

## **Datasheets on Countermeasures and Waste Disposal Options for the Management of Food Production Systems Contaminated following a Nuclear Accident**

**A F Nisbet<sup>1</sup>, J A Mercer<sup>1</sup>, N Hesketh<sup>1</sup>, A Liland<sup>2</sup>,  
H Thørring<sup>2</sup>, T Bergan<sup>2</sup>, N A Beresford<sup>3</sup>, B J Howard<sup>3</sup>,  
J Hunt<sup>4</sup> and D H Oughton<sup>5</sup>**

### **ABSTRACT**

---

This report contains a compendium of information on countermeasures and waste disposal options applicable to agricultural areas and semi-natural ecosystems from which terrestrial foodstuffs are derived. A datasheet template was used to record, in a standardised format, information on all of the criteria that a decision-maker might wish to consider when evaluating different options. These include a short description of the option, its key attributes, constraints, effectiveness, feasibility, waste generated, additional doses incurred, costs, side effects, stakeholder opinion and practical experience. Datasheets are presented for 29 countermeasures and 12 rural waste disposal options, all of which have undergone extensive peer review. The information provided is considered to be broadly applicable across the European Union.

<sup>1</sup> National Radiological Protection Board, Chilton, UK

<sup>2</sup> Norwegian Radiation Protection Authority, Norway

<sup>3</sup> Centre for Ecology and Hydrology, Lancaster, UK

<sup>4</sup> Lancaster University, UK

<sup>5</sup> Agricultural University of Norway, Norway

---

This study was part funded by the Commission of the European Communities.

---

© National Radiological Protection Board  
Chilton  
Didcot  
Oxon OX11 0RQ

Approval: May 2004  
Publication: June 2004  
£30.00  
ISBN 0 85951 539 7



---

## EXECUTIVE SUMMARY

---

The aim of the STRATEGY project (Sustainable Restoration and Long-Term Management of Contaminated Rural, Urban and Industrial Ecosystems) was the establishment of a holistic framework for the selection of optimal remediation strategies for long-term sustainable management of contaminated areas in Western Europe. A fundamental requirement of this framework was the development of compendia containing state-of-the-art information on individual countermeasures that might be applicable to food production systems and inhabited areas. This report provides a compendium of countermeasures for agricultural areas and semi-natural ecosystems from which terrestrial foodstuffs are derived. The radionuclides mainly considered are radiocaesium and radiostrontium: these can be important contributors to ingestion doses in the medium to long term.

To facilitate comparisons between different countermeasures, a datasheet template was designed taking into account all of the criteria that decision-makers might wish to consider when evaluating different options. These included a short description of the countermeasure, its key attributes, constraints, effectiveness, feasibility, waste generated, additional doses incurred, costs, side effects, stakeholder opinion and practical experience. Following a critical evaluation of the literature, datasheets were produced for 29 countermeasures. An additional 12 options were identified for the management of wastes arising from the application of these countermeasures. In addition to a wealth of published literature, new information, bespoke calculations and stakeholder feedback were included in the 41 datasheets. The datasheets subsequently underwent extensive peer review before publication.

This countermeasure compendium for food production systems has been well received by national and international bodies and plans are currently being made for its further development. For example, the joint FAO/IAEA division plans to adapt the datasheets to other climate types, whilst a new EC initiative will expand the range of radionuclides and types of production systems being considered. The resulting revised countermeasure compendium will form the basis of recovery handbooks being developed in collaboration with stakeholders for future use in Europe.

---

## PREFACE

---

The work described in this report was initiated under the STRATEGY project which received partial financial support from the Commission of the European Communities under the 5<sup>th</sup> Framework Programme (Contract FIKR-CT-2000-00018). One of the main objectives of the STRATEGY project was to identify and describe countermeasures for sustainable restoration and long-term management of rural, urban and industrial environments following a nuclear accident. Further details of the STRATEGY project can be found at <http://www.strategy-ec.org.uk/>.

The contributors to this report are specified below.

AF Nisbet, JA Mercer & N Hesketh (NRPB): are the principal report authors and originators of the datasheets for agricultural countermeasures and rural waste disposal options.

A Liland, H Thorrying and T Bergan (NRPA): are the originators of datasheets for countermeasures applicable to semi-natural ecosystems.

NA Beresford and BJ Howard (CEH): are the main contributors to the sections relating to the agricultural and environmental impact of countermeasures. They also provided valuable comments on other sections.

J Hunt (University of Lancaster) and D H Oughton (Agricultural University of Norway): are the contributors to the sections on ethical, legal, social and communication aspects of countermeasures.

---

## CONTENTS

---

<b>Preface</b>		<b>iv</b>
<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Compilation of information</b>	<b>2</b>
	2.1 Countermeasure selection	2
	2.2 Selection of waste disposal options	3
	2.3 Criteria used to describe countermeasures and waste disposal options	4
	2.4 The datasheet template	4
	2.4.1 Criteria requiring new information	5
<b>3</b>	<b>Countermeasures and options for waste disposal</b>	<b>10</b>
<b>4</b>	<b>Future developments and applications</b>	<b>12</b>
<b>5</b>	<b>References</b>	<b>12</b>
<b>6</b>	<b>Acknowledgements</b>	<b>13</b>
<b>APPENDIX A</b>	<b>Peer reviewers and STRATEGY end users</b>	<b>14</b>
<b>APPENDIX B</b>	<b>Countermeasures for agricultural and semi-natural ecosystems</b>	<b>15</b>
<b>APPENDIX C</b>	<b>Waste disposal options</b>	<b>106</b>



## 1 INTRODUCTION

---

Following a large-scale release of radioactivity into the environment, food production systems and inhabited areas may be contaminated for many years. Accident response throughout Europe has tended to focus on management of the early phase, addressing issues such as evacuation, sheltering, restrictions on food and drinking water and provision of stable iodine tablets. Currently there is little systematic consideration of the long-term management to ensure the sustainability of these areas. To sustain acceptable living and working conditions in such areas it is necessary to construct practicable restoration strategies that consider the many different types of environment, land use and ways of life.

The STRATEGY project (Sustainable Restoration and Long-Term Management of Contaminated Rural, Urban and Industrial Ecosystems) was launched in 2000, with part funding from the European Commission, under its 5<sup>th</sup> Framework Programme (Howard et al., 2004). The overall objective of the project is to establish a holistic framework for the selection of optimal remediation strategies for long-term sustainable management of contaminated areas in Western Europe. A fundamental requirement of such a framework is the development of databases containing state-of-the-art information on individual countermeasures and waste disposal options that might be applicable to food production systems and inhabited areas. Full descriptions of the databases for countermeasure options relevant to residential and industrial areas have been published separately (Anderson et al., 2003; and Eged et al., 2003, respectively). This report provides a complementary compendium of information for agricultural areas and semi-natural ecosystems from which terrestrial foodstuffs are derived. It is hoped that the information presented will be of general use to the decision-making community in the development of strategies for reducing the impact of contaminated food production systems on society. The data provided are intended to be of general applicability in Western Europe.

Ideally, countermeasures should be applicable to a wide range of radionuclides that might be released from all conceivable accidents. However, particularly in terms of release from nuclear installations, it is the relatively volatile isotopes of radioiodine and radiocaesium together with the much less volatile radiostrontium that have the potential to cause the greatest radiological impact on the foodchain. Fortunately, most of the information on countermeasures that is available relates to these radionuclides because they have been of importance in previous accidents. Many countermeasures are of general applicability and are independent of the radionuclide or indeed the type of contaminant involved. However, for many radionuclides, notably some of those that might be encountered in a terrorist incident, the selection of the most appropriate countermeasure may be hampered by a lack of information. The work reported here focuses mainly on countermeasures for radiocaesium and radiostrontium as these radionuclides are of significance in the medium to long-term. The countermeasures are aimed at food production systems, principally to reduce doses from ingestion of contaminated foodstuffs.

## 2 COMPILATION OF INFORMATION

---

### 2.1 Countermeasure selection

A large number of potential countermeasures for use in agricultural and semi-natural ecosystems has been developed since the accident at the Chernobyl Nuclear Power Plant (NPP), Ukraine in 1986. Descriptions of these are well documented in the scientific literature and various compilations of information are available (e.g. IAEA, 1994; Andersson et al., 2000; BMU, 2001). However, not all of these countermeasures were considered appropriate for inclusion in the restoration strategies being developed in the STRATEGY project. Some options were rejected because countermeasure effectiveness has not been conclusively proven (e.g. bioremediation, administration of clay minerals to soil, leaching of soil). Other countermeasures were inappropriate for application in the medium to long term (e.g. administration of stable iodine to livestock). A third category, comprising countermeasures with potential for implementation in the future, was omitted because further experimental work would be required to quantify effectiveness (e.g. administration of alginates to animal feed, selection of different crop variety or species). As a consequence of applying these criteria, 29 countermeasures for use in agricultural areas and semi-natural ecosystems were selected for further study (Table 1). The primary aim of agricultural countermeasures is the reduction of doses due to ingestion of contaminated foodstuffs. However, for the purposes of this study a slightly broader approach has been adopted. One notable example is the inclusion of live monitoring. This provides reassurance that meat containing concentrations of gamma-ray emitting radionuclides above a chosen intervention level is not entering the foodchain. Live monitoring can therefore be used as an adjunct to various other measures to demonstrate that they are being effective. In this study however it has been considered in isolation.

A restriction on the entry of food into the foodchain is commonly referred to as a "food ban", and for this reason the term has been used in places in this report. In addition, this type of restriction has for many years been widely regarded as an individual countermeasure. The decision to impose restrictions is an intervention, but any restriction has to be followed by an action either to reduce activity concentrations below a chosen intervention level and/or to select a suitable waste management strategy. Strictly, it is this subsequent action that is the countermeasure. In the context of these datasheets however there are important issues to consider that are specifically associated with the decision to set an intervention level above which food restrictions will be implemented. For this reason a separate datasheet is also provided for the imposition of restrictions on foodstuffs.

Some options that have been classified as countermeasures might be regarded as waste management options. One example is use of milk or crops considered unfit for human consumption as animal feedstuffs. This type of option reduces

the amount of waste requiring disposal; those that deal only with disposal options are for convenience considered separately (Section 2.2).

## 2.2 Selection of waste disposal options

Considerable volumes of contaminated waste can be generated as a result of implementing countermeasures. The placing of restrictions on the marketing of crops, milk and meat is particularly noteworthy in terms of the volumes of foodstuffs requiring disposal. Similarly, the removal of topsoil from relatively small areas of agricultural land results in several tonnes of contaminated waste that must be disposed of. There are other types of countermeasures that also generate waste, e.g. the production of contaminated by-products such as crop residuals, whey, and brine from the industrial processing of crops, milk and meat. It is only recently that options for the disposal of contaminated food products have been investigated (Woodman and Nisbet, 2000; Wilkins et al., 2001; Shaw et al., 2001; Marchant and Nisbet, 2002; Nisbet et al., 2003). Based on this work, twelve options for the management of rural wastes were selected for inclusion in the STRATEGY compendium of information (Table 2). These range from relatively simple in situ disposal methods (ploughing in, composting and landspreading) to off-site commercial treatment facilities (i.e. landfill and incineration). Few of these options have previously been considered in the context of restoration strategies.

**Table 1 Countermeasures**

Countermeasures	
Administration of AFCF boli to ruminants	Land improvement
Administration of clay minerals to feed	Live monitoring
Application of K fertilisers to arable soils/grassland	Manipulation of slaughter time
Application of lime to arable soils/grassland	Processing of milk for human consumption
Clean feeding	Processing of crops for consumption
Change of hunting season	Restrictions on the entry of food into the foodchain (food bans)
Dilution	Salting of meat for consumption
Decontamination techniques for milk	Selective grazing regime
Distribution of saltlicks containing AFCF	Select edible crop that can be processed
Distribution of concentrates with AFCF	Select alternative land use
Distribution of concentrates with added calcium	Slaughtering dairy cows
Deep ploughing	Shallow ploughing
Early removal of crops	Skim and burial ploughing
Feeding animals with crops/milk containing activity concentrations in excess of intervention levels	Suppression of lactation before slaughter
	Topsoil removal

**Table 2 Waste disposal options**

	Option
Biological treatment (digestion) of crops	Incineration
Biological treatment (digestion) of milk	Landfill
Burning of carcasses	Landspreading of milk and slurry
Burial of carcasses	Ploughing in of standing crops
Composting	Processing and storage of milk for disposal
Disposal of contaminated milk to sea	Rendering

### **2.3 Criteria used to describe countermeasures and waste disposal options**

Until relatively recently, information on countermeasures has largely been based on their effectiveness in terms of cost or reductions in dose or activity concentrations. In designing restoration strategies to ensure long term sustainability of contaminated areas, it is necessary to adopt a more holistic approach based on a range of factors rather than simply the cost effectiveness of individual countermeasures. Recent recommendations from the International Commission on Radiological Protection (ICRP) acknowledge that the costs of countermeasures may be both social and economic, and there may be benefits other than dose reduction (ICRP, 2000).

Evaluations of countermeasures on a much wider basis began in the mid 1990's with studies on overall practicability. Information on factors such as technical feasibility, capacity, direct and indirect costs, environmental impact, radiological impact and stakeholder acceptability was collected and evaluated for a limited range of agricultural countermeasures and rural waste disposal options (e.g. Woodman and Nisbet, 1997; Nisbet and Woodman, 2000). The STRATEGY project has enabled this approach to be taken further by extending the range of options previously considered and by including additional criteria on factors such as social and ethical aspects, environmental considerations and side effects. Furthermore, close liaison with the FARMING stakeholder network (Nisbet et al, 2004) has facilitated the evaluation of countermeasures from stakeholder perspectives in the UK, Finland, Belgium, Greece and France.

### **2.4 The datasheet template**

As the volume of information on individual management options grows, there is a requirement to record data systematically in a standardised format to facilitate comparisons between options. A datasheet template was designed for this purpose, taking into account all of the criteria that decision-makers might wish to consider when evaluating different countermeasures. These include:

- a a short description of the option

---

b	its key attributes
c	constraints
d	effectiveness
e	feasibility
f	waste generated
g	additional doses incurred as a result of implementing the option
h	costs
i	side effects
j	stakeholder opinion
k	practical experience

A brief explanation of all the criteria included in the datasheet template is given in Table 3. Datasheets were produced for all of the countermeasures and waste disposal options listed in Tables 1 and 2 using literature sources, new information (on ethics), bespoke calculations (for additional doses) and stakeholder feedback (based on the UK node of the FARMING network). A brief description of the methodologies involved in generating new information or data for inclusion in the datasheets (i.e. when not directly gathered from the literature) is given in Section 2.4.1 below.

The completed datasheets were circulated for internal comment by project participants and sent to international experts and end-users for peer review (Appendix A). Final amendments were made to the datasheets to take into account relevant feedback. For some criteria (legal, social and communication constraints, ethical considerations, averted dose, cost-effectiveness and additional doses) the inclusion of more detailed guidance has subsequently been made possible by adopting a CDROM format with hyperlinks to underlying documents (CDROM STRATEGY, 2003).

### **2.4.1 Criteria requiring new information**

#### *2.4.1.1 Ethics of countermeasures*

Four ethical criteria relevant to the evaluation of countermeasures were identified. These were to answer the following questions:

- (i) Is the distribution of cost and benefits equitable? The imposition of a countermeasure should result in a reduction in the collective dose received by all of the people affected. However, while the individual doses received by consumers of foodstuffs would be decreased, additional doses could be incurred by those implementing the countermeasure or by those living or spending time around a waste disposal facility.
- (ii) Are the risks imposed or voluntary? Voluntary countermeasures (e.g. self-help measures for farmers) that are carried out by affected individuals, or that increase personal understanding or control over the situation, respect fundamental ethical values of autonomy, liberty and dignity. Imposed countermeasures (e.g. radical changes in farming practice) are highly disruptive and infringe upon liberty.

- (iii) Have stakeholders been involved in the decision-making process? The need for informed consent, as well as political human rights and the principles of autonomy, equality and democracy, stress the need to include affected parties in decision-making. Stakeholder participation also recognises an important public dimension in societal policy-making and can enhance public acceptability of decisions.
- (iv) Does the countermeasure carry a risk of serious environmental damage? Countermeasures that change or interfere with ecosystems may have uncertain or unpredictable consequences for the environment. Environmental risk raises a variety of ethical concerns including consequences for future generations, sustainability and the balancing of harm to the environment or animals against benefits to humans.

Information on ethical criteria is included in the datasheets as a subsection of 'Side effects' (Table 3).

#### *2.4.1.2 Additional doses*

The implementation of most types of countermeasures will lead to additional doses to those implementing them, as well as to those affected by the management of any waste produced. The additional dose is an incremental dose that specifically excludes doses resulting from (i) contamination already present in the environment and (ii) operations that would be carried out whether or not the countermeasure was implemented. The magnitude of the additional dose could influence decisions on whether a countermeasure or waste disposal option should be implemented. It can be compared with a dose criterion, the numerical value of which would be decided by the appropriate authorities after an accident, depending on the specific circumstances. The procedures involved in implementing a countermeasure or waste disposal option are given in the 'Additional dose' section of the datasheet. This section also provides information on all of the major relevant pathways for (a) operatives (external irradiation, inhalation of resuspended material and inadvertent ingestion of contaminated material) and (b) members of the public (ingestion of foodstuffs grown on land to which contaminated waste products has been applied). Information on additional doses to operatives from a unit deposit of  $^{131}\text{I}$ ,  $^{134}\text{Cs}$ ,  $^{137}\text{Cs}$  and  $^{89}\text{Sr}$  and  $^{90}\text{Sr}$  on an hourly and yearly basis as well as to the public on an annual basis are given in a separate but complementary report (Hesketh and Harvey, 2004).

#### *2.4.1.3 Stakeholder Opinion*

Stakeholder opinion is important in determining the overall acceptability of a countermeasure and whether it should be implemented. Stakeholder feedback on the STRATEGY compendium of countermeasures was achieved through liaison with the FARMING network (Mercer and Nisbet, 2002) during the meetings of the national groups held in 2002. The network comprises more than 100 individual stakeholders in groups from the UK, Finland, France, Belgium and Greece. Participation is at a senior level and involves individuals involved in making

policy decisions within government departments and agencies, regulatory authorities, the water, milk and farming industries, the retail trade, consumer and green groups. The datasheets given here contain the opinions of the UK stakeholders because this group has been in existence longer than the others and so has had time to reach a consensus on the acceptability of many of the countermeasures. Feedback from other groups is of a more preliminary nature, as discussions with stakeholders are continuing (Nisbet et al, 2004).

