) Act 1991 and the Radioactive Material (Road Transport) (Northern Ireland) Order 1992. The Radioactive Material (Road Transport) (Definition of Radioactive Material) Order 2002 also applies in England, Scotland and Wales. For rail transportation the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 apply in England, Scotland and Wales. In Northern Ireland the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 apply, and also cover class 7 road vehicles. During 2007 the road and rail regulations for England, Scotland and Wales will be combined to form the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 made under the Health and Safety at Work etc Act 1974. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
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.
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 (ie 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.

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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 37 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 costs	Cost of storage of milk powder and disposal to landfill or other facility. Cost of disposal of rinsing waters to dairy effluent or 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 or 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.
UK stakeholder opinion	There may be reluctance to allow contaminated milk into the dairy because after the event, retailers and consumers would not have the confidence that the plant could revert to normal operation without putting milk and milk products at risk of becoming contaminated. The NFU believes that the milk purchaser has a duty to take responsibility for contaminated milk and its disposal - this is because the producer has a contract with the purchaser. NFU consider that it would be reasonable for one processing facility within a milk producing area to be devoted to drying milk into powder.
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. *J Radioecol* **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. Chilton, NRPB-W15.
Document history	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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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	The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service, have the statutory powers to authorise the accumulation and disposal of 'radioactive waste' as defined by sections 29 and 30 of the Radioactive Substances Act 1993 (RSA93). If it is defined as 'radioactive waste' then authorisation would be required to send the waste to an authorised incinerator (eg private incinerator) or if VLLW then may require authorisation to send to municipal incinerator. However, radioactively contaminated foodstuffs may not meet the strict legal definition of 'radioactive waste' as set down in section 2 RSA93 and the Secretary of State can by order exclude particular descriptions of radioactive waste from RSA93. If they have activity concentrations in excess of the Maximum Permitted Levels (MPLs) and are not considered 'radioactive waste' they will be regarded as agricultural waste and the following legislation will apply. In the UK rendering plants have been controlled by the Local Air Pollution Control (LAPC) regime made under the Environmental Protection (Prescribed Processes and Substances) Regulations 1991 as amended, as Part I of the Environmental Protection Act 1990 (EPA90). By the end of 2007 they will be transferred to a permitting regime (PPC) made under Pollution Prevention and Control (England and Wales) Regulations 2000 as amended, the Pollution Prevention and Control (Scotland) Regulations 2000 as amended or the Pollution Prevention and Control Regulations (Northern Ireland) 2003 as amended, made under the Pollution Prevention and Control Act 1999 and implementing the EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). Rendering plants must be approved under the Animal By-Products Regulations 2005 (ABPR) in England, the Animal By-Products (Scotland) Regulations 2003, the Animal By-Products (Wales) Regulations 2003 or the Animal By-Products Regulations (Northern Ireland) 2003, which enforce the EU Animal By-Products Regulation (EC) No. 1774/2002 (ABPR) made under the European Communities Act 1972. Other applicable legislation is the TSE (No.2) Regulations 2006 in England, TSE (Scotland) Regulations 2002 as amended, TSE (Wales) Regulations 2002 as amended and TSE Regulations (Northern Ireland) 2006, which implement the EU TSE Regulation EC 999/2002 (as amended) into law, and the Older Cattle Disposal Scheme (OCDS). Rendering by-products (MBM, tallow and greaves) have to be disposed of to landfill or incineration under ABPR regulations, and are subject to the EC Framework Directive on Waste (75/442/EEC as amended) (WFD), the EC Landfill Directive (1999/31/EC) and the EC Waste Incineration Directive (2000/76/EC). Rendering plants which treat waste liquids on site will be subject to the Urban Waste Water Treatment (England and Wales) Regulations 1994 as amended, the Urban Waste Water Treatment (Scotland) Regulations 1994 as amended or the Urban Waste Water Treatment Regulations (Northern Ireland) 1995 as amended which implement

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	the Urban Waste Water Directive 91/271/EEC. The regulations ensure certain standards of wastewater treatment are attained. The disposal of rendering fluid effluent (condensate) is controlled by the Rendering (Fluid Treatment) (England) Order 2001 or the Rendering (Fluid Treatment) (Scotland) Order 2001 made under the Animal Health Act 1981. For Northern Ireland the Rendering (Fluid Treatment) Order (Northern Ireland) 2001 is used, which is made under the Diseases of Animals (Northern Ireland) Order 1981. It requires all discharges and disposal of ruminant related fluid to sewers be consented under the Water Industry Act 1991 in England and Wales, the Sewerage (Scotland) Act 1968 and the Water and Sewerage Services (Northern Ireland) Order 1973. Discharges and disposal of ruminant related fluid to controlled waters (surface and ground waters) must be consented under the Water Resources Act (England and Wales) 1991, the Control of Pollution Act 1974 and Water Environment and Water Services (Scotland) Act 2003 in Scotland, and the Water (Northern Ireland) Order 1999 as amended. If wastes are defined as 'radioactive waste' then for road transportation the Radioactive Material (Road Transport) Regulations 2002 as amended, apply to England, Scotland and Wales. For Northern Ireland the Radioactive Substances (Carriage by Road) Regulations (Northern Ireland) 1992 apply. These regulations are implemented by the Radioactive Material (Road Transport) Act 1991 and the Radioactive Material (Road Transport) (Northern Ireland) Order 1992. The Radioactive Material (Road Transport) (Definition of Radioactive Material) Order 2002 also applies in England, Scotland and Wales. For rail transportation the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004 apply in England, Scotland and Wales. In Northern Ireland the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (Northern Ireland) 2006 apply, and also cover class 7 road vehicles. During 2007 the road and rail regulations for England, Scotland and Wales will be combined to form the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 made under the Health and Safety at Work etc Act 1974. The Ionising Radiation Regulations 1999 and Ionising Radiation Regulations (Northern Ireland) 2000 give effect to the basic safety standards for the protection of the health of workers and the general public from ionising radiation.
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 are fully implemented.
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 or 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 eg 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;