**Table 3: Datasheet template**

<b>Name of countermeasure</b>	
<b>Key attributes:</b>	<b>Provides general information about the countermeasure.</b>
Objective	Primary aim of the countermeasure (e.g., reduction of external or internal dose).
Other Benefits	Secondary aims of the action (if any). For instance, the primary objective may be reduction of external dose, whereas an additional benefit may be a limited reduction in internal dose.
Countermeasure description	Short description of how to carry out the countermeasure
Target	Type of object, on/to which the countermeasure is to be applied (e.g. soil, crop, animal).
Targeted radionuclides	Radionuclide(s) that the countermeasure is aimed at.
Scale of application	An indication of whether the countermeasure can be applied on a small or large scale.
Contamination pathway	The step in the contamination pathway at which the countermeasure acts (e.g. soil to plant, plant to animal).
Exposure pathway	The pathway(s) through which people may be exposed as a result of the contamination, prior to implementation of the countermeasure (e.g. inhalation, ingestion, external exposure).
Time of application	Elapsed time period before the countermeasure is applied. Can be short term (days), medium term (weeks-months), or long term (months-years). An indication of the frequency of application is useful (e.g. once only, annually etc.)
<b>Constraints:</b>	<b>Provides information on the various types of restrictions that have to be considered before applying the countermeasure.</b>
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 countermeasure 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.
Communication constraints	The needs for public explanation and dialogue in selection of countermeasures.
<b>Effectiveness:</b>	<b>Provides information on the effectiveness of the countermeasure and factors affecting effectiveness.</b>

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

Countermeasure effectiveness	For countermeasures, effectiveness is a reduction in activity concentration in the target (e.g. crop or animal product or surface in the environment). For food waste disposal options, effectiveness can be expressed as the proportion of contaminated produce that can be removed from the foodchain by any one disposal route.
Factors influencing effectiveness of procedure (Technical)	Technical factors that may, under different circumstances, influence the effectiveness of the method (e.g. climate, soil fertility, fat content of milk, surface material)
Factors influencing effectiveness of procedure (social)	'Social' factors that may, under different circumstances, influence the effectiveness of the method (e.g., whether the method is fully understood by workers, whether there are markets for alternative produce).
<b>Feasibility:</b>	<b>Provides information on all of the equipment required to carry out the countermeasure.</b>
Required specific equipment	Primary equipment for carrying out the countermeasure.
Required ancillary equipment	Secondary equipment that may be required to implement the countermeasure (e.g. monitoring equipment, tankers).
Required utilities and infrastructure	Utilities may be required in connection with implementing the countermeasure (e.g. water and power supplies, distribution networks including roads).
Required consumables	Consumables may be required to implement the countermeasure (e.g. fuel, fertiliser, and sorbents).
Required skills	Skills may be required to implement the countermeasure, necessitating the training of operators.
Required safety precautions	Safety precautions may be necessary before the operative can implement the countermeasure.
Other limitations	Feasibility limitations that are not covered under other headings (e.g. capacity).
<b>Waste:</b>	<b>Some countermeasures create waste, the management of which must be carefully considered at the time the countermeasure is selected.</b>
Amount and type	Nature and volume of waste (e.g. number of livestock carcasses, volume of milk, soil or street dust). Also, indication of whether waste is contaminated and if so to what level compared with the original material.
Possible transport, treatment and storage routes.	Type of vehicle required to transport waste. Requirement to treat waste in situ or at an off site facility. Options for storage if no direct disposal option.
Factors influencing waste issues	Factors that may influence the way that wastes are dealt with (e.g. public acceptability and legal feasibility of the waste treatment /storage route).
<b>Doses:</b>	<b>Provides information on how the countermeasure leads to changes in the distribution of dose to individuals and populations.</b>
Averted dose <sup>a</sup>	Individual and collective doses can be averted by the countermeasure, although this depends on the scenario.
Factors influencing averted dose <sup>a</sup>	Overview of factors other than the countermeasure effectiveness, which may influence the magnitude of the averted dose (e.g. consumption rates, population density and behaviour pattern).
Additional dose	Incremental doses that may be received by individuals in connection with the implementation of the countermeasure (e.g. operators, members of the public). This dose is influenced by procedures (if any) adopted to protect operators. The inclusion of a pathway in the datasheets means that it needs to be considered; it may not be important in particular circumstances.

<b>Intervention Costs:</b>	<b>Provides information on the direct costs that may be incurred from implementing the countermeasure.</b>
Equipment	Cost of the primary equipment.
Consumables	Cost of the consumables.
Operator time	Time required to carry out the countermeasure 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.
Communication costs	Cost of providing public information and dialogue in connection with implementation of the countermeasure.
Compensation costs	Cost of lost production, loss of use.
Waste cost	Cost of managing any waste arisings, including final disposal.
Assumptions	Any other assumptions which might significantly influence the intervention costs.
<b>Cost-effectiveness<sup>a</sup></b>	<b>Provides information on how to calculate cost-effectiveness from the direct monetary costs of reducing a unit collective dose when implementing a countermeasure.</b>
<b>Side-effect evaluation:</b>	<b>Provides information on side-effects incurred following implementation of the countermeasure.</b>
Ethical considerations	Possible positive and/or negative ethical aspects (e.g. promotion of Self-help, requirement for informed consent of workers, distribution of costs and benefits)
Environmental impact	Impact that a countermeasure may have on the environment (e.g., with respect to biodiversity or wildlife reserves, pollution).
Agricultural impact	Impact that a countermeasure may have on the future suitability of land for agricultural use e.g. after reductions in soil fertility.
Social impact	Impact that a countermeasure may have on behaviour and on society's trust in institutions.
Other side effects, pos. or neg.	Some countermeasures may have other side effects, e.g., clean/renew urban surfaces, maintain farmer income, help communities affected by overproduction by encouraging diversification, promotion of self-help, distribution of costs and benefits
<b>UK Stakeholder opinion</b>	<b>Stakeholder opinion from the UK node of the FARMING network.</b>
<b>Practical experience</b>	<b>State-of-the-art experience in carrying out the countermeasure. Some countermeasures have only been tested on a limited scale, whilst others are standard agricultural practices.</b>
<b>Key references</b>	<b>References to key publications leading to other sources of information.</b>
<b>Comments</b>	<b>Any further comments not covered by the above.</b>
<p><sup>a</sup> Due to their site specificity, information on averted dose and cost-effectiveness is only available via a hyperlinked document on the CDROM. This document provides equations for the calculation of averted dose and presents a scenario for illustrative purposes. All reference to averted dose and cost effectiveness has been omitted from the datasheets subsequently presented in this report.</p>	

### 3 COUNTERMEASURES AND OPTIONS FOR WASTE DISPOSAL

Datasheets for the 29 countermeasures selected for inclusion in the STRATEGY compendium of countermeasures are presented in Appendix B. To aid navigation, they have been divided into three broad categories: those that are of general applicability (Table 4), those directed at soils/crops (Table 5) and those that are targeted at animal products (Table 6). Each category is subdivided according to the aim of a particular set of countermeasures. Datasheets for the 12 waste disposal options are presented in Appendix C. To aid navigation, they have been divided into four broad categories: those targeted at all products types, and those aimed specifically at crops, milk or animal carcasses (Table 7).

**Table 4: Countermeasures of general applicability**

Objective	Page No.
<b>Countermeasures that restrict entry of contaminated food into foodchain</b>	
Food bans	16
<b>Countermeasures that take land out of food production</b>	
Select alternative land use	19
<b>Countermeasures that reduce the volume of contaminated produce requiring disposal</b>	
Dilution	22
Feeding animals with crops or milk in excess of Intervention Levels	25

**Table 5: Countermeasures directed at soils/crops**

Objective	Page No.
<b>Countermeasures that remove contamination from the human foodchain</b>	
Topsoil removal	28
Early removal of crops	31
<b>Countermeasures that reduce soil-to-plant transfer of radionuclides by physical or chemical means</b>	
Shallow ploughing	34
Deep ploughing	37
Skim and burial ploughing	40
Application of potassium fertilisers to arable soils and grassland	43
Application of lime to arable soils and grassland	46
Land improvement	49
<b>Countermeasures that reduce the concentration of radionuclides in crops by industrial-scale processing</b>	
Select edible crop that can be processed	52
Processing of crops for subsequent human consumption	55

**Table 6: Countermeasures directed at animal products**

Objective	Page No.
<b>Countermeasures to remove contamination from human foodchain</b>	
Slaughter dairy cows	58
Suppression of lactation before slaughter	61
<b>Countermeasures that reduce ingestion of contaminated feed by livestock by management of their feeding regime</b>	
Clean feeding	64
Selective grazing regime	68
<b>Countermeasures that reduce gut uptake of the radionuclide</b>	
Distribution of concentrates with added calcium	70
Distribution of concentrates with AFCF	73
Administration of clay minerals to feed	76
Distribution of saltlicks containing AFCF	79
Administration of AFCF boli to ruminants	82
<b>Countermeasures that reduce the concentration of radionuclides in animal products by management of slaughtering times</b>	
Manipulation of slaughter times	86
Change of hunting season	90
<b>Countermeasures that reduce the concentration of radionuclides in animal products by industrial-scale processing</b>	
Decontamination techniques for milk	93
Processing of milk for subsequent human consumption	96
Salting of meat for subsequent human consumption	100
<b>Countermeasures that provide reassurance to consumers</b>	
Live monitoring	103

**Table 7: Waste disposal options**

Objective	Page No.
<b>Disposal of all produce</b>	
Incineration	107
Landfill	112
<b>Disposal of crops</b>	
Ploughing in of standing crop	115
Composting	118
Biological treatment of crops	122
<b>Disposal of milk</b>	
Landspreading milk and/or slurry	126
Biological treatment of milk	129
Disposal of contaminated milk to sea	134
Processing and storage of milk products for disposal	137
<b>Disposal of animal carcasses</b>	
Rendering	140
Burning of animal carcasses	143
Burial of animal carcasses	147

## 4 FUTURE DEVELOPMENTS AND APPLICATIONS

---

The datasheets have been well received by national and international bodies and plans are currently being made for their further development. For example, a subset of the datasheets are being populated with UK specific information for use in a Recovery Handbook for Emergency Response to Radiation Incidents being developed by NRPB on behalf of several UK government departments. Internationally, the joint FAO/IAEA division plans to adapt the datasheets of agricultural countermeasures and rural waste disposal options to other climate types. They will also be used to update IAEA guidance in agricultural countermeasures currently given in its Handbook 363 (1994). Furthermore, a new EC Framework 6 initiative (EURANOS – European approach to nuclear and radiological emergency management) will expand the range of radionuclides and types of food production system considered and include additional countermeasures for the early phase. Updated versions of the CDROM, for both food production systems and inhabited areas, are expected by the end of 2005. These revised countermeasures compendia will form the main input to recovery handbooks being developed in collaboration with stakeholders for future use in Europe.

## 5 REFERENCES

---

- Andersson KG, Rantavaara A, Roed J, Rosén K, Salbu B, Skipperud L (2000). A guide to Countermeasures for Implementation in the Event of a Nuclear Accident Affecting Nordic Food-Producing Areas. Nordic Nuclear Safety Research Report no: NKS-16, ISBN: 87-7893-066-9.
- Andersson KG, Roed J, Eged K, Kis Z, Voigt G, Meckbach R, Oughton DH, Hunt J, Lee R, Beresford NA and Sandalls FJ (2003). Physical countermeasures to sustain acceptable living and working conditions in radioactively contaminated residential areas. Risø-R-1396(EN), ISBN 87-550-3190-0, ISSN 0106-2840, 144p, Denmark.
- BMU (German Federal Ministry for Environment, Nature Conservation and Nuclear Safety, 2001). Catalogue of Countermeasures: Compendium of measures to reduce radiation exposure following events with not insignificant radiological consequences. Bonn.
- CD-ROM STRATEGY Countermeasures compendium CD. Available from [www.strategy-ec.org.uk](http://www.strategy-ec.org.uk).
- Eged K, Kis Z, Voigt V, Andersson KG, Roed J and Varga K (2003). Guidelines for planning interventions against external exposure in industrial area after a nuclear accident. Part 1: A holistic approach of countermeasure application. GSF- Bericht 01/03, Germany.
- Hesketh N and Harvey M (2004) Incremental doses to operatives and members of the public following implementation of agricultural countermeasures and rural waste disposal options. NRPB-W (in press).

- Howard BJ, Liland A, Beresford NA, Andersson KG, Cox G, Gil JM, Hunt J, Nisbet AF, Oughton D and Voigt G (2004). A critical evaluation of the STRATEGY project. Proceedings of the International Symposium on 'Off-site Nuclear Emergency Management' held in Salzburg from 29 September- 3 October 2003. *Radiation Protection Dosimetry* (in press).
- International Atomic Energy Agency (1994). Guidelines for agricultural countermeasures following an accidental release of radionuclides. Technical report series 363 (Vienna: IAEA).
- International Commission on Radiological Protection (2000). Protection of the public in situations of prolonged radiation exposure. ICRP Publication 82, Volume 29/1-2 Sutton (UK) ISBN 0-08-043898-9.
- Marchant JK and Nisbet AF (2002). Management options for food production systems affected by a nuclear accident. 6. Landspreading as a waste disposal option for contaminated milk. NRPB-W11.
- Mercer JA and Nisbet AF (2002) Stakeholder involvement in the management of rural areas following a nuclear accident: The FARMING network. Proceedings of the European IRPA Congress 2002. Towards harmonisation of radiation protection in Europe, Florence, Italy (8-11 Oct 2002).
- Nisbet AF and Woodman RFM (2000). Options for the Management of Chernobyl-Restricted Areas in England and Wales. *Journal of Environmental Radioactivity* 51 239-254.
- Nisbet AF, Marchant JK, Woodman RFM, Wilkins BT and Mercer JA (2003). Management options for food production systems affected by a nuclear accident. 7. Biological treatment of contaminated milk. NRPB-W38.
- Nisbet AF, Mercer JA, Rantavaara A, Hanninen R, Vandecasteele C, Hardeman F, Ioannides KG, Tziaila C, Ollagnon H, Pupin V, Jullien T (2004). Variation in stakeholder opinion on countermeasures across Europe. *Journal of Environmental Radioactivity* (accepted).
- Shaw S, Green N, Hammond DJB and Woodman RFM (2001). Management options for food production systems affected by a nuclear accident. 1. Radionuclide behaviour during composting NRPB-R328.
- Wilkins BT, Woodman RFM, Nisbet AF and Mansfield PA (2001). Management options for food production systems affected by a nuclear accident. 5. Disposal of waste milk to sea. NRPB-R323.
- Woodman RFM, Nisbet AF and Penfold JSS (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.
- Woodman RFM and Nisbet AF (2000). Options for managing foodstuffs contaminated with radiocaesium and radiostrontium. *Health Physics* 78(1): 37-45.

---

## 6 ACKNOWLEDGEMENTS

---

The authors would like to gratefully acknowledge the constructive feedback from the peer reviewers and STRATEGY end-users. The work was part funded by the European Commission Fifth Framework Programme (Nuclear Fission, Radiation Protection) under Contract No: FIKR-CT-2000-00018. The information provided is the sole responsibility of the authors and does not reflect the Commission's opinion. Furthermore, the Commission is not responsible for any use that might be made of the data appearing in this report.

## APPENDIX A PEER REVIEWERS AND STRATEGY END USERS

Peer Reviewers (PR) and End Users (EU)	Affiliation
C Attwood (PR)	Environment Agency, UK
J Barikmo (EU)	Directorate for Nature Management, Norway
A Bayer (EU)	Bundesamt fuer Strahlenschutz, Germany
F Brechignac (PR)	Institute for radioprotection and nuclear safety, France
L Brynildsen (EU, PR)	Ministry of Agriculture, Norway
C Forster (PR)	University of Birmingham, UK
J Gilbert (PR)	Composting Association, UK
O Harbitz (EU, PR)	Norwegian Radiation Protection Authority
D Humphreys (PR)	Cumbria Emergency Planning Unit, UK
B Mayes (PR)	Macaulay Land Use Research Institute
J Pearce (PR)	Department of Agriculture & Rural Development, Northern Ireland
D Pollard (PR)	Radiological Protection Institute of Ireland
Radiological Protection and Research Management Division (EU,PR)	Food Standards Agency, UK
A Rantavaara (PR)	Radiation and Nuclear Safety Authority, Finland
M Vidal (PR)	Universitat de Barcelona, Spain
R Arkle (PR)	Cumbria County Council, UK

## **APPENDIX B COUNTERMEASURES FOR AGRICULTURAL AND SEMI-NATURAL ECOSYSTEMS**

- B1 Countermeasures of general applicability**
- B2 Countermeasures applicable to soils/crops**
- B3 Countermeasures applicable to animal products**

**Table B1.1 Food Bans**

<b>Food Bans</b>	
<b>Objective</b>	To remove food that is contaminated above the intervention level from the foodchain.
<b>Other Benefits</b>	Maintenance of confidence in food products.
<b>Countermeasure description</b>	Milk, meat and crops with activity concentrations over the intervention limit may be banned from sale. Condemnation completely removes contaminated food from the market but can leave large quantities of waste needing disposal.
<b>Target</b>	Milk, meat and crops.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large scale.
<b>Contamination pathway</b>	Direct deposit onto a standing crop; soil to plant transfer; plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk, meat and crops.
<b>Time of application</b>	Early to long term.
<b>Constraints:</b>	
<b>Legal constraints</b>	Council Food Intervention Levels (CFILs) will be legally binding for marketed foodstuffs. There will be legal constraints on the fate of the banned foodstuffs.
<b>Social constraints</b>	Extensive banning of milk, meat, crops and their derivative products may lead to market shortages. If the price of 'clean' food increases in response to demand, then poorer populations will find it harder to afford a healthy, varied diet and there is the risk that they will resort to eating cheaper (possibly black market) contaminated food – enforcement then becomes an issue.
<b>Environmental constraints</b>	The fate of banned foodstuffs must be considered when food bans are introduced. Subsequent disposal of banned foodstuffs may cause a major environmental problem.
<b>Communication constraints</b>	Following food bans communication regarding the comparative safety of foodstuffs below intervention levels will be required, but this is likely to provide only partial reassurance. Labelling of foodstuffs with residual levels of contamination may be requested.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	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.
<b>Factors influencing effectiveness of procedure (technical)</b>	None.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability and compliance with countermeasure. There is a potential for a black market in banned produce.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Banning of food must be carried out in conjunction with some form of measurement programme to demonstrate that the restrictions are working, which does require specific equipment depending on the radionuclide involved.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Extensive monitoring and surveillance programme.
<b>Required consumables</b>	None.
<b>Required skills</b>	None, provided enough skilled people are available to carry out the monitoring programme.

<b>Required safety precautions</b>	None.
<b>Other limitations</b>	None.
<b>Waste:</b>	
<b>Amount and type</b>	Milk, meat and crops. Long-term restrictions may also lead to slaughter and disposal of whole livestock carcasses from dairy producing animals.
<b>Possible transport, treatment and storage routes.</b>	Milk may be landspread, processed, biologically treated or disposed of to sea. Livestock carcasses may be disposed of directly by rendering, incineration, burial or burning on open pyres. Alternatively, the carcass may be rendered and the meat and bone meal subsequently buried or incinerated at a later date. Ash would be disposed of to landfill. Crops may be ploughed in, composted, processed, landfilled or incinerated. Waste products may be fed to fur producing animals since transfer to fur is negligible.
<b>Factors influencing waste issues</b>	Area under restrictions and duration of restrictions. Acceptability of, and compliance with, waste disposal practice. Local availability of suitable disposal routes. Legal constraints on the fate of banned foodstuffs.
<b>Doses:</b>	
<b>Additional dose</b>	None, but subsequent management of large quantities of waste crops, animal carcasses and milk will incur an additional dose.
<b>Intervention Costs:</b>	
<b>Equipment</b>	Appropriate monitoring equipment.
<b>Consumables</b>	Fuel for enforcement officers' vehicles.
<b>Operator time</b>	Enforcement officers' time.
<b>Factors influencing costs</b>	Time and distances involved in travelling to areas under restrictions for monitoring purposes.
<b>Communication costs</b>	Possible cost of labelling.
<b>Compensation costs</b>	To farmer for banned products.
<b>Waste cost</b>	Dependent on subsequent disposal route selected for banned foodstuffs and quantities of waste produced.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Negative consequences for farming communities. Knock-on effects to consumers i.e. price increases, shortages. Redistribution of doses from consumers to those involved in disposing of produce including individuals living close to disposal sites. One area may bear the economic brunt of food banning, yet the protection offered to the people there would not compensate for this.
<b>Environmental impact</b>	If land not re-stocked following slaughter of livestock, under-grazing of pasture would cause changes in the ecology of the land.
<b>Agricultural impact</b>	If there are delays in re-stocking land, under-grazing of pasture could be a problem when animals return.
<b>Social impact</b>	Disruption to the supply of milk, meat and crops to food industry and market shortages. Disruption to farming and other related (e.g. food industry) activities. Need to maintain farming and associated communities. Policing the countermeasure and averting growth of a black market. Stigma associated with areas where the countermeasure has been applied. Perceived contamination of all food products (and loss of confidence in crops, dairy, and meat). Potential for generating mistrust of food production

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<b>Social impact (cont.)</b>	systems or conversely, possible increase in public confidence that the problem of contamination is being effectively managed. Negative social and psychological impact of the fact that people's food/food supply is contaminated.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	Generally accepted that there has to be agreed limits above which food is banned. It is important to harmonise these limits between member states. There must be recognition that food bans have associated waste disposal problems.
<b>Practical experience</b>	Condemnation of meat occurred in the FSU and Norway following the Chernobyl accident. In Norway condemned meat has been used as feed for fur animals.
<b>Key references</b>	Tveten, U., Brynildsen, L. I., Amundsen, I and Bergan, T. (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. <i>Journal of Environmental Radioactivity</i> , 41 (3), 233-255.
<b>Comments</b>	Condemnation of meat was found to be the most expensive countermeasure in Norway after the Chernobyl accident. Because intervention limits only apply to commercial production, food bans do not fully protect foodchain. The implementation of other countermeasures must be considered if restrictions expected to continue for a long period.

Table B1.2 Select alternative land use

<b>Select alternative land use</b>	
<b>Objective</b>	To select crops or animals for the production of non-edible products.
<b>Other Benefits</b>	Keeps land in production and provides income to farmer.
<b>Countermeasure description</b>	Contaminated land may be used for non-food production, such as cotton/flax for fibre; rapeseed for bio-diesel; sugar beet for bio-ethanol; perennial grasses or coppice for biofuel. Agricultural land may also be used for the production of leather and wool. In extreme situations land may be used for forestry.
<b>Target</b>	Crops and livestock.
<b>Targeted radionuclides</b>	Radiocaesium, radiostrontium.
<b>Scale of application</b>	Large.
<b>Contamination pathway</b>	Soil to plant transfer, plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated crops, meat or milk.
<b>Time of application</b>	Long-term.
<b>Constraints:</b>	
<b>Legal constraints</b>	External doses from non-edible products to personnel must not exceed limits.
<b>Social constraints</b>	Food must be available from other sources. Acceptability of non-edible products from contaminated land to industry and consumers. Ease of substitution of non-edible crops for farmer and associated industries. Markets for alternative products.
<b>Environmental constraints</b>	The agricultural limitations of the affected land – this will determine the crops and practices that the land can support.
<b>Communication constraints</b>	Farmers/operators require information on choice of crop. Possible requirement for labelling products directly or indirectly affected by application of the countermeasure.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Ingestion pathway is no longer relevant since inedible crops have replaced crops grown for the foodchain. The countermeasure is therefore 100% effective.
<b>Factors influencing effectiveness of procedure (technical)</b>	Expertise in growing alternative crops and supporting different livestock.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of alternative crops or livestock to farmers. Acceptability to processors and public of using contaminated crops/animal products to make non-food products.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Sowing/harvesting equipment for alternative crop type.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Processing facilities for chosen crop/animal product.
<b>Required consumables</b>	Fuel, seed stock of alternative crop (availability may be limited), stock of alternative livestock, feed.
<b>Required skills</b>	Expertise in cultivation of alternative crop/livestock.
<b>Required safety precautions</b>	Consider respiratory protection for farmers if very dry conditions.
<b>Other limitations</b>	There must be a market for the new products.

<b>Waste:</b>	
<b>Amount and type</b>	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.
<b>Possible transport, treatment and storage routes.</b>	On-site treatment plants or sewage treatment works for processing by-products.
<b>Factors influencing waste issues</b>	Alternative crop chosen and processing required
<b>Doses:</b>	
<b>Additional dose</b> <i>(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 biological treatment of crops, incineration and landfill.))</i>	Depends on non-food crop selected and production process. Pathways could include: Driver: <ul style="list-style-type: none"> <li>• External exposure while transporting crops or livestock for processing</li> <li>• <i>External exposure while transporting waste by-products to disposal site</i></li> </ul> Processing plant operative: <ul style="list-style-type: none"> <li>• External exposure to non-food crop at processing plant (depending on degree of automation)</li> </ul> Operative at wood burning power plants (from coppice) <ul style="list-style-type: none"> <li>• External exposure to the fly-ash</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Sowing/harvesting equipment for alternative crop type may not be available on farm and have to be hired.
<b>Consumables</b>	Seed, fuel, livestock.
<b>Operator time</b>	Sowing/harvesting of alternative crop. Looking after new livestock type. Transportation of crop or livestock to processing plant.
<b>Factors influencing costs</b>	Crop type, livestock type, new equipment required, training.
<b>Communication costs</b>	Dissemination of information to farmers about replacing food crops with non-food crop/livestock. Labelling of alternative products may be required.
<b>Compensation costs</b>	To farmer for changes in land use on the farm, including requirements for additional manpower, training and equipment. To processing plants for accepting contaminated produce. Possible decontamination of equipment.
<b>Waste cost</b>	Depends on by-products.
<b>Assumptions</b>	That there is a market for the new products. Monitoring of non-food products.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Redistribution of dose from consumers to those involved in producing and using alternative crop and animal products.
<b>Environmental impact</b>	Change in ecosystem.
<b>Agricultural impact</b>	Change in crop type, fertiliser requirements, nutrient cycling.
<b>Social impact</b>	Maintenance of farming and associated communities. Disruption to people's image/perception of 'countryside' e.g. where traditional crops are changed, with potential impacts on tourism etc. Possible loss of confidence in products.

<b>Social impact (cont.)</b>	Disruption/adjustment of farming and related industrial activities. Change may affect sense of well being in the affected population.
<b>Other side effects, pos. or neg.</b>	Markets may be limited for alternative crop/animal products. Maintains income to the farmer. In communities affected by overproduction, diversification may be advantageous.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Existing commercial processes.
<b>Key references</b>	Alexakhin, R. M., Frissel, M. J., Shulte, E. H., Prister, B. S., Vetrov, V. A. and Wilkins, B. T. (1993). Change in land use and crop selection The Science of the Total Environment, 137, 169-172.  Vandenhove, H. (1999). Relevancy of short rotation coppice vegetation for the remediation of contaminated areas. Project F14-CT95-0021c (PL 960 386). Co-funded by the Nuclear Fission Safety Programme of the European Commission. RECOVER Final report 99, BLG 826. SCK.CEN, Mol, Belgium.
<b>Comments</b>	This countermeasure assumes that land has been cleared of previous land use where necessary. For example, crops will have already been ploughed in, composted or sent for disposal. Meat-producing livestock will have been moved from contaminated land.

**Table B1.3 Dilution**

<b>Dilution</b>	
<b>Objective</b>	To provide foodstuffs with activity concentrations less than the intervention level.
<b>Other Benefits</b>	Reduces amount of food requiring disposal.
<b>Countermeasure description</b>	Contaminated produce may be mixed with uncontaminated produce in the appropriate proportions until the overall activity concentration in the bulk foodstuff is less than the intervention level.
<b>Target</b>	Grain and milk.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small to medium.
<b>Contamination pathway</b>	Soil to plant transfer or plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated grain or milk.
<b>Time of application</b>	Early to medium term.
<b>Constraints:</b>	
<b>Legal constraints</b>	The sale of grain and milk intended for human consumption is subject to Council Food Intervention Levels (CFILs).
<b>Social constraints</b>	Resistance to allowing contaminated milk/grain into dairies/mills because retailers and consumers would not have the confidence that plants could be put back to normal operation after treatment has taken place, without the risk of contaminating milk and milk/grain products. Reluctance by hauliers to transport contaminated produce. Foodstuffs with activity concentrations that have been brought below the relevant CFIL by dilution are unlikely to be acceptable to the retail trade when foodstuffs can be obtained from other sources. The principle of informed consent suggests that such foodstuffs should have their origins labelled, and consumers are likely to prefer 'clean' foodstuffs.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Probable requirement for labelling products that have undergone dilution.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Can be highly effective in reducing volumes of milk requiring disposal.
<b>Factors influencing effectiveness of procedure (technical)</b>	Relative activity concentrations in contaminated and uncontaminated produce. Relative quantities of contaminated and uncontaminated produce. Extent to which supplies of either contaminated or uncontaminated produce are homogeneous.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability and compliance/resistance to the countermeasure by all stakeholders.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	None.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Dairy or mill.
<b>Required consumables</b>	Uncontaminated produce.
<b>Required skills</b>	The operators at the dairy and mill would have the necessary skills to carry out the dilution. Monitoring would be carried out by trained personnel.
<b>Required safety precautions</b>	Consider respiratory protection for operators at mill, if not standard practice.

<b>Other limitations</b>	Availability of produce that is either clean or contains concentrations of radionuclides below the chosen intervention levels.
<b>Waste</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes.</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	<p>Driver:</p> <ul style="list-style-type: none"> <li>External exposure while transporting contaminated grain and milk to dairy/mill</li> </ul> <p>Operative at dairy/mill:</p> <ul style="list-style-type: none"> <li>External exposure to contaminated milk at milk processing plant</li> <li>External exposure to contaminated grain at flourmill</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	None.
<b>Consumables</b>	Uncontaminated milk and grain from outside the affected area.
<b>Operator time</b>	Operators at dairy or mill if additional labour is required.
<b>Factors influencing costs</b>	None.
<b>Communication costs</b>	Probable cost of labelling. Possible advertising campaign highlighting environmental concerns/animal welfare issues if this countermeasure is rejected in favour of disposal or slaughtering options.
<b>Compensation costs</b>	To dairy or mill for accepting contaminated produce. Possible decontamination of equipment.
<b>Waste cost</b>	None.
<b>Assumptions</b>	Monitoring programme to ensure diluted products are less than CFILs.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	If prices are lowered in response to reduced demand, there is an inequitable distribution of the residual contamination to poorer populations, and the possibility of their incurring a higher dose than that received by typical members of the population. Loss of profit to producers if the treated food is not accepted by consumers. "Dilute and Disperse" has a negative reputation in environmental ethics. The practice could be perceived as actively causing contamination of previously non-contaminated foodstuffs. Liability and responsibility for negative side-effect consequences will have to be addressed.
<b>Environmental impact</b>	None.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Potential for generating widespread mistrust of food production systems. Potential for dispute regarding selection of produce for dilution. Possible rejection of the final product, decrease in market price.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	There is consensus that it would be unacceptable to knowingly contaminate the foodchain. It would reduce consumer confidence.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<b>Practical experience</b>	Dilution was used in Valdres, Norway where Chernobyl deposition was around 100 kBq/m <sup>2</sup> . Some milk tankers collecting milk from this area were redirected to other dairies further away. In return, tankers from clean areas were sent to Valdres to dilute local supplies and so avoid the bulk milk exceeding the intervention limit. The redirection of milk tankers was a locally based decision that was not widely publicised.
<b>Key references</b>	Woodman, R. F. M., Nisbet, A. F. and Penfold, J. S. S. (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295
<b>Comments</b>	This countermeasure would have limited applicability in that it would be most likely to be adopted when clean supplies were limited. However, under such circumstances the amount of milk available as a diluent would also be limited.

Table B1.4 Feeding animals with crops/milk in excess of Intervention Levels

<b>Feeding animals with crops/milk in excess of Intervention Levels</b>	
<b>Objective</b>	To minimise volumes of contaminated crops and milk requiring disposal.
<b>Other Benefits</b>	Offsets the loss in cash value of the contaminated crop/milk by making use of it as animal feed. Can reduce requirements for animal feed on the farm.
<b>Countermeasure description</b>	In general, only a fraction of the activity present in a feed is transferred to the meat or milk of an animal consuming that feed. Foodstuffs with activity concentrations exceeding the CFIL could therefore be fed to animals while still subsequently producing meat or milk acceptable for human consumption. Cereals make an important contribution to the typical daily ration of pigs, poultry, dairy and beef cattle. Cereals grown for human consumption could therefore be fed to animals. Immature cereal crops (grain plus haulm) with the grain at the 'milk' stage, have a higher feeding value for ruminants than that from a mature crops (grain plus straw). Immature cereal crops can be fed directly or ensiled. Furthermore, contaminated land could be specifically used to grow other crops for the purpose of animal feeding. Crops as well as milk could also be used for feeding to animals that are not the last link in the human food chain e.g. replacement heifers, dry cows, suckler beef cows, breeding ewes and gimmers, breeding gilts and pregnant sows, adult cashmere goats and males kept for breeding purposes (bulls, rams, boars and billy goats). There is also the potential of feeding these materials to horses of all types and to animals used in fur production.
<b>Target</b>	Crops and milk.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small scale. Restricted to mixed farming systems where crops or milk produced on the farm can be fed to livestock on the same farm. The transportation of contaminated crops to other farms, particularly outside an affected area is likely to be unacceptable.
<b>Contamination pathway</b>	Soil to plant transfer; plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk and crops.
<b>Time of application</b>	Early to medium term. Most suitable at times of year when livestock are housed.
<b>Constraints:</b>	
<b>Legal constraints</b>	Marketed animal feedstuffs are subject to Maximum Permitted Levels (MPLs) set by the EC (CEC, 1990). These are only available for radiocaesium.
<b>Social constraints</b>	Acceptability of method with respect to animal welfare issues (if diet less palatable). Acceptability to food industry/consumers of residual levels of contamination in animal products after applying this countermeasure.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	High likelihood of media scare stories. Possible requirement for labelling products directly or indirectly affected by application of the countermeasure.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Most effective if fed to animals not producing milk or not immediately destined for the foodchain, in which case effectiveness is 100%.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Factors influencing effectiveness of procedure (technical)</b>	Activity concentration of radionuclide in crop/milk (see Nisbet et al, 1998). Number of animals on the farm compared to the amount of crop production. Availability of pigs/veal for consumption of milk.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability to farmers, food industry and consumers of feeding contaminated produce to animals destined for foodchain. Acceptability of and compliance with countermeasure. Acceptability of selection process for areas where this countermeasure is applied.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Equipment to convert crop into suitable form to be used as animal feed. Stock proof fencing if cereal or vegetable crops are grazed in the field in summer.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Storage facilities may be required for contaminated crops prior to feeding. Water, power supply and ventilation if animals are housed.
<b>Required consumables</b>	Additional concentrates or supplements may be required to nutritionally balance the diets.
<b>Required skills</b>	Farmers would possess necessary skills but would need guidance on feeding alternative diets.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	Milk can only be incorporated into the diets of pigs and veal, although with modern ration mixing equipment it may be possible to mix milk with a dry cereal to produce a high quality concentrate feed. Crops will deteriorate in storage unless processed. Some crops can only be included in small amounts in order to maintain nutritional balance and palatability of diets. Other crops such as onions, garlic and herbs cannot be used as they will taint milk and meat. Changes in dietary composition are often introduced gradually over a 1-2 week period to minimise welfare issues.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes.</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer while ensiling: <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and inhalation while ensiling harvested crops</li> </ul> Farmer while feeding animals: <ul style="list-style-type: none"> <li>External exposure from silage while feeding animals</li> <li>Inadvertent ingestion of silage while feeding animals</li> <li>Hand skin exposure to silage while feeding animals</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Equipment for producing animal feed. Fencing.
<b>Consumables</b>	Additional concentrates/supplements.
<b>Operator time</b>	Extra work by farmer e.g. processing crop to suitable form for feeding to livestock; overseeing implementation of the alternative feeding regime; erecting fencing.
<b>Factors influencing costs</b>	Availability of alternative housing. Need to modify housing. Requirement for concentrate supplements to make nutritionally balanced diets. Manpower. Social concerns.