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	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. See datasheets on 36 Incineration and 37 Landfill.
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 37 Landfill or by 36 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 37 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 costs	Transportation of waste products to disposal site or 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	The entire infrastructure needed is readily available.
Communication needs	Operators require information and training on rendering contaminated carcasses.
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 ground water arising from landfilling ash and rendering wastes.
Agricultural impact	None.
Social impact	Minimal.
Other side effects	None.
UK stakeholder opinion	The Environment Agency's hierarchy of acceptance ranks rendering followed by incineration above landfill and burial.
Practical experience	Rendering was the preferred option for disposing of livestock during the FMD outbreak

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	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	Nisbet AF, Hesketh N and Mercer JA (2005). Agricultural Food Production. UK Recovery Handbook for Radiation Incidents, Version 1, 2005. Chilton, HPA-RPD-002. Datasheet reviewed in 2014 as part of the update of UK Recovery Handbook for Radiation Incidents.

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42 Soil washing

Objective	To remove radionuclides from topsoil soil that has already been removed from areas of food production (agricultural and domestic).
Other benefits	Reduction in volumes of contaminated soil requiring disposal.
Management option description	Soil washing is an ex-situ volume reduction/waste minimisation process, whereby the contaminated soil particles are separated from the bulk soil which can be recycled if sufficiently clean, by return to its original location or by use on another site as fill. Otherwise, it might require separate storage or may be disposed of relatively inexpensively as less hazardous material. The contaminated fine soil particles and wash water can either be further treated or disposed of directly. Water is mixed with contaminated soil and debris to produce a slurry feed. As radioactive contaminants tend to bind more to fine soil particles (silt and clay), passing the slurry though separation processes, such as precipitation, filtration or ion exchange, separates fine soil particles from granular soil particles and removes contamination from the soil. Separation screens the slurry feed to separate the coarse and fine fractions. The sand and gravel parts are typically subjected to abrasive scouring or scrubbing to remove surface contamination, while the fine particles are further separated in a sedimentation tank, with the possible use of a flocculating agent. The exact process(es) used can vary. Soil washing systems can be designed to accommodate a wide variety of soil types, including those with moderately high clay content.
Target	Contaminated soil.
Targeted radionuclides	
Scale of application	
Contamination pathway	Soil to plant transfer.
Exposure pathway pre-intervention	Ingestion of foodstuffs, inhalation of soil, external exposure from soil.
Time of application	
Constraints	
Legal constraints	Legal constraints relate to removal of topsoil (13 Removal of topsoil).
Social constraints	Public or farmers resistance to management option - acceptability of returning cleaned soil to excavation site. Associated removal of flora and fauna raises wildlife issues are likely to be contested. Resistance to changes to landscape and other environmental effects.
Environmental constraints	Waste water from soil washing will generally require some form of run-off control. There is also a risk of contamination of ground water.
Effectiveness	
Management option effectiveness	Soil washing is only effective if radionuclides are concentrated in a fraction of the original soil volume, or are transferred to the wash water. Evaluation of separation techniques used in Japan, showed a range of decontamination levels. For radioactive caesium, tests showed a 36% reduction, though higher reductions, up to 90%, may be achieved, depending on soil properties.
Factors influencing effectiveness of procedure	Soil type: efficiency depends on soil properties (clay and humus contents). Soil washing is most effective when the contaminated soil consists of less than 25% silt and clay and at least 50% sand and gravel. However, soil washing systems can be designed to accommodate moderately high clay content. Efficiency decreases with increasing organic matter content. Soil particles should be 0.25 to 2mm diameter for optimum performance. Process(es) used.
Feasibility	
Required specific equipment	Equipment to remove soil (eg bulldozer or mechanical digger) and to replace clean soil to excavation site. Screening/filtration/scouring/sedimentation equipment for the separation processes.
Required ancillary equipment	Vehicles to transport soil and wastes.

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	Monitoring equipment.
Required utilities and infrastructure	Roads for transport. Water and power supplies. Soil washing facility. Suitable disposal facilities.
Required consumables	Water Processes may use flocculating agents. Fuel and parts for vehicles.
Required skills	Soil removal/replacement could be carried out by already skilled operators such as municipal workers. Suitably skilled/trained workers will be required for soil washing processes.
Required safety precautions	Consider respiratory protection if very dry or dusty conditions when removing/replacing soil. PPE required during soil washing processes.
Other limitations	
Waste	
Amount and type	Contaminated fine soil particles and wash water. Volume of waste will typically be much smaller than the original soil volume. If cleaned soil is returned to excavation site then option generates up to 33 times less wastes than topsoil removal.
Possible transport, treatment and storage routes	N/A
Factors influencing waste issues	Contamination level of waste. Volume of waste. Acceptability of waste disposal options. Acceptability of returning cleaned soil to excavation site.
Doses	
Incremental dose	**Operative removing soil**: external exposure, inadvertent ingestion and inhalation while removing soil surface. **Driver**: external exposure while transporting soil to soil washing facilities, or while transporting wastes to disposal facilities **Operative at soil washing facility:** External exposure , inadvertent ingestion and inhalation
Intervention costs	
Equipment	Equipment to remove soil (eg bulldozer or mechanical digger) and to replace clean soil to excavation site. Screening/filtration/scouring/sedimentation equipment for the separation processes. Soil washing for reduction of soil waste can be impractical for large scale implementation due to high running costs.
Consumables	Fuel for equipment (ca 40 l ha^{-1}). Transporters.
Operator time	Soil removal typically some 50-100 h ha^{-1}, including loading to transport truck, but excluding waste transport and work at soil washing facility.
Factors influencing costs	Type of equipment used for soil removal. Technique(s) used at soil washing facility. Soil type and conditions, field size and shape, topography and operator experience. Distances of contaminated site to equipment hire and to facility site.

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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 costs	Transport to landfill site and subsequent landfill costs (including landfill tax). Soil washing for reduction of soil waste can be impractical for large scale implementation due to requirements for secondary wastes.
Assumptions	None.
Communication needs	Need for dialogue regarding timing and selection of areas considered suitable for treatment with this management option. Clarification of the costs and benefits before decisions on implementation are made. Provision of information on correct application of procedure including radiological hazards.
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/members of the public.
Environmental impact	Risk of ground water contamination. Soil biota in washed soil will be affected. Soil washing for reduction of soil waste can be impractical for large scale implementation due to potential environmental impacts.
Agricultural impact	Where washed soil is returned to the excavated site, soil fertility may be affected as organic matter will have been lost. Similarly, fertilisation may be required.
Social impact	Stigma associated with affected areas. Disruption to farming and other related activities (eg 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 in food industry; if returning of cleaned soil to excavation site is not accepted there may be 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.
UK stakeholder opinion	
Practical experience	Tested in Japan following the Fukushima accident.
Key references	Hardie SML and McKinley IG (2014) Fukushima remediation: status and overview of future plans. J Environ Radioact 2014; 133:17-85. IAEA (2011) Final Report of the International mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Dai-ichi NPP 7-15 October 2011, Japan, IAEA NE/NEFW/2011, 15/11/2011 NCRP SC 5-1 Decision Making for Late-Phase Recovery from Nuclear or radiological Accidents. Shiratori Y and Tagawa A (2012) Report of the Results of the Decontamination Technology Demonstration Test Project, FY2011 'Decontamination Technology Demonstration Test Project', Presentation to meeting at Fukushima City Public Hall, March 26 2012.
Comments	
Document history	Datasheet developed in 2014 as part of update of UK Recovery Handbook for Radiation Incidents

8 Glossary

Term	Definition
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 ruminant livestock to reduce the uptake of radiocaesium to meat and milk: caesium binds to the AFCF and is then excreted by the animal.
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}.
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. In the event of an accident the AFCWG would be convened to provide advice to the Recovery Working Group.
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 is 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 an option and the impact of its implementation.
Domestic food production	Food that is produced by individuals in private or kitchen gardens or allotments
Dose	General term used for a quantity of ionising radiation. Unless used in a specific context, it refers to the effective dose.
Effective dose	The effective dose is the sum of the weighted equivalent doses in all the tissues and organs of the body. It takes account of the relative biological effectiveness of different types of radiation and variation in the susceptibility of organs and tissues to radiation damage. Unit sievert, Sv.
Emergency countermeasures	Actions taken during the emergency phase with the aim of protecting people from short-term relatively high radiation exposures, eg 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 radiation emergency or incident.
Equivalent dose	A quantity used in radiological protection dosimetry, which incorporates the ability of different types of radiation to cause harm in living tissue. Unit sievert, Sv (1Sv = 1 J kg^{-1}).
Extensive management systems	Extensive farming (as opposed to intensive farming) is an agricultural production system that uses low inputs on large areas of land. Extensive farming most commonly refers to sheep and cattle farming in areas with low agricultural

Term	Definition
	productivity such as the uplands of western Britain.
Flux	The rate of flow of fluid, particles, or energy through a given surface.
Free foods	Foods collected from the wild.
Gamma ray, γ	High energy photons, without mass or charge, emitted from the nucleus of a radionuclide following radioactive decay, as an electromagnetic wave. They are very penetrating.
Half-life	The time taken for the activity of a radionuclide to lose half its value by decay. Symbol $t_{1/2}$.
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: $t_{1/2,b}$.
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.
Intensive management systems	Intensive farming or intensive agriculture is an agricultural production system characterized by the high inputs of capital, fertilizers, labour, or labour-saving technologies such as pesticides relative to land area
Intergenerational	Being or occurring between generations
Ionising radiation	Radiation that produces ionisation in matter. Examples are alpha particles, gamma rays, x-rays and neutrons. When these radiations pass through the tissues of the body, they have sufficient energy to damage DNA.
Improvised terrorist (explosive) device	A device intended to disperse radioactive material using conventional explosives. Also known as a dirty bomb.
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.
Operative	An individual implementing a *management option* (eg a farmer or a worker at a food or waste processing facility).
Photon	A quantum or packet of electromagnetic radiation (eg gamma rays or visible light) which may be considered a particle.
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.
Radiation 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

Term	Definition
	long-term management of the contaminated area and the implementation of specific management options. The development of the strategy should involve all stakeholders.
Recovery Working Group	A group comprising government departments and agencies, local authorities, site operator, water utilities and others as required, that meets during the early phase to consider the long-term implications of the emergency. The RWG develops strategies for return to normality.
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 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, time since deposition.
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 3 weeks.
Sievert, Sv	The SI unit of *effective dose.* Symbol: Sv (1 Sv = 1 J kg^{-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), ie one thousandth of one sievert, and microsieverts (µSv), ie one thousandth of a millisievert. The average annual radiation dose to the UK population is 2.7 mSv.
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, (eg 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 Typical examples include: 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.

Appendix A History of the Development of the Food Handbook

The 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 1990s (see

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 initiatives, was subsequently adopted 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 handbooks

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, 2002; Andersson et al, 2000). In the UK, consultations with individual experts from a range 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, 1995). This prompted the National Radiological Protection Board* 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 (Nisbet and Mondon, 2001). 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, the first version of the UK Recovery Handbook for Radiation Incidents was published (Health Protection Agency, 2005), the food production section of which was produced in close collaboration with the stakeholders.

Based on the success of the UK group, it was possible over the period 2000-2004 to extend the approach to Europe by setting up the FARMING network. This network of more than 100 stakeholders comprises panels in the UK, Finland, Belgium, France and Greece (Nisbet et al, 2005). The national stakeholder panels met regularly to discuss the issues surrounding long term contamination of the foodchain by radioactivity. National panels belonging to the FARMING network were reconvened during 2005 and 2006 to provide feedback on whether a handbook similar to the one published for use in the UK could be

* The NRPB was incorporated into the Health Protection Agency in 2005. On 1 April 2013 the HPA was abolished and its functions transferred to Public Health England (PHE).