<b>Communication costs</b>	Potential need to facilitate widespread debate regarding ethics and practice of this countermeasure. Possible cost of labelling milk and meat products from regions where the countermeasure is applied.
<b>Compensation costs</b>	To farmer for loss of value of crop grown originally for human consumption, for additional work, especially if crops need processing before feeding to animals, for loss of income from not adhering to conservation schemes.
<b>Waste cost</b>	None.
<b>Assumptions</b>	That there is a market for products from animals fed contaminated crops/milk.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Whether this countermeasure increases dose from animal products that would otherwise be less contaminated.
<b>Environmental impact</b>	None.
<b>Agricultural impact</b>	Reduced grazing on fields.
<b>Social impact</b>	Maintenance of farming and related communities. Some disruption of farming practice although this can be minimised if contaminated crops are made into silage and stored and fed over a lengthy period. Disruption to supply of crops to food industry. Potential for generating mistrust in food production. Stigma associated with areas, and particularly animal products from areas, where the countermeasure has been applied.
<b>Other side effects, pos. or neg.</b>	Reduction in cost of buying in animal feed.
<b>UK Stakeholder opinion</b>	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 food-chain. However, there was consensus that any crop/milk over the intervention limit must be destroyed to prevent subsequent unauthorised entry into the foodchain.
<b>Practical experience</b>	Many farmers have experience of formulating balanced animal rations from a wide range of feedstuffs.
<b>Key references</b>	Brown, J., Wilkins, B. T. and Nisbet, A. F. (2002). Management options for food production systems affected by a nuclear accident: Diversion of crops grown for human consumption to animal feed. NRPB-W18 Nisbet, A. F., Woodman, R. F. M., Brown, J., Smith, J. G. and Wilkins, B. T. (1998). Derivation of working levels for animal feedstuffs for use in the event of a future nuclear accident. NRPB-R299. CEC. Council Regulation (Euratom) No. 770/90 laying down maximum permitted levels of radioactive contamination of feedingstuffs following a nuclear accident or any other case of radiological emergency. Off. J. Eur. Commun., L83/78 (1990)
<b>Comments</b>	With modern silage-making methods it is possible to ensile any vegetable crop, including not only cereals, but also brassicas, legumes and root crops (whole or tops). Such silage can be stored for a number of years; this would allow long-term planning of livestock feeding practices. It would also allow shorter-lived radionuclides time to decay to less hazardous levels.

**Table B2.1 Topsoil removal**

<b>Topsoil removal</b>	
<b>Objective</b>	To reduce radionuclide uptake by crops, including pasture.
<b>Other Benefits</b>	Reduction in external dose from contaminated land.
<b>Countermeasure description</b>	If no crop is present, the top 2-5 cm is removed using road construction equipment such as a bobcat or mini-bulldozer. In this way, much of the contamination is removed. When the amount of waste is taken into consideration is only applicable on a small scale.
<b>Target</b>	Pasture or uncultivated arable land.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Achievable in large scale where equipment is available but when the amount of waste is taken into consideration is only applicable on a small scale.
<b>Contamination pathway</b>	Soil to plant transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated food products. External exposure from land.
<b>Time of application</b>	Early to long term. Should be carried out as soon as possible, but significant reductions are still possible in the medium to long term for relatively immobile radionuclides such as caesium. There is a tendency for the more mobile radionuclides such as strontium to move down the soil profile with time.
<b>Constraints:</b>	
<b>Legal constraints</b>	Cultural heritage protection, especially in conservation areas or equivalent.
<b>Social constraints</b>	Acceptability of topsoil removal with associated removal of flora and fauna e.g. this raises wildlife issues that are likely to be contested. Aesthetic consequences of amenity/landscape changes. Acceptability of waste disposal options.
<b>Environmental constraints</b>	Soils that are shallow and stoney cannot always be treated. It can be difficult to use large machinery on wet peaty soils. On heavy clay soils, decontamination may be limited to times of the year when the soil is workable. Sandy structureless soils cannot be removed effectively as a thin layer. Large negative consequences for the environment.
<b>Communication constraints</b>	Need for dialogue regarding selection of areas for treatment.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	90-97% (factor of >20) of the activity is removed.
<b>Factors influencing effectiveness of procedure (technical)</b>	Optimisation of thickness of removed layer. Vertical radionuclide distribution. Soil texture. Presence of vertical cracks in the soil. Operator skill ensuring contamination is not ploughed into clean surface during removal. Time (for downward migration).
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of the implementation of the countermeasure to farmers and the public. Compliance/resistance to the countermeasure.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Bobcat mini bulldozer or bulldozer.
<b>Required ancillary equipment</b>	Vehicle to transport waste.
<b>Required utilities and infrastructure</b>	Roads to transport waste.
<b>Required consumables</b>	Fuel.

<b>Required skills</b>	Can be carried out by already skilled operators such as municipal workers and additional operators could be instructed within a day. Possible need for radiation protection training of workers.
<b>Required safety precautions</b>	Consider respiratory protection if very dry/dusty conditions.
<b>Other limitations</b>	Dose limits for workers.
<b>Waste:</b>	
<b>Amount and type</b>	If 5 cm of topsoil is removed, 70 kg m <sup>-2</sup> of waste would be produced. Contamination will be around 20 Bq m <sup>-3</sup> per Bq m <sup>-2</sup> .
<b>Possible transport, treatment and storage routes.</b>	Disposal to landfill sites or purpose built repositories.
<b>Factors influencing waste issues</b>	Contamination level of waste. Volume of waste. Acceptability of waste disposal options. Location of disposal site especially if outside affected area.
<b>Doses:</b>	
<b>Additional dose</b> <i>(There is a separate datasheet for landfill as a waste disposal option for the soil.)</i>	Operative removing soil: <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and inhalation while removing soil surface</li> </ul> Driver: <ul style="list-style-type: none"> <li>External exposure while transporting soil to landfill</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Bobcat or bulldozer shared between a number of farms. Vehicle to transport waste.
<b>Consumables</b>	Fuel for bobcat (ca 40 l ha <sup>-1</sup> ) and transporter.
<b>Operator time</b>	Typically some 50-100 h ha <sup>-1</sup> , including loading to waste transport truck, but excluding waste transport and work at repository.
<b>Factors influencing costs</b>	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.
<b>Communication costs</b>	Dialogue regarding selection of areas considered suitable for application of this countermeasure. Provision of information to operators on objectives of procedure.
<b>Compensation costs</b>	To farmer for loss of grazing areas and re-establishment of vegetation. Labour costs may be higher to compensate operators for exposure to radiation.
<b>Waste cost</b>	Transport to landfill site and subsequent landfill costs (including landfill tax). Siting and building of purpose-built repository.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Potential redistribution of dose to workers. Free informed consent of workers. Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Disruption to farming and other related activities (e.g. tourism). Stigma associated with areas and perceived contamination of food products (crops, dairy, meat) where the countermeasure has been applied. Appropriate selection of priority areas for application of the countermeasure. Environmental consequences of waste generation. Inequity due to redistribution of dose to populations living close to waste disposal areas.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<b>Environmental impact</b>	Risk of soil erosion. Soil biota affected. Loss of biodiversity. Changes in landscape. Large volumes of waste generated.
<b>Agricultural impact</b>	Soil fertility may be affected by the loss of top 5cm of soil. Fertilisation may be required. The underlying soil may be compacted with implications for subsequent cultivation. Vegetation needs to be re-established.
<b>Social impact</b>	Acceptability and potential for dispute regarding waste disposal sites.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	Unlikely to be an option considered in the UK, except for very localised contamination because of the volumes of waste generated.
<b>Practical experience</b>	Used in FSU as a countermeasure following the Chernobyl accident. It was also used on a small scale after the Goiania, Palomares and Mayak accidents.
<b>Key references</b>	<p>Andersson, K. G. (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, 93 p.</p> <p>Andersson, K. G. and Roed, J. (1999). A Nordic Preparedness Guide for Early Clean-up in Radioactively Contaminated Residential Areas. J. Environmental Radioactivity, 46 (2), 207-223.</p> <p>Fogh, C. L., Andersson, K. G., Barkovsky, A. N., Mishine, A. S., Ponomarjov, A. V., Ramzaev, V. P. and Roed, J. (1999). Decontamination in a Russian Settlement. Health Physics, 76 (4), 421-430.</p> <p>Roed, J., Andersson, K. G., Barkovsky, A. N., Fogh, C. L., Mishine, A. S., Olsen, S. K., Ponomarjov, A. V., Prip, H., Ramzaev, V. P. and Vorobiev, B. F. (1998). Mechanical decontamination tests in areas affected by the Chernobyl Accident. Risø-R-1029, ISBN 87-550-2361-4, 101 p.</p> <p>Vovk, I. F., Blagoyev, V. V., Lyashenko, A. N. and Kovalev, I. S. (1993). Technical approaches to decontamination of terrestrial environments in the CIS (former USSR). The Science of the Total Environment, 137, 49-63.</p>
<b>Comments</b>	Countermeasure limited by requirement for waste disposal facilities.

Table B2.2 Early removal of crops

<b>Early removal of crops</b>	
<b>Objective</b>	To reduce contamination of arable land and its products.
<b>Other Benefits</b>	Reduction of external dose from land.
<b>Countermeasure description</b>	Radionuclides may be retained on the surface of growing crops immediately after fallout. The transfer of this contamination to the soil may be minimised by removing such crops from the land as soon as possible after deposition and ideally before the first rainfall. The crops require disposal.
<b>Target</b>	Dense/leafy crops.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large.
<b>Contamination pathway</b>	Direct deposition to plant surface (atmosphere to plant transfer).
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated crops. External irradiation from arable land.
<b>Time of application</b>	Early phase - as soon as possible.
<b>Constraints:</b>	
<b>Legal constraints</b>	There will be legal constraints on the disposal of harvested crops.
<b>Social constraints</b>	The removal/disposal of crops may lead to market shortages. Acceptability of subsequent 'disposal' options for harvested crops, especially if transported to uncontaminated areas.
<b>Environmental constraints</b>	The fate of harvested crops must be considered before countermeasure is introduced. Subsequent disposal may cause a major environmental problem. There will be environmental constraints if crops are composted, sent to landfill or incinerated.
<b>Communication constraints</b>	Need for dialogue regarding selection of areas for treatment.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Reduction of external dose on contaminated fields may be up to 95% (factor of 20), although 50-70% (factors of 2-4) is more likely. Greatest effectiveness is before first rainfall. Experiments (Vandecasteele et al, 2001) have shown that the first simulated rain, applied 6 days after contamination, removed around 50% of the intercepted radiocaesium and around 20% of radiostrontium from aerial parts of spring wheat.
<b>Factors influencing effectiveness of procedure (technical)</b>	Interception of radionuclide aerosols is dependent on the amount of biomass present at the time of deposition. A dense crop can intercept 25-50% of wet deposition and more if deposited as an aerosol. Occurrence of rainfall. Weather conditions. Time between deposition and harvest of the crops – in general the half-time of loss of contamination on undisturbed vegetation is 2-4 weeks.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability to farmers. Acceptability of disposal options to other stakeholders.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Forage or combine harvester.
<b>Required ancillary equipment</b>	Tractor.
<b>Required utilities and infrastructure</b>	Collection and transportation of crops once harvested. Storage and disposal facilities.
<b>Required consumables</b>	Fuel.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Required skills</b>	Farmers and agricultural workers would have the required skills, but must be instructed carefully about the objectives.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions.
<b>Other limitations</b>	Dose limits for farmers/agricultural workers.
<b>Waste:</b>	
<b>Amount and type</b>	Contaminated crops: the amount will depend on stage of development. The countermeasure will be most effective when the crops are near maturity (i.e. dense and leafy).
<b>Possible transport, treatment and storage routes</b>	Crops may be composted <i>in situ</i> or at commercial facilities or disposed of to landfill or incinerated. Alternatively, crops may be processed into a form suitable for storage and subsequent disposal. It is also possible but unlikely that crops would be processed into products for subsequent consumption.
<b>Factors influencing waste issues</b>	Legal constraints on the fate of contaminated crops, level of contamination of crops, storage characteristics of crops, volume of waste, acceptability of subsequent waste disposal option.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Additional doses will be incurred from the disposal of harvested crops either via composting, landfill, incineration or biological treatment. There are separate datasheets for these waste disposal options.)</i>	Farmer harvesting crops: <ul style="list-style-type: none"> <li>• External exposure, inadvertent ingestion and inhalation while harvesting crops</li> </ul> Driver: <ul style="list-style-type: none"> <li>• External exposure while transporting harvested crops to place of disposal</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Minimal. Forage or combine harvesters should be readily available on the farm or could be shared.
<b>Consumables</b>	Fuel (ca 15 l ha <sup>-1</sup> )
<b>Operator time</b>	Normal time to harvest crop. Additional time depending on subsequent management of harvested crop. Transportation of crop.
<b>Factors influencing costs</b>	Time and distance involved in transporting crop to processing or disposal site.
<b>Communication costs</b>	Dialogue regarding selection of areas considered suitable for application of this countermeasure.
<b>Compensation costs</b>	To farmer for loss of income from crop. Labour costs may be higher to compensate operators for exposure to radiation. To farmer if crop is composted <i>in situ</i> .
<b>Waste cost</b>	Dependent on subsequent disposal route selected for harvested crops and quantities of waste produced.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Appropriate selection of priority areas for countermeasure. Redistribution of dose from consumers to farmers implementing the countermeasure, to those involved with disposal of produce including populations living close to disposal sites. Free informed consent of workers. Potential for self-help for farmers. Environmental consequences of waste generation.
<b>Environmental impact</b>	Dependent on subsequent disposal route chosen for harvested crops.
<b>Agricultural impact</b>	Harvesting of crops at or close to maturity is a normal agricultural practice – no additional impact.

<b>Social impact</b>	Disruption to farming activities. Disruption to the supply of crops to food industry and possible market shortages. Potential for dispute regarding the selection of areas for disposal.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Lettuce was removed (and ploughed in) in Norway after the Chernobyl accident to avoid human consumption.
<b>Key references</b>	Vandecasteele, C.M., Baker, S., Forstel, H., Muzinsky, M., Millan, R., Madoz-Escande, C., Tormos, J., Sauras, T., Schulte, E., Colle, C. (2001). Interception, retention and translocation under greenhouse conditions of radiocaesium and radiostrontium from a simulated accident source. <i>The Science of the Total Environment</i> . Vol. 278 p119-214.
<b>Comments</b>	Only applicable to leafy crops nearing maturity.

**Table B2.3 Shallow ploughing**

<b>Shallow ploughing</b>	
<b>Objective</b>	To reduce radionuclide uptake by crops, including pasture.
<b>Other Benefits</b>	Reduction in external dose from contaminated land.
<b>Countermeasure description</b>	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.
<b>Target</b>	Pasture or arable land.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large scale application where ploughing is possible. Such areas could be identified using geographical information systems (GIS) and information on soil type and altitude.
<b>Contamination pathway</b>	Soil to plant transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated food products. External exposure from land.
<b>Time of application</b>	Early to long-term, preferably as early as possible – for arable crops this would be prior to sowing new crop.
<b>Constraints:</b>	
<b>Legal constraints</b>	Ploughing may be restricted under some environmental protection schemes.
<b>Social constraints</b>	Acceptability of making contamination less retrievable. Potential resistance where ploughing is not standard practice. Aesthetic consequences of any subsequent landscape/amenity changes.
<b>Environmental constraints</b>	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 stoney soils cannot be ploughed. Use of machinery difficult on land with slopes > 16°. Whilst steep slopes and shallow soils cannot be ploughed these are unlikely to be found within areas of arable land.
<b>Communication constraints</b>	Farmers/operators require information on this countermeasure (i) for areas of land not normally ploughed; (ii) when ploughing is to be undertaken at non-standard times of the year.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	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).
<b>Factors influencing effectiveness of procedure (technical)</b>	Soil type and conditions. Rooting depths of different crops. Radionuclide distribution within soil profile.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability if it is a divergence from standard farming procedure. Compliance/resistance to the countermeasure from the public.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Plough.
<b>Required ancillary equipment</b>	Tractor.
<b>Required utilities and infrastructure</b>	None.
<b>Required consumables</b>	Fuel.

<b>Required skills</b>	Farmers/agricultural workers will possess the necessary skills, but must be instructed carefully about the objective.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions.
<b>Other limitations</b>	Very high groundwater table. Dose limits for farmers/agricultural workers.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer: <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and inhalation while ploughing</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Tractor and single furrow plough are already available.
<b>Consumables</b>	Fuel (ca 7 l ha <sup>-1</sup> ).
<b>Operator time</b>	One operator per plough : 1.2 h ha <sup>-1</sup> .
<b>Factors influencing costs</b>	Work rates vary depending on soil type and conditions, field size and shape, topography and operator experience.
<b>Communication costs</b>	Provision of information to operators on correct application of procedure.
<b>Compensation costs</b>	To farmer for ploughing land not normally ploughed, for loss of income from non-adherence to conservation schemes. Labour costs may be higher to compensate operators for exposure to radiation.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side effect evaluation:</b>	
<b>Ethical considerations</b>	<i>In situ</i> treatment of contaminated soil. Self-help for farmer. Free informed consent and compensation for operators. Ethical considerations increase if ploughing diverges from common practice. Potential redistribution of dose to farmers & agricultural workers.
<b>Environmental impact</b>	The procedure brings contamination closer to the groundwater. No further environmental impact on land normally ploughed. If soil has undergone conservation tillage for > 5 years ploughing dilutes organic matter, reduces earthworm populations and microbial biomass. Changes in landscape.
<b>Agricultural impact</b>	Fertilisation may be required. Pasture land will require reseeded.
<b>Social impact</b>	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. Stigma associated with food products where the countermeasure has been applied. Disruption to farming and other related activities (e.g. tourism). Contamination of the soil may restrict subsequent uses. Appropriate selection of priority areas for application of the countermeasure.
<b>Other side effects, pos. or neg.</b>	Could improve some soils that have been infrequently managed and have become compacted. Severely complicates subsequent removal of the contamination.

<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Normal agricultural practice. Tested widely in FSU following the Chernobyl accident. Tested on a limited scale in Denmark.
<b>Key references</b>	Maubert, H., Vovk, I., Roed, J., Arapis, G. and Jouve, A. (1993). Reduction of soil-plant transfer factors:mechanical aspects. <i>The Science of the Total Environment</i> , 137, 163-167. Vovk, I. F., Blagoyev, V. V., Lyashenko, A. N. and Kovalev, I. S. (1993). Technical approaches to decontamination of terrestrial environments in the CIS. <i>The Science of the Total Environment</i> , 137, 49-63.
<b>Comments</b>	Ploughing is more effective when carried out in conjunction with fertiliser and lime application. Potassium and calcium reduce uptake of radiocaesium and radiostrontium.

Table B2.4 Deep ploughing

<b>Deep ploughing</b>	
<b>Objective</b>	To reduce radionuclide uptake by crops, including pasture.
<b>Other Benefits</b>	Reduction in external doses from contaminated land.
<b>Countermeasure description</b>	If no crop is present an ordinary single-furrow mouldboard plough can be used to invert the top 45cm of the soil profile. Much of the contamination at the surface will be buried deep in the vertical profile, which (i) will reduce radionuclide uptake by plant roots depending on their specific rooting behaviour; and (ii) reduce external exposure from the contaminants.
<b>Target</b>	Pasture or uncultivated arable land.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	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.
<b>Contamination pathway</b>	Soil to plant transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated food products. External exposure from land.
<b>Time of application</b>	Early to long term, provided no crop present. Ideally should be carried out as early as possible. However, timing of application is not so critical for radiocaesium.
<b>Constraints:</b>	
<b>Legal constraints</b>	Ploughing may be restricted under some environmental schemes.
<b>Social constraints</b>	Acceptability of topsoil burial with associated removal of flora and fauna e.g. this raises wildlife issues that are likely to be contested. Acceptability of making contamination less retrievable when long-term mobility of radionuclides is not known. Potential resistance where ploughing is not standard practice due to change in landuse. Acceptability of changes to landscapes and of other environmental effects, to relevant populations.
<b>Environmental constraints</b>	Sandy soils are friable and may crumble during ploughing and inversion may be incomplete. Soils which are excessively wet, dry or frozen cannot be ploughed without damaging soil structure. Soil profiles must be > 0.5 m deep. Use of machinery difficult on land with > 16° slope. Excessively stoney soils cannot be ploughed.
<b>Communication constraints</b>	Farmers/operators require information on this countermeasure (i) for areas of land not normally ploughed; (ii) when ploughing is to be undertaken at non-standard times of the year. Need for dialogue regarding selection of areas for treatment. Need dialogue between farmers, ecologists and public because of potential for groundwater contamination.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	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.
<b>Factors influencing effectiveness of procedure (technical)</b>	Efficiency of inversion of upper layer. Radionuclide distribution within soil profile after inversion. Rooting depths of different crops.
<b>Factors influencing effectiveness of procedure (social)</b>	Depends on usual practice on the farm and the potential for ecosystem change/damage. Acceptability of the implementation of the countermeasure to farmers and the public. Compliance/resistance to the countermeasure.

<b>Feasibility:</b>	
<b>Required specific equipment</b>	Plough (with minimum furrow width of 0.75 m).
<b>Required ancillary equipment</b>	Tractor (Deep ploughing requires powerful tractors e.g. 76-90 kW).
<b>Required utilities and infrastructure</b>	None.
<b>Required consumables</b>	Fuel.
<b>Required skills</b>	Farmers/agricultural workers are likely to possess the necessary skills but must be instructed carefully about the objectives.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions.
<b>Other limitations</b>	High ground water level. Dose limits for farmers/agricultural workers.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer: <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and inhalation while ploughing</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Tractor (76-90 kW) may not be available on farm and will need to be hired. Single furrow plough should be available
<b>Consumables</b>	Fuel (ca. 15 l ha <sup>-1</sup> ).
<b>Operator time</b>	One operator per plough: 0.2 man-days ha <sup>-1</sup> , i.e. 1.5 h ha <sup>-1</sup>
<b>Factors influencing costs</b>	Work rates vary depending on soil type and conditions, field size and shape, topography and operator experience.
<b>Communication costs</b>	Dialogue regarding selection of areas considered suitable for application of this countermeasure. Provision of information to operators on correct application of procedure.
<b>Compensation costs</b>	To farmer for carrying out deep ploughing. To farmer for loss of income for non-adherence to conservation schemes. Labour costs may be higher to compensate operators for exposure to radiation.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	<i>In situ</i> treatment of contaminated soil. Self-help for farmer. Free informed consent and compensation for operators. Ethical considerations increase if ploughing diverges from common practice. Potential redistribution of dose to farmers & agricultural workers. Environmental risk i.e. groundwater contamination can transfer radionuclides to other areas and affect other populations.
<b>Environmental impact</b>	The procedure brings contamination closer to the groundwater. Changes in physical characteristics of the surface horizon. Enhanced mineralisation of organic matter. Soil erosion. Biodiversity could be affected, particularly for soil dwelling organisms. Future restriction on land use: must not be deep tilled. Changes in landscape.

<b>Agricultural impact</b>	Soil fertility markedly reduced – fertilisation may be required. Change of nutrient loading. Field drainage systems destroyed.
<b>Social impact</b>	Change of ecosystem, potential environmental risks. 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. Stigma associated with food products where the countermeasure has been applied. Disruption to farming and other related activities (e.g. tourism). Contamination of soil at depth may restrict subsequent uses. Appropriate selection of priority areas for application of this countermeasure.
<b>Other side effects, pos. or neg.</b>	Subsequent normal ploughing (to ca. 25 cm) will not bring much contamination back to the surface. Radionuclides may enter ground water. Severely complicates subsequent removal of the contamination. Long-term loss of soil fertility/structure.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Used widely in FSU as a countermeasure following the Chernobyl accident. Tested on a limited scale in Denmark.
<b>Key references</b>	Maubert, H., Vovk, I., Roed, J., Arapis, G. and Jouve, A. (1993). Reduction of soil-plant transfer factors: mechanical aspects. <i>The Science of the Total Environment</i> , 137, 163-167. Vovk, I. F., Blagoyev, V. V., Lyashenko, A. N. and Kovalev, I. S. (1993). Technical approaches to decontamination of terrestrial environments in the CIS (former USSR). <i>The Science of the Total Environment</i> , 137, 49-63.
<b>Comments</b>	Deep ploughing should not be carried out again otherwise effectiveness of this countermeasure would be markedly reduced.

**Table B2.5 Skim and burial ploughing**

<b>Skim and burial ploughing</b>	
<b>Objective</b>	To reduce radionuclide uptake by crops, including pasture.
<b>Other Benefits</b>	Reduction in external doses from contaminated land.
<b>Countermeasure description</b>	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.5-50 cm) is lifted by the other ploughshare and placed at the top without inverting the 5-45 cm horizon. Direct exposure and root uptake from the contaminants are reduced and effect on soil fertility minimised.
<b>Target</b>	Pasture or uncultivated arable soil.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	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.
<b>Contamination pathway</b>	Soil to plant transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated food products. External exposure from land.
<b>Time of application</b>	Ideally should be carried out as early as possible. In practice it is more likely to be carried out in the medium – longer term because only a limited number of these specialist ploughs are available. Timing of application is not so critical for radiocaesium, but for other radionuclide-soil type combinations, efficiency reduces with time due to movement down the soil profile.
<b>Constraints</b>	
<b>Legal constraints</b>	Skim and burial ploughing would not be permitted under various agri-environmental agreements.
<b>Social constraints</b>	Acceptability of topsoil burial with associated removal of flora and fauna e.g. this raises wildlife issues that are likely to be contested. Acceptability of making contamination less retrievable when long-term mobility of radionuclides is not known. Potential resistance where ploughing is not standard practice due to change in land use. Acceptability of changes to landscapes and of other environmental effects, to relevant populations.
<b>Environmental constraints</b>	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° slope. Excessively stony soils cannot be ploughed.
<b>Communication constraints</b>	Effective communication with farmers regarding correct way to carry out skim and burial ploughing. Farmers/operators also require information on this countermeasure (i) for areas of land not normally ploughed; (ii) when ploughing is to be undertaken at non-standard times of the year. Need for dialogue regarding selection of areas for treatment. Need dialogue between farmers, ecologists and public because of potential for groundwater contamination.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Reduction of contamination by about 83-92%, if optimised according to contaminant distribution in the soil. Reduction in soil-to-plant transfer by a 90% (factor of 10). Reduction in external dose of around 94%.

<b>Factors influencing effectiveness of procedure (technical)</b>	Efficiency of inversion of upper layer. Radionuclide distribution within soil profile after inversion. Fertility of new top soil. Rooting depths of different crops.
<b>Factors influencing effectiveness of procedure (social)</b>	Willingness and ability of farmers to adapt to a new procedure. Efficient use of equipment and conduct of procedures. Potential for ecosystem change/damage. Compliance/resistance to the countermeasure.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Skim and burial plough (limited availability)
<b>Required ancillary equipment</b>	Tractor (Skim and burial ploughing requires powerful tractors e.g. 90 kW which are not necessarily widely available).
<b>Required utilities and infrastructure</b>	Road network for transporting plough.
<b>Required consumables</b>	Fuel.
<b>Required skills</b>	Can be carried out by farmers or agricultural contractors who are familiar with ploughing, but additional instruction will be required to meet objectives.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions.
<b>Other limitations</b>	Shallow soils. High groundwater table. Dose limits for farmers/agricultural workers.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer: <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and inhalation while ploughing</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Skim and burial plough shared between a number of farms. Tractor (min. 90 kW) shared between a number of farms.
<b>Consumables</b>	Fuel (ca. 15 l ha <sup>-1</sup> ).
<b>Operator time</b>	One operator per plough: 0.4 man-days ha <sup>-1</sup> , i.e. (3 h ha <sup>-1</sup> ).
<b>Factors influencing costs</b>	Work rates vary depending on soil type and conditions, field size and shape, topography and operator experience. Number of skim and burial ploughs available.
<b>Communication costs</b>	Dialogue regarding selection of areas considered suitable for application of this countermeasure. Provision of information to operators on correct application of procedure.
<b>Compensation costs</b>	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.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	<i>In situ</i> treatment of contaminated soil. Self-help for farmer. Free informed consent and compensation for operators.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Ethical considerations (cont.)</b>	Ethical considerations increase if ploughing diverges from common practice. Potential redistribution of dose to farmers & agricultural workers. Environmental risk i.e. groundwater contamination can transfer radionuclides to other areas and affect other populations.
<b>Environmental impact</b>	The procedure brings contamination closer to the groundwater. Changes in physical characteristics of the surface horizon. Enhanced mineralisation of organic matter. Soil erosion. Biodiversity could be affected, particularly for soil dwelling organisms. Future restriction on land use: must not be deep tilled. Changes in landscape.
<b>Agricultural impact</b>	Soil fertility may be affected by the inversion of the top 5cm of soil. Fertilisation may therefore be required. Field drainage systems destroyed.
<b>Social impact</b>	Change of ecosystem, potential environmental risks. 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. Stigma associated with food products where the countermeasure has been applied. Disruption to farming and other related activities (e.g. tourism). Contamination of soil at depth may restrict subsequent uses. Appropriate selection of priority areas for application of this countermeasure.
<b>Other side effects, pos. or neg.</b>	Subsequent ordinary ploughing (to ca. 25 cm) will not redistribute contaminants.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Used in FSU as a countermeasure following the Chernobyl accident but on a fairly limited scale. Also tested in Denmark on a small scale (typically 1000-2000 m <sup>2</sup> areas).
<b>Key references</b>	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, K. G. and Prip, H. (1996). The Skim and Burial Plough: A new implement for reclamation of radioactively contaminated land. Journal of Environmental Radioactivity, 33 (2), 117-128.
<b>Comments</b>	The method severely complicates contaminant removal.

Table B2.6 Application of potassium fertilisers to arable soils and grassland

<b>Application of potassium fertilisers to arable soils and grassland</b>	
<b>Objective</b>	To reduce plant uptake of radiocaesium by addition of potassium fertilisers to the soil.
<b>Other Benefits</b>	Improvement in soil fertility in some soils. Also potential increase in crop yield.
<b>Countermeasure description</b>	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. Potassium is mixed in soil by harrowing or ploughing. It can also be applied as a top dressing to grassland.
<b>Target</b>	Arable soils and grassland.
<b>Targeted radionuclides</b>	Radiocaesium.
<b>Scale of application</b>	Large. Areas can be identified using Geographical Information Systems (GIS) from readily available soil characteristic information.
<b>Contamination pathway</b>	Soil to plant transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated food products
<b>Time of application</b>	Early to long term.
<b>Constraints:</b>	
<b>Legal constraints</b>	Restrictions on farms with organic status. Amounts may also be limited on farms that have entered into some environmental protection schemes.
<b>Social constraints</b>	If fertilisation is part of normal practice, social constraints are unlikely. However, if the area is perceived to be 'natural' pasture land or if it is for example, a tourist area, there may be resistance to a change in the ecosystem. Willingness of farmer to change farming practice.
<b>Environmental constraints</b>	Potassium fertilisers are normally ploughed into the soil before the planting/sowing of arable crops. It may not be possible to plough or harrow soils that are excessively wet, dry or frozen without damaging soil structure. Slope/stoniness of some grassland may make it unsuitable for a tractor and spreader.
<b>Communication constraints</b>	Need for dialogue regarding selection of areas for treatment. Need for dialogue between land owners/farmers, ecologists and public if recommended for areas not normally receiving potassium fertilisers.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Potassium is most effective when exchangeable potassium status is less than 0.5 meq/100g soil. Under these conditions reduction factors of up to 5 (~80%) have been reported in the literature based on field experiments. Repeated applications of potassium may be necessary to maintain low transfer of radiocaesium. Specific effectiveness factors for soils of different potassium status are available in Woodman and Nisbet (1999).
<b>Factors influencing effectiveness of procedure (technical)</b>	Potassium status of the soil/soil solution.
<b>Factors influencing effectiveness of procedure (social)</b>	Depends on usual practice on the farm and the potential for ecosystem change/damage. The countermeasure may be less acceptable to farmers and the public if land is not intensively farmed.

<b>Feasibility:</b>	
<b>Required specific equipment</b>	Tractor with spreading device.
<b>Required ancillary equipment</b>	Plough or harrow.
<b>Required utilities and infrastructure</b>	Fertiliser production facilities/distribution network.
<b>Required consumables</b>	Fuel, fertiliser.
<b>Required skills</b>	Farmers would possess the necessary skills, as this is an existing practice.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions.
<b>Other limitations</b>	None.
<b>Waste:</b>	
<b>Amount and type</b>	None – assuming applied when no standing crop, or grassland receives a top-dressing.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer: <ul style="list-style-type: none"> <li>• External exposure while spreading fertiliser</li> <li>• External exposure, inadvertent ingestion and inhalation while ploughing</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Ideally 55-67 kW tractor with broadcast spreader (However, lower power tractor may be sufficient). Plough or harrow. All equipment should be available.
<b>Consumables</b>	Fuel (ca. 5 l ha <sup>-1</sup> ). Fertiliser as K <sub>2</sub> O or KCl (100-200 kg K ha <sup>-1</sup> ), although larger applications have been made to great effect under specific scenarios previously.
<b>Operator time</b>	1 operator ca. 0.3 hr ha <sup>-1</sup> (excluding transport and loading of potassium).
<b>Factors influencing costs</b>	Repeated application may be required.
<b>Communication costs</b>	Dialogue regarding selection of areas considered suitable for application of this countermeasure. Provision of information to operators on appropriate application rates. Possible cost of labelling products.
<b>Compensation costs (cont.)</b>	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.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	<i>In situ</i> treatment of contaminated soil. Self-help for farmer. If not standard practice, potassium applications can be seen as risky in terms of ecological impact and change in amenity. Potential redistribution of dose to farmers/ agricultural workers.

<b>Environmental impact</b>	Minimal on intensively managed arable soil as potassium fertilisers are routinely applied at the rates proposed. Changes in species composition of grassland not usually receiving potassium fertiliser – possible changes in landscape and biodiversity. Grasslands are often the habitat of endangered species and a change in nutrient status may be harmful for these species. Changes in bioavailability and mobility of nutrients and pollutants may lead to effects on water quality.
<b>Agricultural impact</b>	Assuming that this countermeasure 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.
<b>Social impact</b>	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. Stigma associated with food products where the countermeasure has been applied. Potassium fertilisation may restrict subsequent use of the land (e.g. organic farming). Appropriate selection of priority areas for application of the countermeasure.
<b>Other side effects, pos. or neg.</b>	Possible improvement of soil fertility.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Routinely applied in agriculture to optimise crop yields. Used widely in conjunction with other fertilisers and lime in FSU following Chernobyl accident.
<b>Key references</b>	Nisbet, A. F., Konoplev, A. V., Shaw, G., Lembrechts, J. F., Merckx, R., Smolders, E., Vandecasteele, C. M., 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. <i>The Science of the Total Environment</i> , 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. <i>Environmental Science and Technology</i> , 31(12), 3432-3438.  Woodman, R. F. M and Nisbet, A. F. (1999). Deep ploughing, potassium and lime applications to arable land. Chilton, NRPB-M1072.
<b>Comments</b>	Potassium would normally be applied in conjunction with nitrogen (not ammonium) and phosphorus-based fertilisers. Mg-fertilisation and liming may be required to maintain optimal ionic equilibrium in soil and plant. Little experience on unimproved pastures.