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. A multinational steering group took responsibility for drafting of the new European handbook which was co-ordinated by the HPA (Nisbet et al, 2006).*

Handbooks are living documents that should be updated over time to remain state-of-the-art. Consequently, versions 2 and 3 of the UK Recovery Handbook for Food Production Systems were further developed to reflect improvements made in the European handbook as well as end-user requirements, feedback from the AFCWG and recent changes to UK legislation.

Since version 3 was published in 2009 there have been a number of developments that have led to the production of this 4th version of the UK Recovery Handbook for Food Production Systems. An extensive review of the literature concerning remediation of areas contaminated with radioactive material has generated additional information on the effectiveness and constraints associated with management options. A major portion of this information has arisen from recovery work, following the earthquake and tsunami in Japan in March 2011 and the subsequent accident at the Fukushima Dai-ichi Nuclear Power Plant. Since the accident, there has been a major focus on clean-up, with 1,317 billion Yen allocated in the years 2011 to 2013 for remediation and management of associated waste (IAEA, 2013). This work has included two decontamination pilot projects set up by the Japanese Atomic Energy Agency, which are helping develop recommendations on how to assure efficient and effective remediation, improving clean-up efficiency and worker safety while reducing time, cost, subsequent waste management and environmental impact (Miyahara et al, 2012). Additionally, feedback following the 2012 publication of the UK Recovery Handbook for Chemical Incidents (Wyke-Sanders et al, 2012) has led to changes in the UK Recovery Handbook for Radiation Incidents.

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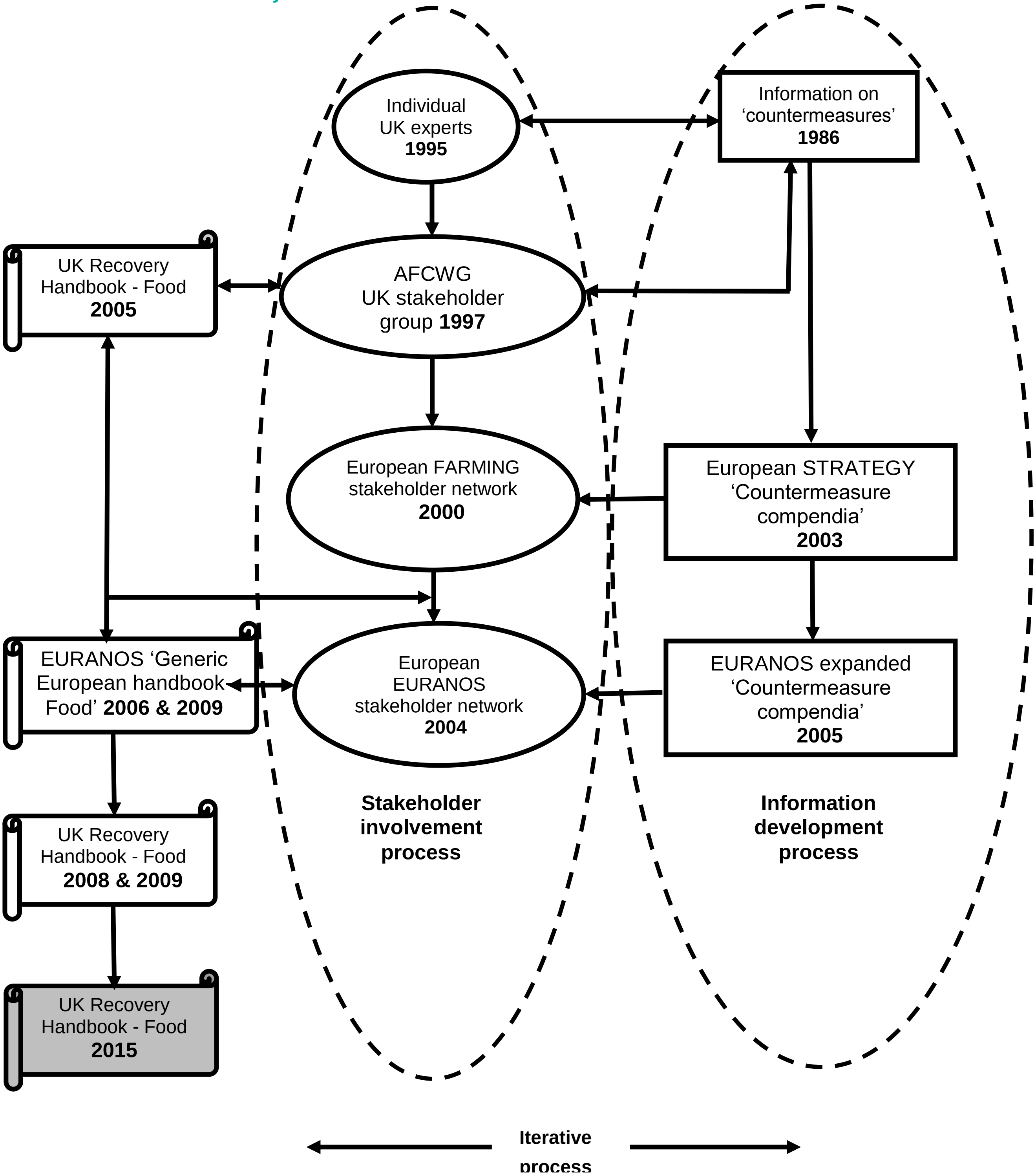
Figure A1 Diagram to illustrate the history of development of the UK Recovery Handbook for Food Production Systems from 1995-2015



Appendix B Management Options Excluded From the Food Handbook

Since 1997, the Agriculture and Food Countermeasures Working Group (AFCWG) has debated the practicability of many management options (Alexander et al, 2005; Nisbet and Mondon, 2001). When the AFCWG met in November 2002 group members were asked to reach a consensus on which options should be included in version 1 of the UK Recovery Handbook and which should be excluded. Following work with European stakeholders 10 additional management options were included in version 2. The AFCWG met again in October 2008 to discuss these options and as a result only 4 options were retained for inclusion in version 3. A list of all of the management options that have been excluded by the AFCWG and the reasons for their exclusion are given in Table B8.1.

A European project, given the acronym STRATEGY (Sustainable Restoration and Long-term Management of Contaminated Rural, Urban and Industrial Ecosystems) was undertaken to establish a framework to enable the selection of robust and practicable remediation strategies for Europe (Howard et al, 2005). Discussions with members of the STRATEGY project as well as end-users of the project's outputs over the period 2000-2003 enabled a consensus to be reached on those management options that were considered to not be sufficiently effective or sufficiently well developed for immediate implementation in Europe. The options that were excluded by the STRATEGY team and reasons for their exclusion are listed in Table B8.1. These options were also excluded from the range of management options considered in this handbook.

Table B8.1 Management options that have been excluded from the handbook

Option	Reason for exclusion
Administration of stable iodine to feed	The amounts of stable iodine required to give a significant reduction in the transfer of radioiodine to goat milk (eg by 50%) will result in stable iodine levels in milk greatly in excess of World Health Organisation limits (Crout et al, 2000). Furthermore, the effect of stable iodine administration is influenced by the animal's current iodine status; if the administration rate of stable iodine is too low, it could result in an increase in the ^{131}I activity concentration in milk (Crout et al, 2000; Vandecasteele et al, 2000). A proviso on the first of these reasons for exclusion is that the majority of recent research has been conducted using dairy goats and not cattle. However, in some countries (eg the UK) high levels of stable iodine in cow milk are under normal circumstances a cause for concern (MAFF, 1997). (Consensus of STRATEGY project members and end-users)
Application of AFCF to soil	Not cost-effective for pastures - much cheaper to treat animals with AFCF in feed or boli. It is also not effective on fine textured soils such as loam and clay - which are widespread soil types. The effectiveness on coarse textured soils has only been studied in small-scale (ie pots) experiments of 1 year duration. Furthermore, the public may oppose use of a soil treatment that contains cyanide. (Consensus of STRATEGY project members and end-users)
Application of clay minerals to soil	Currently not able to recommend as effectiveness not clearly established. Furthermore, clay minerals are very expensive. (Consensus of STRATEGY project members and end-users)
Biological treatment (digestion) of crops	Technology not sufficiently developed or widespread to be a major option. (AFCWG 2002 meeting)
Change livestock type	The replacement of sheep or goats with cattle has previously been suggested as a countermeasure. However, it cannot currently be recommended because: it may not be possible to graze cattle on the poorer quality land where sheep/goats are often found (sheep and goats are better able to utilise poor quality herbage than cattle); and the potential variability in transfer and dry matter intake is such that lower contamination levels may not be achieved. (Consensus of STRATEGY project members and end-users)
Compensation scheme	Outside the remit of the handbook. (AFCWG 2008 meeting).
Covering of standing crops	Overall not a practical option. Unlikely to be covering material available. Unlikely that covering material could be applied in time, especially as fields could be at a distance from the farmhouse. There would be secondary waste issues associated with the covering material. There could also be health and safety issues for personnel involved in covering the crops quickly. (AFCWG 2008 meeting).
Decontamination techniques for milk	Unlikely to be an option considered in the UK for all but the most severe and unlikely incidents. The dairy industry and British Retail Consortium consider that it would be unacceptable from consumers' perspective to produce clean milk from contaminated raw milk. Furthermore, dairies would be unwilling to accept contaminated milk into their processing plants. (AFCWG 2002 meeting).
Dilution	There is consensus that would be unacceptable to contaminate knowingly the foodchain. It would reduce consumer confidence. (AFCWG 2002 meeting).
Distribution of salt licks containing AFCF	Unlikely to be an option considered in the UK as most areas are not salt deficient. (AFCWG 2002 meeting).
Early removal of crops	It is generally felt that there is not a strong case for this option in terms of effectiveness in minimising radionuclide transfer to soils. There must be recognition that removal of crops will have associated waste disposal problems. (AFCWG 2002 meeting).
Feeding animals with crops/milk in excess of Intervention Levels	For farmers, the acceptability of this management option is driven by the availability of suitable markets for the resultant produce. However, both retailers and consumers consider that, except in the most extreme of circumstances, the feeding of contaminated foods to animals would not be acceptable, particularly when clean feed was still available. The option might be more acceptable for animals not in the foodchain. However, there was consensus that any crop/milk over the intervention limit must be destroyed to prevent subsequent unauthorised entry into the foodchain. (AFCWG 2002 meeting)