**Table B2.7 Application of lime to arable soils and grassland**

<b>Application of lime to arable soils and grassland</b>	
<b>Objective</b>	To reduce plant uptake of radiostrontium by addition of lime to the soil.
<b>Other Benefits</b>	Improvement in soil fertility in some soils. Also potential increase in crop yields.
<b>Countermeasure description</b>	Lime may be applied to soils of low pH or low Ca status to reduce plant uptake 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.
<b>Target</b>	Arable soils and grassland.
<b>Targeted radionuclides</b>	Radiostrontium.
<b>Scale of application</b>	Large. Areas can be identified using Geographical Information Systems (GIS) from readily available soil characteristic information.
<b>Contamination pathway</b>	Soil to plant transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated food products.
<b>Time of application</b>	Early to long-term.
<b>Constraints:</b>	
<b>Legal constraints</b>	Restrictions on farms with organic status. Amounts may also be limited on farms that have entered into some environmental protection schemes.
<b>Social constraints</b>	If fertilisation is part of normal practice, social constraints are unlikely. However, if the area is perceived to be 'natural' pasture land or if it is for example, a tourist area, there may be resistance to a change in the ecosystem. Willingness of farmer to change farming practice.
<b>Environmental constraints</b>	Lime is normally ploughed into the soil before the planting/sowing of arable crops. It may not be possible to plough or harrow soils that are excessively wet, dry or frozen without damaging soil structure. Slope/stoniness of some grassland may make it unsuitable for a tractor and spreader. Application may need to be restricted near watercourses and on flood plains – GIS could identify such areas. Difficult to apply in windy conditions.
<b>Communication constraints</b>	Need for dialogue regarding selection of areas for treatment. Need for dialogue between land owners/farmers, ecologists and public if recommended for areas not normally receiving lime.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Liming from pH 5 to pH 7 may decrease plant uptake of <sup>90</sup> Sr by 50% (factor of 2) on sandy soils, 67% (factor of 3) on loamy soils and 75% (factor of 4) on clay soils, from pH 4 to pH 6 by 83% (factor of 6) on organic soils. Liming in excess of pH 7/6 has no effect. Corrective liming lasts for at least 5 years. Maintenance liming every 5 years, to pH 7 on mineral soils and to pH 6 on organic soils, is recommended (0.5-2 tonnes CaO ha <sup>-1</sup> ).
<b>Factors influencing effectiveness of procedure (technical)</b>	Soil type and pH, cation exchange capacity, calcium status of soil. Type of lime applied (e.g. CaCO <sub>3</sub> can be more effective at changing soil pH). Whether rainfall follows lime application.
<b>Factors influencing effectiveness of procedure (social)</b>	Depends on usual practice on the farm and the potential for ecosystem change/damage. The countermeasure may be less acceptable to farmers and the public if land is not already intensively farmed.

<b>Feasibility:</b>	
<b>Required specific equipment</b>	Tractor with spreading device.
<b>Required ancillary equipment</b>	Plough or harrow.
<b>Required utilities and infrastructure</b>	Lime production facilities/distribution network.
<b>Required consumables</b>	Fuel, lime (CaO or CaCO <sub>3</sub> ).
<b>Required skills</b>	Farmers would possess the necessary skills, as this is an existing practice.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions.
<b>Other limitations</b>	None.
<b>Waste:</b>	
<b>Amount and type</b>	None – assuming applied when no standing crop, or grassland receives a top-dressing.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer: <ul style="list-style-type: none"> <li>• External exposure while spreading potassium lime</li> <li>• External exposure, inadvertent ingestion and inhalation while ploughing</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Ideally 55-67 kW tractor with broadcast spreader (However, lower power tractor may be sufficient). Plough or harrow. All equipment should be available.
<b>Consumables</b>	Fuel (ca. 5 l ha <sup>-1</sup> ), lime (1 - 8 tonnes CaO per ha).
<b>Operator time</b>	1 operator ca. 0.25 hr ha <sup>-1</sup> (excluding loading and transport of lime).
<b>Factors influencing costs</b>	Repeated application may be required.
<b>Communication costs</b>	Dialogue regarding selection of areas considered suitable for application of this countermeasure. Provision of information to operators on appropriate application rates. Possible cost of labelling products.
<b>Compensation costs</b>	To farmer for applying lime when not part of normal practice and for loss of income for non-compliance to environmental protection schemes.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	<i>In situ</i> treatment of contaminated soil. Self-help for farmer. If not standard practice, lime applications can be seen as risky in terms of ecological impact and change in amenity. Potential redistribution of dose to farmers/agricultural workers.
<b>Environmental impact</b>	Minimal on intensively managed arable soils as lime is routinely applied at the rates proposed. Can change nutrient status and thus plant and animal diversity – possible changes in landscape and biodiversity. 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.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<b>Agricultural impact</b>	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.
<b>Social impact</b>	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. Stigma associated with food products where the countermeasure has been applied. Liming may restrict subsequent use of the land (e.g. organic farming). Appropriate selection of priority areas for application of this countermeasure.
<b>Other side effects, pos. or neg.</b>	Possible improvement of soil fertility.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Standard agricultural practice. Used widely in conjunction with NPK fertilisers in FSU following Chernobyl accident.
<b>Key references</b>	Nisbet, A. F., Konoplev, A. V., Shaw, G., Lembrechts, J. F., Merckx, R., Smolders, E., Vandecasteele, C. M., 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. <i>The Science of the Total Environment</i> , 137, 173-182.  Woodman, R. F. M. and Nisbet, A. F. (1999). Deep ploughing, potassium and lime applications to arable land. Chilton, NRPB-M1072.
<b>Comments</b>	K- and Mg-fertilisation may be required to maintain optimal ionic equilibrium in soil and plant.

Table B2.8 Land Improvement

<b>Land Improvement</b>	
<b>Objective</b>	To reduce activity concentrations of radionuclides in animals grazing unimproved pasture.
<b>Other Benefits</b>	Reduction in external dose from contaminated land.
<b>Countermeasure description</b>	Improvement of poorer quality pasture reduces uptake of radiocaesium and radiostrontium. Improvement involves ploughing, rolling, reseeding and the application of NPK fertilisers and lime. Application of a broad spectrum herbicide prior to ploughing is recommended to destroy the existing vegetation. In some cases, drainage may be required. If only small areas are improved, fencing may also be necessary to prevent livestock grazing unimproved land.
<b>Target</b>	Unimproved pasture.
<b>Targeted radionuclides</b>	Radiocaesium and radiostrontium.
<b>Scale of application</b>	Medium scale. Improvement of pasture should be possible on farms where suitable land is available. This land could be identified using a Geographical Information System (GIS).
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated animal products.
<b>Time of application</b>	Improvement can commence in the short to medium term and continued in the longer term.
<b>Constraints:</b>	
<b>Legal constraints</b>	Unimproved pastures may be within environmentally protected areas. Some practices (e.g. NPK, herbicides) might be unsuitable for use on farms with organic status.
<b>Social constraints</b>	If the area is perceived to be 'natural' there may be resistance to change the ecosystem and landscape. Willingness of farmer to change farming practice.
<b>Environmental constraints</b>	Areas of pasture with steep slopes and shallow or stoney soils mean that some areas cannot be ploughed or drained. At certain times of the year the ground is too wet for ploughing. Physical characteristics that determine if a soil can be cultivated are: Slope < 12° cultivation possible Slope 12-16° some limitations Slope > 16° unsuitable for cultivation Depth < 0.3m unsuitable for cultivation Depth 0.3-0.5 shallow ploughing only Depth > 0.5m skim and burial/deep ploughing possible.
<b>Communication constraints</b>	Need for dialogue regarding selection of areas for treatment, between land owners/ farmers, ecologists and public.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	This countermeasure was used extensively in the FSU after Chernobyl and is referred to as radical improvement. Several studies have shown that reduction factors for soil-plant transfer of radiocaesium following radical improvement, liming and fertilisation were in the range:

<b>Countermeasure effectiveness (cont.)</b>	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%), but only in the second year after treatment.
<b>Factors influencing effectiveness of procedure (technical)</b>	Soil type, nutrient status and pH. Plant species selected for reseeding. Application rates of NPK and lime.
<b>Factors influencing effectiveness of procedure (social)</b>	Willingness and ability of farmers to adapt to a new land management regime – they may be unhappy with the adjustments they have to make.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Tractor, plough, fertiliser spreader, seeder, roller.
<b>Required ancillary equipment</b>	Fencing and drainage equipment (e.g. digger) may be required.
<b>Required utilities and infrastructure</b>	Fertiliser/lime production facilities. Access to road network in remote areas. Spare land on the farm to graze livestock while improvements are carried out.
<b>Required consumables</b>	Fuel, NPK fertilisers, lime, grass seed, herbicide (e.g. Glyphosate). May also require consumables associated with fencing and drainage operations.
<b>Required skills</b>	Agricultural workers/farmers would possess the necessary skills as these are existing practices but must be instructed carefully about the objectives.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions.
<b>Other limitations</b>	None.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes.</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer: <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and inhalation while ploughing</li> <li>External exposure while rolling, reseeding, fertilising</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Tractor, mouldboard plough, sprayer, roller, fertiliser spreader, seeder and digger.
<b>Consumables</b>	26 kg ha <sup>-1</sup> grass seed, 70 kg ha <sup>-1</sup> N fertiliser, 80 kg ha <sup>-1</sup> P fertiliser, 80 kg ha <sup>-1</sup> K fertiliser, 7.5 t ha <sup>-1</sup> lime, 6 l ha <sup>-1</sup> herbicide (e.g. Glyphosate), 7 l ha <sup>-1</sup> fuel. Improvement of pastures is typically maintained on a rolling programme with NPK applied annually, lime every 5 years and land re-improved after 10 years.
<b>Operator time</b>	1.6 h ha <sup>-1</sup> ploughing, 1.3 h ha <sup>-1</sup> rolling, 0.7 h ha <sup>-1</sup> broadcasting seed, 0.4 h ha <sup>-1</sup> broadcasting fertiliser. Installing fences. Carrying out drainage.
<b>Factors influencing costs</b>	Work rates vary depending on soil type and conditions, topography and operator experience. Requirements for drainage and fencing.
<b>Communication costs</b>	Dialogue regarding selection of areas considered suitable for application of this countermeasure.

<b>Compensation costs</b>	To farmer if additional forage is required whilst improvements are being carried out. To farmer for loss of income for non-adherence to conservation schemes. To farmer for loss of organic status if improvements carried out. Labour costs may be higher to compensate operators for exposure to radiation.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	All infrastructure listed in feasibility is available.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	<i>In situ</i> treatment of contaminated soil. Self-help for farmer, although dependent on resources. Potential redistribution of dose from consumers to farmers/agricultural workers. Knock-on effects for public use of amenity. Potentially high environmental risk from change of ecosystem.
<b>Environmental impact</b>	Ploughing, application of herbicides and fertilisers and reseeded would change the ecology of the land and biodiversity would be lost. 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. Ploughing may lead to soil erosion. Contamination will be moved closer to the water table possibly resulting in enhanced contamination of ground water.
<b>Agricultural impact</b>	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.
<b>Social impact</b>	Disruption to farming and other related activities. 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. Fertilisation and liming may restrict subsequent use of the land (e.g. organic farming).
<b>Other side effects, pos. or neg.</b>	Availability of improved grazing can reduce wintering costs and result in higher prices for improved stock.
<b>UK Stakeholder opinion</b>	Limited applicability in the uplands due to terrain. Unacceptable to environmentalists if carried out on a large scale due to loss of biodiversity.
<b>Practical experience</b>	Radical improvement carried out in Former Soviet Union after the Chernobyl accident.
<b>Key references</b>	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 <sup>137</sup> Cs and <sup>90</sup> Sr uptake by grasses in natural meadows: the REDUP project. <i>Journal of Environmental Radioactivity</i> 56: 139-156.  Nisbet, A. F. and Woodman, R. F. M. (1999). Options for the Management of Chernobyl-restricted areas in England and Wales. NRPB-R305.  Wilkins, B. T., Nisbet, A. F., Paul, M., Ivanov, Y., Perepelyatnikova, L., Perepelyatnikova, G., Fesenko, S., Sanzharova, N., Spiridinov, S., Lisyanski, B., Bouzdalkin, C. and Firsakova, S. (1996). Comparison of data on agricultural countermeasures at four farms in the former Soviet Union. NRPB-R285.
<b>Comments</b>	NPK application rates traditionally used on agricultural lands may not be sufficient to maximise decrease in radiocaesium transfer to re-seeded pastures.

**Table B2.9 Select edible crop that can be processed**

<b>Select edible crop that can be processed</b>	
<b>Objective</b>	To select crops suitable for processing such that the final edible product has activity concentrations less than intervention levels.
<b>Other Benefits</b>	Keeps land in production and provides income to farmer.
<b>Countermeasure description</b>	Processing removes activity from the final food product. Sugar and oil-producing crops, for example, may be substituted for crops that do not undergo processing.
<b>Target</b>	Crop.
<b>Targeted radionuclides</b>	Radiocaesium, radiostrontium.
<b>Scale of application</b>	Small to medium.
<b>Contamination pathway</b>	Soil to plant transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated crops.
<b>Time of application</b>	Medium to long term.
<b>Constraints:</b>	
<b>Legal constraints</b>	The sale of products intended for human consumption are subject to Council Food Intervention Levels (CFILs).
<b>Social constraints</b>	Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade when foodstuffs can be obtained from other sources. The principle of informed consent suggests that such foodstuffs should have their origins labelled, and consumers are likely to prefer 'clean' foodstuffs. If prices are lowered in response to reduced demand, there is an inequitable distribution of the residual contamination to poorer populations, and the possibility of their incurring a higher dose than that received by typical members of the population. Ease of substitution of new crop for the farmer and associated industries. Farmer resistance and disruption to farming practice. Markets for alternative products.
<b>Environmental constraints</b>	The soil type/climate may limit which crops can grow.
<b>Communication constraints</b>	Farmers require information on the choice of crop. Possible requirement for labelling products.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	<p>Processing can be very effective at removing radionuclides from the final product (e.g. sugar, oil).</p> <p>The change in radionuclide content of a foodstuff due to processing may be assessed by calculating the food processing retention factor. This indicates the fraction of the radionuclide which remains in the food following processing and is shown by the equation below:</p> $\text{Processing retention factor} = \frac{\text{Total activity of the radionuclide in the processed food (Bq)}}{\text{Total activity of the radionuclide in the raw material (Bq)}}$ <p>Olive when pressed into a cake: the retention factor for Cs in the cake is 0.4.</p> <p>Olive when pressed to produce oil: the retention factor for Cs in the oil is 0.1.</p>

<b>Factors influencing effectiveness of procedure (technical)</b>	Crop type. Soil-to-plant transfer factor of crop. Processing selected.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of processing contaminated crops for consumption to the food industry/retailers and consumers. There must be a market for the end products.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Sowing/harvesting equipment for alternative crop type (may not be available on farm). Processing equipment.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Waste treatment facilities for disposal of contaminated by-products.
<b>Required consumables</b>	Fuel, seed stock of alternative crop (availability may be limited), processing consumables.
<b>Required skills</b>	Expertise in cultivation of alternative crop.
<b>Required safety precautions</b>	Consider respiratory protection for operators at processing plant.
<b>Other limitations</b>	Availability of processing plants if there is a reluctance to move contaminated raw materials to a plant located outside an affected area. Capacity of processing plants to accept additional raw materials (i.e. crops). Markets for the products could be limited.
<b>Waste:</b>	
<b>Amount and type</b>	Depends on crop selected. Waste includes food processing residuals i.e. materials remaining after processing of primary products, such as peel and foliage.
<b>Possible transport, treatment and storage routes</b>	Solid residuals such as peel, sugar beet tops etc may be converted to useful by-products depending of the type of residual. Alternatively, these and other by-products could be treated at the processing site, incinerated or disposed of to landfill.
<b>Factors influencing waste issues</b>	Depends on crop type and type of processing selected. The high moisture content and readily putrescible nature of the food residuals means that waste treatment cannot be delayed.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Dose pathways in italics are indirectly incurred as a result of transportation of waste by products. Additional doses will be incurred from disposal of these wastes either at landfill sites or incinerators. There are separate datasheets for waste disposal options. Any waste water generated during processing may be sent to a Sewage Treatment Works (STW): the relevant dose pathways for this disposal route are given on Table C2: Landfill.)</i>	Driver: <ul style="list-style-type: none"> <li>External exposure while transporting crops to processing plant</li> <li><i>External exposure while transporting waste by-products to place of disposal</i></li> </ul> Operative at food processing plant: <ul style="list-style-type: none"> <li>External exposure at processing plant (depending on degree of automation)</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Sowing/harvesting equipment for alternative crop type (may have to be hired). Processing equipment. Appropriate monitoring equipment.
<b>Consumables</b>	Seed, fuel and additional processing consumables.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Operator time</b>	Farmer for sowing and cultivation of alternative crop. Drivers for transporting contaminated crop to processing factories. Operators at processing plant if additional manpower required.
<b>Factors influencing costs</b>	Distance to processing plant, quantities of crops for processing.
<b>Communication costs</b>	Information for farmers regarding crop substitution and husbandry. Possible cost of labelling.
<b>Compensation costs</b>	To farmers if they receive a reduction in income because new crops have lower value. To processing plants for handling contaminated produce. Possible decontamination of processing equipment.
<b>Waste cost</b>	Dependent on subsequent disposal route for contaminated by-products.
<b>Assumptions</b>	That there is a market for alternative crop. That appropriate monitoring is carried out at processing plant.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Informed consent. Distribution of costs and benefits (e.g., possible inequity due to change in prices of produce and lower income populations buying the treated food). Loss of profit to producers if the treated food is not accepted by consumers.
<b>Environmental impact</b>	Change in ecosystem.
<b>Agricultural impact</b>	Change in crop type, fertiliser requirements, nutrient cycling, disease resistance.
<b>Social impact</b>	Maintenance of farming and associated communities. Possible loss of confidence in products/potential for generating mistrust of food production system. Stigma associated with area and product where the countermeasure is applied. Disruption to people's image/perception of 'countryside' e.g. where traditional crops are changed, with potential impacts on tourism etc.
<b>Social impact (cont.)</b>	Disruption/adjustment of farming and related industrial activities. Disruption to the supply of crops to food industry and potential for market shortages.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	An existing commercial process.
<b>Key references</b>	Alexakhin, R. M., Frissel, M. J., Shulte, E. H., Prister, B. S., Vetrov, V. A. and Wilkins, B. T. (1993). Change in land use and crop selection. The Science of the Total Environment, 137, 169-172.