Table B8.1 Management options that have been excluded from the handbook

Option	Reason for exclusion
Processing of crops for subsequent consumption	Unlikely to be an option considered in the UK. Retailers will not accept processed crops that had once been contaminated. Furthermore, there was consensus that any crop over an intervention level must be destroyed to prevent subsequent unauthorised entry into the foodchain. If processing was permitted it was felt that there could be potential for the market to be destroyed for all canned and blanched products. (AFCWG 2002 meeting).
Food labelling	Not acceptable. Retailers should not be required to label food products. Either food is safe or unsafe. If activity concentrations are less than intervention levels food should be sold without additional labelling. The following precedents have already been set: • retailers are not required to label if there is a legal residue of any other environmental contaminant, eg heavy metals or dioxins, why is a radioisotope any different? • there are several mineral water products on sale, both in the UK and Europe, that already contain low levels of radioisotopes due to the natural presence in the rocks through which the water filters - these products are not labelled (AFCWG 2008 meeting)
Processing of milk for subsequent human consumption	Unlikely to be an option considered in the UK for all but the most severe and unlikely incidents. The dairy industry, the Meat and Livestock Commission and British Retail Consortium consider that it would be unacceptable from consumers' perspective to produce milk products from contaminated raw milk. Furthermore, dairies would be unwilling to accept contaminated milk into their processing plants. (AFCWG 2002 meeting)
Pruning/defoliation of fruit trees	Overall not a practical option. There are numerous logistical constraints as pruning/defoliation needs to be done as soon as possible after deposition. Needs more research and field trials to prove effectiveness. (AFCWG 2008 meeting)
No active implementation of management option (do nothing)	Not relevant to food production systems. If a food product has activity concentrations that exceed intervention levels restrictions are placed on the sale of that food product, ie a decision to implement a management option is taken. If activity concentrations are less than intervention levels, the food product can be sold and no management options are therefore required. (AFCWG 2008 meeting)
Salting of meat for subsequent consumption	Unlikely to be an option considered in the UK. It would be unacceptable from a consumers' perspective to produce meat products from contaminated raw meat. Furthermore, apart from bacon there is only a limited interest in salted meat dishes. (AFCWG 2002 meeting)
Raising of intervention levels	Outside the remit of the handbook. There are already provisions at the European level to lower or raise intervention levels after an incident according to the specific circumstances. Furthermore, retailers consider that all control levels should be based on sound scientific advice or evidence, not on protecting certain markets. They recognise that there may be extreme situations where a review of the controls may be necessary, for example in the event of major food shortages or where a specific segment of the food industry is unable to function. (AFCWG 2008 meeting)
Select different crop variety/species with low uptake	Currently not able to recommend as effectiveness not clearly established. For radiocaesium and radiostrontium, variations in soil-to-plant transfer factor (TF) typically in the order 2-5 have been noted between different varieties of the same crop. However, a similar variation has been observed for the same variety of crop grown in different years. Fluctuating environmental conditions may therefore be responsible for observed variations in transfer within and between crop variety. Furthermore, for radiocaesium and radiostrontium, differences in soil-to-plant TF between crop species for any one soil type are around an order of magnitude, when expressed on a dry mass basis. However, these differences are much reduced when TFs are expressed on a fresh mass basis: for example differences of less than a factor of 2 are observed between cereals and green vegetables. The availability of alternative crop varieties or species would also be extremely limited. (Consensus of STRATEGY project members and end-users)
Select edible crop that can be processed	Unlikely to be an option considered in the UK. It was thought to be not viable from an economic point of view as markets for processed crops are limited. It would be more logical to pay the farmer to set aside the land for a period of time. The processing of crops would inevitably contaminate processing plants. Furthermore, the input of processed crops to the foodchain would not be acceptable to consumers. (AFCWG 2002 meeting)

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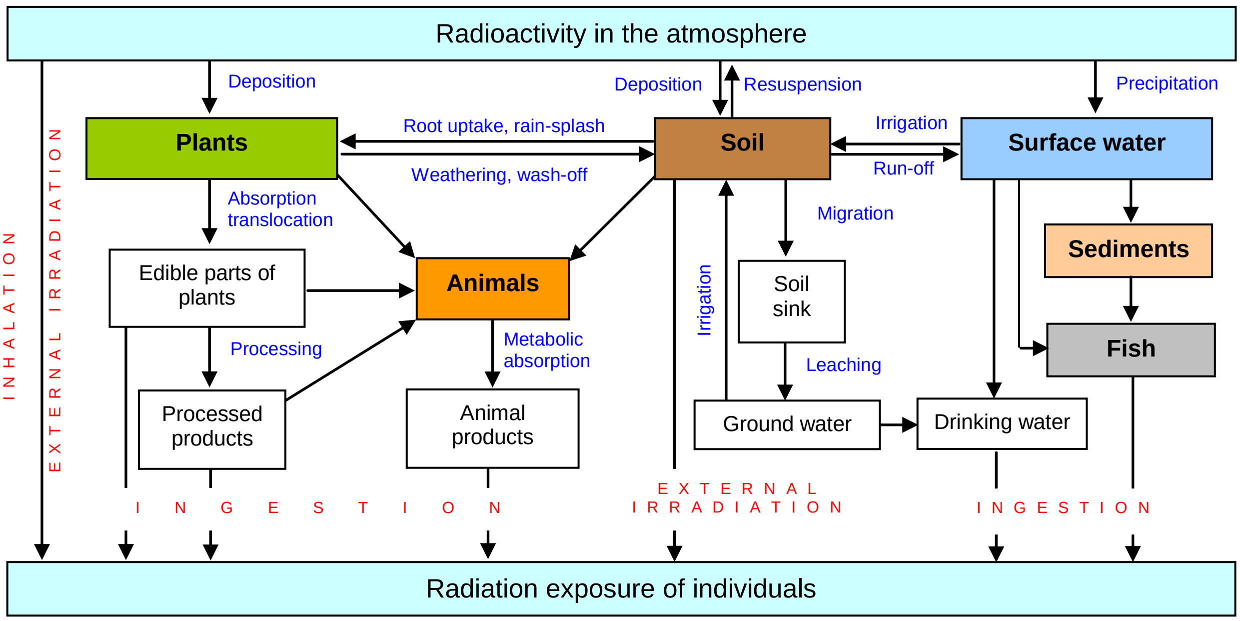
Appendix C Transfer and Impact on Food

C1 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 C1. Understanding transfer pathways is essential in order to design environmental models and develop effective management options. Each route delineated in Figure C1 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 C1.1 and Section C1.2 (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.

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.

Figure C1 Major pathways involved in the transfer of radionuclides through the foodchain, following a release of radioactivity in the atmosphere



C1.1 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.

C1.1.1 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, (ie 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 (ie wind direction and velocity, precipitation, etc); the physical and chemical form of the deposit; the type of plant and its stage of development (ie 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 (eg 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.

C1.1.2 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).

C1.2 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, eg K/Cs, Ca/Sr); animal (species, mass, age and growth rate) and milk yield, in the case of lactating species.

C1.3 Aquatic ecosystems

Contamination of aquatic ecosystems occurs by direct fallout deposition onto the water surface or by remobilisation of radionuclides, eg 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, eg 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.

C1.4 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 medium to long term after deposition.

C1.5 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).

C2 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 characterised 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 (eg 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 (eg 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.

C2.1 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	Important for mobile radionuclides (eg radiocaesium from organic soils; radiostrontium from mineral soils)
	Resuspension of soil-associated activity	Important for immobile radionuclides (eg actinides)

In the early months after the accident, contamination of agricultural crops is dominated by surface deposition of radionuclides (see Section C1.1). 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 (ie micron-sized stable formations containing a high level of alpha, beta and gamma 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, 2001).

After the first few months, contamination of plants largely arises through root uptake (see Section C1.1), 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).

C2.2 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.

C2.3 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 D Applicability of Management Options for Radionuclides Unlikely to Have a Significant Impact on the Foodchain

Table D1.1 (part 1) Management options for agricultural food production systems with target radionuclides identified

	Radionuclide Half-life							
	^{95}Nb	^{95}Zr	^{99}Mo/^{99m}Tc	^{110m}Ag	^{125}Sb	^{127}Sb	^{132}Te	^{140}Ba
Management options	35.15 d	63.98 d	66 h/6.02 h	249.9 d	2.77 y	3.85 d	78.2 h	12.74 d
Addition of AFCF to concentrate ration (16)	a	a	a	a	a	a	a	a
Addition of calcium to concentrate ration (17)	b	b	b	b	b	b	b	✓
Addition of clay minerals to feed (18)	a	a	a	a	a	a	a	a
Administer AFCF boli to ruminants (19)	a	a	a	a	a	a	a	a
Application of lime to soils (9)	c, d	✓	c, d	c	c	c, d	c, d	d
Application of potassium fertilisers to soils (10)	a	a	a	a	a	a	a	a
Clean feeding (20)	✓	✓	✓	✓	✓	✓	✓	✓
Clean feeding (domestic livestock) (26)	✓	✓	✓	✓	✓	✓	✓	✓
Close air intake systems at food processing plants (1)	✓	✓	✓	✓	✓	✓	✓	✓
Deep ploughing (11)	d	✓	d	✓	✓	d	d	d
Dietary advice (domestic) (27)	✓	✓	✓	✓	✓	✓	✓	✓
Land improvement (12)	c, d	✓	c, d	c	c	c, d	c, d	d
Live monitoring (21)	✓	✓	✓	✓	✓	✓	✓	✓
Manipulation of slaughter times (22)	✓	✓	✓	✓	✓	✓	✓	✓
Natural attenuation (with monitoring) (5)	✓	✓	✓	✓	✓	✓	✓	✓
Prevent contamination of greenhouse crops (2)	✓	✓	✓	✓	✓	✓	✓	✓
Processing or storage of domestic food products (28)	✓	✓	✓	✓	e	✓	✓	✓
Product recall (6)	✓	✓	✓	✓	✓	✓	✓	✓
Protect harvested crops from contamination (3)	✓	✓	✓	✓	✓	✓	✓	✓
Provision of monitoring equipment (domestic produce) (29)	✓	✓	✓	✓	✓	✓	✓	✓
Removal of topsoil (13)	d	✓	d	✓	✓	d	d	d
Restrict entry into the foodchain (incldking FEPA orders)(7)	✓	✓	✓	✓	✓	✓	✓	✓
Restrictions during hunting and fishing seasons (31)	✓	✓	✓	✓	✓	✓	✓	✓

Management options	Radionuclide Half-life							
	^{95}Nb	^{95}Zr	^{99}Mo/^{99m}Tc	^{110m}Ag	^{125}Sb	^{127}Sb	^{132}Te	^{140}Ba
	35.15 d	63.98 d	66 h/6.02 h	249.9 d	2.77 y	3.85 d	78.2 h	12.74 d
Restrictions on foraging (gathering wild foods) (30)	✓	✓	✓	✓	✓	✓	✓	✓
Select alternative land use (8)	d, f	d, f	d	✓	f	d, f	d, f	d, f
Selective grazing (23)	f	f	d	✓	f	d, f	d, f	d, f
Shallow ploughing (14)	✓	✓	d	✓	✓	d	d	d
Short-term sheltering of animals (4)	✓	✓	✓	✓	✓	✓	✓	✓
Skim and burial ploughing (15)	d	✓	d	✓	✓	d	d	d
Slaughtering (culling) of livestock (24)	d, f	d, f	d	✓	f	d, f	d, f	d, f
Suppression of lactation before slaughter (25)	d, f	d, f	d	✓	f	d, f	d, f	d, f

Key:

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

✓ Selected as target radionuclide (ie *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 Radionuclide has low feed-to-meat or milk transfer, making radical management options inappropriate

Table D1.1 (part 2) Management options for agricultural food production systems with target radionuclides identified

	Radionuclide Half-life							
	^{140}La	^{141}Ce	^{144}Ce	^{169}Yb	^{192}Ir	^{226}Ra	^{235}U	^{252}Cf
Management options	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 (16)	a	a	a	a	a	a	a	a
Addition of calcium to concentrate ration (17)	b	b	b	b	b	✓	b	b
Addition of clay minerals to feed (18)	a	a	a	a	a	a	a	a
Administer AFCF boli to ruminants (19)	a	a	a	a	a	a	a	a
Application of lime to soils (9)	✓	✓	✓	✓	✓	✓	✓	✓
Application of potassium fertilisers to soils (10)	a	a	a	a	a	a	a	a
Clean feeding (20)	✓	✓	✓	✓	✓	✓	✓	✓
Clean feeding (domestic livestock) (26)	✓	✓	✓	✓	✓	✓	✓	✓
Close air intake systems at food processing plants (1)	✓	✓	✓	✓	✓	✓	✓	✓
Deep ploughing (11)	c	c	✓	c	✓	✓	d	✓
Dietary advice (domestic) (27)	✓	✓	✓	✓	✓	✓	✓	✓
Land improvement (12)	c	c	✓	c	✓	✓	✓	✓
Live monitoring (21)	✓	✓	✓	✓	✓	✓	e	e
Manipulation of slaughter times (22)	✓	✓	✓	✓	✓	✓	✓	✓
Natural attenuation (with monitoring) (5)	✓	✓	✓	✓	✓	f	e, f	e
Prevent contamination of greenhouse crops (2)	✓	✓	✓	✓	✓	✓	✓	✓
Processing or storage of domestic food products (28)	✓	✓	✓	✓	✓	f	f	f
Product recall (6)	✓	✓	✓	✓	✓	✓	✓	✓
Protect harvested crops from deposition (3)	✓	✓	✓	✓	✓	✓	✓	✓
Provision of monitoring equipment (domestic produce) (29)	✓	✓	✓	✓	✓	✓	e	e
Removal of topsoil (13)	c	c	✓	c	✓	✓	✓	✓
Restriction entry into the foodchain (including FEPA orders) (7)	✓	✓	✓	✓	✓	✓	✓	✓
Restrictions during hunting and fishing seasons (31)	✓	✓	✓	✓	✓	✓	✓	✓
Restrictions on foraging (gathering wild foods) (30)	✓	✓	✓	✓	✓	✓	✓	✓
Select alternative land use (8)	c	c	g	c	c	✓	g,h	g,h
Selective grazing (23)	c, g	g	g	✓	✓	g	g	g