Table B2.10 Processing of crops for subsequent consumption

<b>Processing of crops for subsequent consumption</b>	
<b>Objective</b>	To process contaminated crops to produce final food products with activity concentrations less than intervention limits.
<b>Other Benefits</b>	Maintenance of agricultural production systems and provision of foodstuffs to consumers.
<b>Countermeasure description</b>	Commercial food processing, such as blanching and canning, may achieve some reductions in the activity concentration of some processed foodstuffs.
<b>Target</b>	Crops.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small to medium.
<b>Contamination pathway</b>	Soil to plant transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated crops.
<b>Time of application</b>	Early to long term.
<b>Constraints:</b>	
<b>Legal constraints</b>	The sale of crops intended for human consumption is subject to Council Food Intervention Levels (CFILs).
<b>Social constraints</b>	Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade when foodstuffs can be obtained from other sources. The principle of informed consent suggests that such foodstuffs should have their origins labelled, and consumers are likely to prefer 'clean' foodstuffs. If prices are lowered in response to this demand pattern, there is an inequitable distribution of the residual contamination to poorer populations, and the possibility of their consuming a higher than average dose from residual contamination.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Labelling of treated products.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	The removal of inedible parts, washing and blanching are processes commonly applied prior to canning. In general more than 50% of radiocaesium contamination is removed during blanching or boiling. Following canning additional decontamination (~50%) occurs via transfer from product to canning solution during storage.
<b>Factors influencing effectiveness of procedure (technical)</b>	Process selected, radionuclide(s) present, time lag between deposition and washing, texture of crop surface (rough & leafy will make decontamination more difficult), quantity of external edible parts of crop, storage time, volume of canning solution.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of processing contaminated crops for consumption to the food industry/retailers and consumers. There must be a market for the end products.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Processing plant, storage facilities for food products (for short-lived radionuclides).
<b>Required ancillary equipment</b>	Vehicles to transport food.
<b>Required utilities and infrastructure</b>	Waste treatment facilities for disposal of contaminated by-products.
<b>Required consumables</b>	Fuel for vehicles.
<b>Required skills</b>	Operators at processing plants will have the required skills.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Required safety precautions</b>	None.
<b>Other limitations</b>	Availability of processing plants if there is a reluctance to move contaminated raw materials to a plant located outside an affected area. Capacity of processing plants to accept additional raw materials (i.e. crops).
<b>Waste:</b>	
<b>Amount and type</b>	Food processing residuals (i.e. materials remaining after processing of primary products, such as peel and foliage). Large volumes of water and salt from blanching and boiling processes. Following, canning additional decontamination occurs via transfer from the product to the canning solution during the storage period.
<b>Possible transport, treatment and storage routes</b>	Water containing radioactivity and salt may be handled at processing plant or held in a treatment pond. Solid residuals such as peel, foliage etc may be converted to useful by-products depending of the type of residual. Alternatively, they could be incinerated at the processing site or disposed of to landfill.
<b>Factors influencing waste issues</b>	Depends on crop type and type of processing selected. Legal constraints on the fate of contaminated crops. The high moisture content and readily putrescible nature of the food residuals means that waste treatment cannot be delayed.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Dose pathways in italics are indirectly incurred as a result of transportation of waste by products. Additional doses will be incurred from disposal of these wastes either at landfill sites or incinerators. There are separate datasheets for waste disposal options. Any waste water generated during processing may be sent to a Sewage Treatment Works (STW): the relevant dose pathways for this disposal route are given in Table C2: Landfill.)</i>	<p>Driver:</p> <ul style="list-style-type: none"> <li>• External exposure while transporting crops to processing plant</li> <li>• <i>External exposure while transporting waste by-products to place of disposal</i></li> </ul> <p>Operative at food processing plant:</p> <ul style="list-style-type: none"> <li>• External exposure at processing plant (depending on degree of automation)</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Minimal. Processing equipment is already available.
<b>Consumables</b>	Any additional processing consumables. Fuel for transportation.
<b>Operator time</b>	Drivers for transporting contaminated crop to process plants. Operators at processing plants if additional manpower required.
<b>Factors influencing costs</b>	Distance to processing plant, quantities of crops for processing.
<b>Communication costs</b>	Possible cost of labelling.
<b>Compensation costs</b>	To processing plants for handling contaminated produce. To farmers if there is a loss in market value for processed crops. Possible decontamination of processing equipment.
<b>Waste cost</b>	Dependent on subsequent disposal route for contaminated by-products.
<b>Assumptions</b>	That there is a market for the end product. That appropriate monitoring is carried out at processing plant.

<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Informed consent. Distribution of costs and benefits (e.g., possible inequity due to change in prices of processed crops with lower income populations buying the treated food). Loss of profit to producers if the treated food is not accepted by consumers.
<b>Environmental impact</b>	None, although there could be an indirect environmental impact depending on disposal route chosen for by-products.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Maintenance of farming and associated communities. Possible loss of confidence in products/potential for generating mistrust of food production system. Disruption/adjustment of farming and related industrial activities. Disruption to the supply of crops to food industry and potential for market shortages.
<b>Other side effects, pos. or neg.</b>	Parts of the processing plant may become contaminated.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Existing commercial practice.
<b>Key references</b>	<p>Green, N. and Wilkins, B. T. (1995). Effects of processing on radionuclide content of foods: derivation of parameter values for use in radiological assessments. NRPB-M587.</p> <p>Katsuyama, A. M. (ed.) (1979). A guide for waste management in the food processing industry. The Food Processors Institute, Washington, DC.</p> <p>Long, S., Pollard, D., Cunningham, J. D., Astasheva, N. P., Donskaya, G. A. and Labetsky, E. V. (1995). The effects of food processing and direct decontamination techniques on the radionuclide content of foodstuffs: a literature review. Part 2: Meat, fruit, vegetables, cereals and drinks. <i>Journal of Radioecology</i>, 3 (2), 15-38.</p>

**Table B3.1 Slaughtering dairy cows**

<b>Slaughtering dairy cows</b>	
<b>Objective</b>	To remove the source of contaminated milk (i.e. dairy cows) from the foodchain.
<b>Other Benefits</b>	Maintains consumer confidence in food products.
<b>Countermeasure description</b>	Slaughtering could be considered for those dairy cows whose milk would 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 cattle un milked and possibly unfed. Condemnation completely removes contaminated food from the market but can leave large quantities of animal waste needing disposal.
<b>Target</b>	Dairy cattle.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small to medium scale depending on severity of accident.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk.
<b>Time of application</b>	Early to medium term.
<b>Constraints:</b>	
<b>Legal constraints</b>	Slaughter of animals is likely to be subject to animal welfare acts in each Member State. It must be conducted by veterinarians or licensed slaughtermen.
<b>Social constraints</b>	Acceptability of slaughter relative to the impact on the farming community and the cost. Acceptability of selection process for areas where this countermeasure is applied.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Debate and dialogue may be required on ethical premises of this countermeasure. Media interest is likely to be high.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Highly effective (i.e. 100%) at removing contaminated food from foodchain.
<b>Factors influencing effectiveness of procedure (technical)</b>	Availability of licensed slaughtermen to visit farms in immediate aftermath of accident; availability of transport to take dairy cows to abattoirs.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of and compliance with countermeasure. Appropriate selection of priority areas. There is a potential for a black market in slaughtered meat.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Abattoir or slaughtering equipment on farm.
<b>Required ancillary equipment</b>	Vehicles for transport of cattle to abattoir if necessary.
<b>Required utilities and infrastructure</b>	Disposal routes for carcasses e.g. incinerators, rendering plants, burning and burial sites.
<b>Required consumables</b>	Fuel for transport to abattoir if necessary. Cartridges for captive bolts etc.
<b>Required skills</b>	Slaughtering would be carried out by licensed slaughtermen with necessary skills.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	Capacity of disposal routes
<b>Waste:</b>	
<b>Amount and type</b>	Condemned livestock carcasses.

<b>Possible transport, treatment and storage routes</b>	Disposal by; incineration, burial, burning, rendering. In Norway condemned meat has been used as feed for fur producing animals.
<b>Factors influencing waste issues</b>	Acceptability of and compliance with waste disposal practice. Legislative issues, for example 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.
<b>Doses:</b>	
<b>Additional dose</b>	Driver: <ul style="list-style-type: none"> <li>External exposure while transporting cows to abattoir</li> </ul> Operative at abattoir: <ul style="list-style-type: none"> <li>External exposure while slaughtering cows</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Slaughtering equipment already available. Additional transport for carcasses to be taken to abattoir.
<b>Consumables</b>	Fuel for transport. Cartridges for slaughter.
<b>Operator time</b>	Time to slaughter cattle at abattoir or on-farm and to transport livestock to abattoir.
<b>Factors influencing costs</b>	Whether slaughter is carried out at abattoir or on farm.
<b>Communication costs</b>	Potential need to facilitate widespread debate regarding ethics and practice of countermeasure. Explaining countermeasure to farmers.
<b>Compensation costs</b>	Payment to abattoirs. Compensation to farmer for milk unable to be sold, for replacement herd and to maintain pastures if all animals removed. Decontamination of slaughtering equipment if necessary.
<b>Waste cost</b>	Costs of transportation of carcasses to rendering/incineration plant or burial/burning site. The costs of the chosen disposal route; incineration, rendering, burning and burial.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Impact on farming community.
<b>Environmental impact</b>	None. Indirect effect depends on disposal route selected for carcasses.
<b>Agricultural impact</b>	If the entire herd is slaughtered, under-grazing of pasture will occur.
<b>Social impact</b>	Disruption of farming and associated communities. Market shortages. Disruption to people's image/perception of 'countryside' e.g. if there are no animals in the fields, with potential impacts on tourism. Negative social and psychological impact. Policing countermeasure and averting black market sales of contaminated meat.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<b>Practical experience</b>	Slaughtering of cattle has been carried out in the UK and other European countries following the condemnation of beef because of BSE. On a larger scale there has been slaughter and burning/burial of complete farm stocks (ruminants and pigs) as a consequence of the foot and mouth epidemic in the UK. Herds and flocks were also slaughtered and disposed of in many other Member States including France, Belgium, Germany and the Netherlands.
<b>Key references</b>	Smith, J, Nisbet, A. F., Mercer, J. A., Brown, J. and Wilkins, B. T. (2002). Management options for food production systems affected by a nuclear accident: Options for minimising the production of contaminated milk. NRPB-W8. Tveten, U., Brynildsen, L. I., Amundsen, I. and Bergan, T. (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. <i>Journal of Environmental Radioactivity</i> , 41 (3), 233-255.
<b>Comments</b>	It is debatable whether any situation could arise whereby the milk of dairy cows would be so contaminated that it would be unfit for human consumption throughout the productive life of the animal.

Table B3.2 Suppression of lactation before slaughter

<b>Suppression of lactation before slaughter</b>	
<b>Objective</b>	To reduce the volume of milk requiring disposal before dairy cattle are slaughtered.
<b>Other Benefits</b>	None.
<b>Countermeasure description</b>	If a decision has been made to slaughter dairy livestock because the period of lost production is too long, methods for suppressing lactation should be used to reduce volumes of waste milk requiring disposal. Synthetic oestrogens are effective at inhibiting milk production, although many forms are currently banned by the EU for food producing animals. Progestogens or prostaglandins could also be considered. The more natural methods 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.
<b>Target</b>	Dairy cattle.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small to large.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk.
<b>Time of application</b>	Early to medium term.
<b>Constraints:</b>	
<b>Legal constraints</b>	Hormonal treatments using synthetic oestrogens are not permitted for food producing animals in the EU. However, if a decision has been made to slaughter dairy livestock, hormonal treatments may be used to reduce the volumes of waste milk arising before slaughter. There are animal welfare issues associated with the suppression of lactation and these should be taken into consideration.
<b>Social constraints</b>	The process of drying-off in a situation other than for preparation for calving and the next lactation cycle has associated animal welfare concerns. This is because dairy cattle have been bred to produce high volumes of milk daily and are therefore likely to experience much discomfort, pain and possibly disease, if prevented from continuous milk production.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Farmers require information about the countermeasure.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Both hormone treatments and drying-off naturally can be considered as 100% effective if lactation has ceased. The time taken to achieve this depends on the method adopted but can take up to 2 weeks. The shorter the period that drying-off is achieved over, the greater the potential for animal welfare problems to evolve. Suppression of lactation can also be regarded as being highly effective if the rate of milk production is greatly reduced but not ceased.
<b>Factors influencing effectiveness of procedure (technical)</b>	The method used to suppress lactation. If hormonal, the type of treatment selected. The daily milk yield of the dairy cow. For high milk producing cows the drying-off method should be applied gradually over a longer time period than for lower yielding cows. The stage of lactation and pregnancy status of the cow.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of suppressing lactation and methods used to achieve it. Animal welfare issues relating to drying off procedures on pregnancy particularly with regard to the risk of abortion.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	None.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	None.
<b>Required consumables</b>	Synthetic oestrogens, progestogens or prostaglandins. Long acting antibiotic for udders (in case of mastitis) if more natural methods of drying off used.
<b>Required skills</b>	Farmers would possess necessary skills for drying off 'naturally'. Some instruction may be required for administering hormonal treatments.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	None.
<b>Waste:</b>	
<b>Amount and type</b>	Milk contaminated with radionuclides will be produced until milk production ceases. Levels are likely to be in excess of the CFIL and will require disposal. If synthetic oestrogens have been used, all milk will require disposal irrespective of radionuclide content.
<b>Possible transport, treatment and storage routes</b>	Disposal by; landspreading, biological treatment, processing into a milk product suitable for storage prior to disposal, and disposal to sea.
<b>Factors influencing waste issues</b>	High biochemical oxygen demand (BOD) level associated with milk.
<b>Doses:</b>	
<b>Additional dose</b>	None.
<b>Intervention Costs:</b>	
<b>Equipment</b>	None.
<b>Consumables</b>	Depending on method of suppression of lactation used: hormonal treatments, long acting antibiotic for udders.
<b>Operator time</b>	Less time would be spent milking, but an increased amount of time might be spent controlling animal welfare issues.
<b>Factors influencing costs</b>	Method used to suppress lactation.
<b>Communication costs</b>	Provision of information to farmers.
<b>Compensation costs</b>	Compensation to farmer for loss of milk production.
<b>Waste cost</b>	Dependent on disposal route for milk chosen.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Animal welfare issues. Pollution issues related to hormone treatments.
<b>Environmental impact</b>	None. Indirect effect of synthetic oestrogens if waste milk is allowed to contaminate waterways. Synthetic oestrogens are known to persist in waterways causing endocrine disruption to fish.
<b>Agricultural impact</b>	Loss of milk production.
<b>Social impact</b>	Disruption of milk production at dairy farms and to the supply of milk to food industry and market shortages. Negative social and psychological impact. Policing compliance with the countermeasure. Opposition by the public to using hormone treatments due to the perception that hormones would damage the environment.

<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Dairy farmers typically have experience of drying off cows in preparation for calving.
<b>Key references</b>	Smith, J., Nisbet, A. F., Mercer, J. A., Brown, J. and Wilkins, B. T. (2002). Management options for food production systems affected by a nuclear accident: Options for minimising the production of contaminated milk. NRPB-W8.
<b>Comments</b>	Further research is required to establish the most appropriate methods of drying off dairy cattle 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. Thus, the suppression of lactation is only considered if it is to be followed by slaughtering. If dairy cows are also used in meat production then the suppression of lactation could be of benefit.

**Table B3.3 Datasheet for Clean feeding**

<b>Clean feeding</b>	
<b>Objective</b>	To reduce activity concentrations of radionuclides in milk and meat to below intervention levels.
<b>Other Benefits</b>	Reduce amount of milk and meat requiring disposal.
<b>Countermeasure description</b>	Livestock may be fenced in or housed to prevent grazing of contaminated pasture. The animals are then given nutritionally balanced diets comprising uncontaminated/less contaminated feed such that the final animal product has activity concentrations < CFIL. 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. All pasture may be removed from the diet and replaced by uncontaminated or less contaminated feeds such as root crops, cereals and silage. For diets containing root crops and cereals a period of adaptation of 2 weeks is desirable. This is less important when alternative diet contains silage and hay. For intensive farming, any alternative diet that is implemented should be accompanied by a pasture management programme to ensure that intervention levels are not exceeded when the animals are reintroduced to pasture. This would also maintain pasture quality.
<b>Target</b>	All livestock that are destined for the foodchain.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large scale application, although dependent on supply of clean feed at a reasonable price. Fencing in or housing livestock to administer alternative diets should be possible on most livestock farms (particularly dairy).
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk and meat.
<b>Time of application</b>	Early to long term. 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. Finishing lambs grazing forage crops however would have to be housed and given conserved clean feed. Late spring would be the worst time for a contamination event, since cattle and lambs would be grazing outside and no new hay or silage would have been harvested. Later on in summer animals could be fed hay or silage that had been cut before the accident. For some of the alternative diets pasture reduction is only worth considering for restrictions lasting more than a few weeks because of time required to introduce these diets.
<b>Constraints:</b>	
<b>Legal constraints</b>	<p>The sale of milk and meat intended for human consumption is subject to Council Food Intervention Levels (CFILs). 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.</p> <p>Free range schemes may also be restricted following an accident if animals have to be housed. Local regulations on the use and siting of buildings. Some conservation schemes only allow grassland management to take place at certain times of the year to protect nesting birds etc.</p>