	Radionuclide Half-life							
	^{140}La	^{141}Ce	^{144}Ce	^{169}Yb	^{192}Ir	^{226}Ra	^{235}U	^{252}Cf
Management options	**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**
Shallow ploughing (14)	c	✓	✓	✓	✓	✓	d	✓
Short-term sheltering of animals (4)	✓	✓	✓	✓	✓	✓	✓	✓
Skim and burial ploughing (15)	c	c	✓	c	✓	✓	d	✓
Slaughtering (culling) of livestock (24)	c, g	c, g	g	c, g	✓	g	g	g
Suppression of lactation before slaughter (25)	c, g	c, g	g	c, g	✓	g	g	g

Key:

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

✓ Selected as target radionuclide (ie *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

d Management option enhances mobility of radionuclide in soil

e No/low photon energy of radionuclide makes detection difficult

f Management option only effective for short-lived radionuclides

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

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

Table D1.2 (part 1) Waste disposal options with target radionuclides identified

Management options	Radionuclide Half-life						
	^{95}Nb	^{95}Zr	^{99}Mo/^{99m}Tc	^{110m}Ag	^{125}Sb	^{127}Sb	^{132}Te	^{140}Ba
	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
Biological treatment (digestion) of milk[1] (32)	a	✓	b, a	✓	✓	c	c, a	✓
Burial of carcasses[2] (33)	✓	✓	✓	a	✓	c	c	✓
Composting (34)	✓	✓	✓	✓	✓	c	c	✓
Disposal of contaminated milk to sea (35)	d	d	d, a	d	✓	c	d, c	✓
Incineration[2] (1100°C)[3] (36)	✓	✓	✓	✓	✓	c	a, c	✓
Landfill[2] (37)	✓	✓	✓	✓	✓	c	c	✓
Landspreading of milk and/or slurry[1] (38)	✓	✓	b	✓	✓	c	c	c
Ploughing in of a standing crop[1] (39)	✓	✓	b, e	a	✓	✓	✓	✓
Processing and storage of milk products for disposal (40)	✓	✓	a	a	✓	c	c, a	a
Rendering[2] (150°C)[4] (41)	✓	✓	✓	✓	✓	c	c	✓
Soil washing (42)	✓	✓	c	✓	✓	c	c	c

Key:

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

✓ Selected as target radionuclide (ie *known or probable applicability* see Section 5.3)

1 Nuclides placed or deposited onto surface layers of soil - only plant uptake is considered

2 Nuclides are considered to be buried under clean soil - only mobility is considered

3 Maximum temperature at which option is carried out. Operating temperature is typically between 850 and 1100°C but is usually 900°C

4 Maximum temperature at which option is carried out, typically between 100 and 145°C.

a Not recommended as doses resulting from disposal could be similar to those resulting from consumption of the food

b 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

c Not recommended due to comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option

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 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 D1.2 (part 2) Waste disposal options with target radionuclides identified

	Radionuclide Half-life								
	^{140}La	^{141}Ce	^{144}Ce	^{169}Yb	^{192}Ir	^{226}Ra	^{235}U	^{238}Pu	^{252}Cf
Management options	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
Biological treatment (digestion) of milk[1] (32)	a, b	✓	✓	✓	✓	a	✓	✓	✓
Burial of carcasses[2] (33)	b	✓	✓	✓	✓	✓	c	✓	✓
Composting (34)	b	✓	✓	✓	✓	✓	✓	✓	✓
Disposal of contaminated milk to sea (35)	b, d	d	d	✓	d	d	✓	d	d
Incineration[2] (1100°C)[3] (36)	b	✓	✓	✓	✓	✓	✓	✓	✓
Landfill[2] (37)	b	✓	✓	✓	✓	✓	c	✓	✓
Landspreading of milk and/or slurry[1] (38)	b	✓	✓	✓	✓	✓	✓	✓	✓
Ploughing in of a standing crop[1] (39)	b	✓	✓	✓	✓	a	✓	a	a
Processing and storage of milk products for disposal (40)	a, b	✓	✓	✓	✓	✓	✓	✓	✓
Rendering[2] (150°C)[4] (41)	b	✓	✓	✓	✓	✓	c	✓	✓
Soil washing (42)	b	✓	✓	✓	✓	✓	✓	✓	✓

Key:

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

✓ Selected as target radionuclide (ie *known or probable applicability* see Section 5.3)

1 Nuclides placed or deposited on to surface layers of soil - only plant uptake is considered

2 Nuclides are considered to be buried under clean soil - only mobility is considered

3 Maximum temperature at which option is carried out. Operating temperature is typically between 850 and 1100°C but is usually 900°C

4 Maximum temperature at which option is carried out, typically between 100 and 145°C

a Not recommended as doses resulting from disposal could be similar to those resulting from consumption of the food

b Not recommended due to comparatively short physical half-life of radionuclide relative to timescale of implementation of the management option

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

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