<b>Social constraints</b>	Availability of fences or housing and acceptability of new buildings. Willingness of farmer to change farming practice. Acceptability to food industry/consumers of changes in the quality of the food product. For example, 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.
<b>Environmental constraints</b>	Housing of livestock produces large volumes of slurry. This must be stored and disposed of to land at times when pollution would not occur.
<b>Communication constraints</b>	None.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	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 arisings of up to 100%.
<b>Factors influencing effectiveness of procedure (technical)</b>	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.
<b>Factors influencing effectiveness of procedure (social)</b>	Compliance in feed provision. Willingness and the ability of farmers to adapt to the new regime (farmers may be unhappy with the adjustments they have to make), although compensation may help in this respect.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Fences or buildings suitable for livestock.
<b>Required ancillary equipment</b>	Forage harvester to cut contaminated pasture for subsequent disposal. Slurry tanks and spreading equipment.
<b>Required utilities and infrastructure</b>	Water. Power supply. Ventilation. Feeding and drinking troughs.
<b>Required consumables</b>	Alternative feeds (e.g. barley, silage, potato, alfalfa and concentrates). Straw for bedding. On organic farms, organic feed may be required to maintain organic status of farm.
<b>Required skills</b>	Farmers would possess the necessary skills as housing animals is an existing practice.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	Must ensure that alternative diets are nutritionally balanced.
<b>Waste:</b>	
<b>Amount and type</b>	A programme of grassland management must be implemented while livestock are fenced or housed to (i) ensure that intervention levels are not exceeded when the animals are reintroduced to pasture; (ii) ensure pasture quality is maintained. This involves cutting and disposing of contaminated grass before animals are returned to pasture. Slurry produced while livestock are fenced in/housed.
<b>Possible transport, treatment and storage routes</b>	The cut grass may be composted 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 $^{131}\text{I}$ , then the normal storage period of 6-12 month would suffice.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Possible transport, treatment and storage routes (cont.)</b>	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 <i>in situ</i> . Slurry should be stored and landspread at appropriate times.
<b>Factors influencing waste issues</b>	Level of contamination in cut pasture. The spreading of compost back on farmland is only reasonable if the storage period is sufficient for the most important radionuclides to decay, or if the land was used for non-food production. When land is frozen or waterlogged, slurry 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. In summer, slurry could be applied to pasture that would otherwise be grazed, so areas for spreading would be greater.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Additional doses will be incurred from the disposal of grass mowings and slurry either by composting or spreading on land. There are separate datasheets for these waste disposal options.)</i>	Farmer while collecting livestock: <ul style="list-style-type: none"> <li>External exposure from livestock while collecting them from pasture</li> </ul> Farmer while mowing grass: <ul style="list-style-type: none"> <li>External exposure and inhalation while mowing grass</li> </ul> Farmer while ensiling: <ul style="list-style-type: none"> <li>External exposure and inhalation while ensiling grass</li> </ul> Farmer while feeding livestock: <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and hand skin exposure from silage while feeding livestock</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Modification to housing. Construction of new housing/fences. Hire of a forage harvester.
<b>Consumables</b>	Cost of purchasing uncontaminated feed. Cost of using other feeds available on the farm that could result in a shortfall of feeding stuffs for the winter. Additional concentrates may be required to nutritionally balance the alternative diets.
<b>Operator time</b>	Extra work by farmer – obtaining uncontaminated feed, looking after housed/fenced in animals, overseeing implementation of the alternative feeding regime. Collection, storage and disposal of slurry. Cutting and disposal (by composting, silage making) of contaminated grass.
<b>Factors influencing costs</b>	Availability of alternative housing, feeds, machinery and manpower.
<b>Communication costs</b>	Explaining countermeasure to farmers.
<b>Compensation costs</b>	To farmer for using up stores of alternative feed, for additional work, for loss of income from not adhering to conservation schemes.
<b>Waste cost</b>	Farmer time cutting and composting contaminated grass and landspreading additional slurry.
<b>Assumptions</b>	Monitoring of animals is carried out following periods of clean feeding.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Self-help for farmers. Animal welfare issues if animals are housed in the summer when temperature and ventilation could be a problem.

<b>Environmental impact</b>	Housing of livestock in summer could lead to high levels of ammonia in buildings. Inappropriate disposal of additional slurry could lead to pollution of water courses. Changes in landscape due to citing of new buildings.
<b>Agricultural impact</b>	Reduced grazing on fields. Compost available for use on farm.
<b>Social impact</b>	<p>Disruption to people's image/perception of 'countryside' e.g. if there are no animals in the fields, with potential impacts on tourism etc. Policing the countermeasure and averting growth of a black market. Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' resulting in loss of employment in local 'cottage' industries and leading to the need to maintain farming and associated communities. Potential for generating widespread mistrust of the farming practice in relation to food production.</p> <p>Conversely, there may be a possible increase in public confidence that the problem of contamination is being effectively managed.</p>
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Housing of livestock is normal agricultural practice during winter months. Clean feeding is still in use in Norway due to the Chernobyl accident for sheep, reindeer and some cattle grazing unimproved pastures.
<b>Key references</b>	<p>Brynildsen, L. and Strand, P. (1994). A rapid method for the determination of radioactive caesium in live animals and carcasses and its practical application in Norway after the Chernobyl accident. <i>Acta Veterinaria Scandinavica</i>, 35, 401-408.</p> <p>Howard, B., Beresford, N. and Hove, K. (1991). Transfer of radiocaesium to ruminants in natural and seminatural ecosystems and appropriate countermeasures. <i>Health Physics</i>, 61 (6), 715-725.</p> <p>Shaw, S., Green, N., Hammond, D. J. B. and Woodman, R. F. M. (2001). Management options for food production systems affected by a nuclear accident. 1. Radionuclide behaviour during composting. NRPB-R328.</p> <p>Smith, J., Nisbet, A. F., Mercer, J. A., Brown, J. and Wilkins, B. T. (2002). Management options for food production systems affected by a nuclear accident: Options for minimising the production of contaminated milk. NRPB-W8.</p> <p>Tveten, U., Brynildsen, L. I., Amundsen, I. and Bergan, T. D. S. (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. <i>J. Environmental Radioactivity</i>, 41(3), 233-255.</p>
<b>Comments</b>	For extensive farming, 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.

**Table B3.4 Selective grazing regime**

<b>Selective grazing regime</b>	
<b>Objective</b>	To reduce activity concentrations of radiocaesium and radiostrontium in meat and milk to below intervention levels.
<b>Other Benefits</b>	Reduction in quantities of animal produce that will need to be disposed of.
<b>Countermeasure description</b>	Farm animals may be moved to less contaminated pastures. This can be done on a permanent basis or at appropriate times before slaughter to allow contamination levels to fall to below intervention levels at slaughter. Livestock can also be physically excluded from a highly contaminated area by erection of temporary fences.
<b>Target</b>	Meat and milk producing animals.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Medium.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated meat and milk.
<b>Time of application</b>	Early to long term.
<b>Constraints:</b>	
<b>Legal constraints</b>	After selective grazing has been carried out milk and meat would still be subject to Council Food Intervention Levels (CFILs). Depends on land status (i.e. conservation areas, National Parks).
<b>Social constraints</b>	Willingness of farmer to participate.
<b>Environmental constraints</b>	There may be restrictions on where temporary fences can be erected e.g. in National Parks, Environmentally Sensitive Areas.
<b>Communication constraints</b>	None.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Can be highly effective (up to 100%).
<b>Factors influencing effectiveness of procedure (technical)</b>	The availability of monitoring data on the farm on which to base the countermeasure. The availability of land providing less contaminated pasture.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of countermeasure to the farmer. Compliance/resistance to the countermeasure.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Monitoring equipment to assess contamination status of land. Machinery to aid construction of fences to temporarily restrict access of animals to contaminated land.
<b>Required ancillary equipment</b>	Transportation of livestock to less contaminated area.
<b>Required utilities and infrastructure</b>	None.
<b>Required consumables</b>	Fuel for transportation and construction machinery.
<b>Required skills</b>	Farmer should have necessary skills.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	None.

<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes.</b>	None.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer while erecting fencing: <ul style="list-style-type: none"> <li>External exposure and inadvertent ingestion and inhalation of dust while erecting fencing</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Fencing.
<b>Consumables</b>	Fuel.
<b>Operator time</b>	Time to erect fencing. Time to herd animals and transport them to less contaminated areas.
<b>Factors influencing costs</b>	Size of contaminated area to be fenced off. Location of less contaminated land with respect to the farm.
<b>Communication costs</b>	None.
<b>Compensation costs</b>	To farmer for extra labour required in moving animals to less contaminated pasture. To farmer for lost grazing areas.
<b>Waste cost</b>	None.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Self-help for farmer. Knock-on effects for public use of amenity if areas are fenced off.
<b>Environmental impact</b>	Change in biodiversity of fenced area.
<b>Agricultural impact</b>	Undergrazing of fenced areas of pasture.
<b>Social impact</b>	Disruption to farming and other related activities (e.g. tourism).
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	Acceptable to all stakeholders.
<b>Practical experience</b>	Used widely in FSU. Also in uplands of UK, in combination with a live-monitoring scheme, to produce lamb with activity concentrations < CFIL. Was also employed in Norway.
<b>Key references</b>	Nisbet, A. F. and Woodman, R. F. M. (2000). Options for the management of Chernobyl-restricted areas in England and Wales. <i>Journal of Environmental Radioactivity</i> , 51, 239-254. Prister, B. S., Perepelyatnikov, G. P. and Perepelyatnikova, L. V. (1993). Countermeasures used in the Ukraine to produce forage and animal food products with radionuclide levels below intervention limits after the Chernobyl accident. <i>The Science of the Total Environment</i> , 137, 183-198.

**Table B3.5 Distribution of concentrates with added calcium**

<b>Distribution of concentrates with added calcium</b>	
<b>Objective</b>	To reduce the activity concentration of radiostrontium in milk to below intervention levels.
<b>Other Benefits</b>	Reduction in quantities of milk that will need to be disposed of. Normal animal management/grazing regimes can be used.
<b>Countermeasure description</b>	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 diet 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.
<b>Target</b>	Milk producing animals.
<b>Targeted radionuclides</b>	Radiostrontium.
<b>Scale of application</b>	Large.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk.
<b>Time of application</b>	Early to long term.
<b>Constraints</b>	
<b>Legal constraints</b>	The sale of milk intended for human consumption is subject to Council Food Intervention Levels (CFILs). The feeding of diets in excess of 1-2 % Ca as dry matter intake is advised against for prolonged periods. However, it is likely that in most western European countries the Ca intake of animals could be doubled without exceeding these advised levels.
<b>Social constraints</b>	None.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Possible requirement for labelling products directly or indirectly affected by application of the countermeasure.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	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.
<b>Factors influencing effectiveness of procedure (technical)</b>	Dietary intake prior to calcium supplementation. Animal's calcium requirements. Whilst in theory every doubling of Ca intake would reduce Sr concentration in milk by 50 % there are maximum advised Ca intakes over long term.
<b>Factors influencing effectiveness of procedure (social)</b>	Compliance/resistance to the countermeasure. Effective administration of the calcium in concentrate.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	None.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Most likely to be fed with concentrate during milking.
<b>Required consumables</b>	Calcium supplements or pelleted concentrates with enriched levels of Ca or natural feeds rich in calcium. Fuel for transportation.
<b>Required skills</b>	Farmers would already possess the necessary skills because of experience with other additives.
<b>Required safety precautions</b>	None.

<b>Other limitations</b>	High levels of calcium intake can influence the absorption of other essential nutrients; the dietary Ca/P ratio should not exceed 7:1. Cannot be fed on a daily basis to free-grazing animals.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	None.
<b>Intervention Costs:</b>	
<b>Equipment</b>	None.
<b>Consumables</b>	Calcium supplements.
<b>Operator time</b>	Farmer may need to administer the calcium in the feed.
<b>Factors influencing costs</b>	Production cost for the concentrates with calcium, transportation costs.
<b>Communication costs</b>	Possible cost of labelling milk and milk products from regions where the countermeasure is applied.
<b>Compensation costs</b>	To the farmer to compensate for the extra costs associated with buying concentrates with added calcium.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Change in production status for organic farms.
<b>Environmental impact</b>	None.
<b>Agricultural impact</b>	None if advised Ca intakes (1-2% of dry matter intake) are not exceeded.
<b>Social impact</b>	Policing the countermeasure and averting growth of a black market. Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' resulting in loss of employment in local 'cottage' industries and leading to the need to maintain farming and associated communities. Potential for generating widespread mistrust of the farming practice in relation to food production. Although conversely, there may be a possible increase in public confidence that the problem of contamination is being effectively managed.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	None.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<b>Key references</b>	Beresford, N.A., Mayes, R.W., Colgrove, P.M., Barnett, C.L., Bryce, L., Dodd, B.A. & Lamb, C.S. (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. <i>Journal of Environmental Radioactivity</i> , 51, 321-342.
<b>Comments</b>	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 countermeasure on a farm by farm basis. In the shorter term Ca intakes could be enhanced by farmers adding Ca-supplement to feed directly; however in the longer term it may be more efficient/effective to incorporate enhanced Ca into pelleted feeds during manufacture.

Table B3.6 Distribution of concentrates with AFCF

<b>Distribution of concentrates with AFCF</b>	
<b>Objective</b>	To reduce activity concentration of radiocaesium in meat and milk of farmed livestock to below intervention levels.
<b>Other Benefits</b>	Reduction in quantities of animal produce that will need to be disposed of. Normal animal management/grazing regimes can be used.
<b>Countermeasure description</b>	Ammonium-ferric hexacyano-ferrate (AFCF, Giese-salt) is an effective radiocaesium binder, which may be added to the diet of dairy cows, sheep and goats as well as meat producing animals to reduce radiocaesium transfer to milk and meat by reducing absorption in the gut. It can be added to the diet of animals as a powder or incorporated into pelleted feed.
<b>Target</b>	Meat and milk producing animals.
<b>Targeted radionuclides</b>	Radiocaesium.
<b>Scale of application</b>	Large-scale application. Generally applicable to all animals being fed concentrates; especially suitable for dairy animals.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre-intervention</b>	Ingestion of contaminated milk or meat.
<b>Time of application</b>	Early to long term. 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.
<b>Constraints:</b>	
<b>Legal constraints</b>	The sale of milk and meat intended for human consumption is subject to Council Food Intervention Levels (CFILs). 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. May not be allowed under some organic production regimes.
<b>Social constraints</b>	Acceptability to farmers, food industry and consumers of using an additional feed additive to remove contamination from the gut of livestock.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Possible requirement for labelling products directly or indirectly affected by application of the countermeasure.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	80-90% reduction of radiocaesium contamination in milk and 78% reduction of radiocaesium contamination in meat for cows receiving 3g AFCF per day. 87% reduction of radiocaesium contamination in meat for sheep receiving 1g AFCF per day. 90% reduction in radiocaesium contamination in meat for pigs and calves receiving 2g AFCF per day (Giese, 1988 and 1989).
<b>Factors influencing effectiveness of procedure (technical)</b>	Amount of AFCF distributed to the animal per day. Greater effectiveness when farmer uses commercially prepared concentrates. Effectiveness may be more variable when it is shaken on to loose home produced rations.
<b>Factors influencing effectiveness of procedure (social)</b>	Compliance/resistance to the countermeasure. Effective administration of the concentrate.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	None.
<b>Required ancillary equipment</b>	None.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Required utilities and infrastructure</b>	Factory producing AFCF. Concentrate manufacturing plants with the ability to add AFCF.
<b>Required consumables</b>	Concentrates with AFCF. Fuel for transportation.
<b>Required skills</b>	Farmers would possess the necessary skills.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	Cannot be fed on a daily basis to free-grazing animals.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	None.
<b>Intervention costs:</b>	
<b>Equipment</b>	None.
<b>Consumables</b>	AFCF imported from Germany and mixed with concentrates in Norway costs 0.27 EUR per kg concentrates with 0.1 % AFCF.
<b>Operator time</b>	Time required to add concentrate to feed.
<b>Factors influencing costs</b>	Production cost for the concentrates with AFCF, transportation costs.
<b>Communication costs</b>	Possible cost of labelling.
<b>Compensation costs</b>	To the farmer to compensate for the extra costs associated with buying concentrates with AFCF.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Change in production status for organic farms.
<b>Environmental impact</b>	Whilst some soils may contain bacteria or fungi capable of degrading cyanide, toxic levels of HCN should not arise under field conditions.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Policing the countermeasure and averting growth of a black market. Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' resulting in loss of employment in local 'cottage' industries and leading to the need to maintain farming and associated communities.
<b>Social impact</b>	Potential for generating widespread mistrust of the farming practice in relation to food production. Although conversely, there may be a possible increase in public confidence that the problem of contamination is being effectively managed.
<b>Other side effects, pos. or neg.</b>	Can maintain the production of meat and milk without disrupting the normal farming practices.
<b>UK Stakeholder opinion</b>	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

<b>UK Stakeholder opinion (cont.)</b>	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.
<b>Practical experience</b>	Used frequently after the Chernobyl accident in Norway with good results for cows and goats and reindeers; in the FSU a different hexacyanoferrate compound has been used. Less and variable data available for pigs and poultry.
<b>Key references</b>	<p>Garmo, T. H. and Grønnerud, T. B. (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).</p> <p>Giese, W.W. (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.</p> <p>Giese, W.W. (1989). Countermeasures for reducing the transfer of radiocaesium to animal derived foods. The Science of the Total Environment, 85, 317-327.</p> <p>Hove, K. (1993). Chemical methods for reduction of the transfer of radionuclides to farm animals in semi-natural environments. The Science of the total Environment, 137 235-248.</p> <p>Howard, B. J., Beresford, N. A., and Voigt, G. (2001). Countermeasures for animal products: a review of effectiveness and potential usefulness after an accident. Journal of Environmental Radioactivity, 56, 115-137.</p> <p>IAEA (1994). Handbook of parameter values for the prediction of radionuclide transfer in temperate environments. IAEA Technical Report Series No. 364.</p> <p>Pearce, J. (1994). Studies on any toxicological effects of Prussian Blue compounds in mammals – a review. Food Chem. Toxicol., 32, 577-582.</p> <p>Salt, C.A. and Rafferty, B. (2001). Assessing potential secondary effects of countermeasures in agricultural systems: a review. Journal of Environmental Radioactivity, 56, 99-114.</p>
<b>Comments</b>	<p>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 manure from farm animals. Yet, this is not believed to reach levels of concern in practice.</p> <p>(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 et al., 1992)).</p> <p>Live-monitoring prior to slaughtering can be a good supplement to control the effectiveness of the countermeasure for each animal or a selection within a herd/flock.</p>

**Table B3.7 Administration of clay minerals to feed**

<b>Administration of clay minerals to feed</b>	
<b>Objective</b>	To reduce activity concentration of radiocaesium in meat and milk of farmed livestock to below intervention levels.
<b>Other Benefits</b>	Some clay minerals may also reduce radiostrontium absorption. Reduction in quantities of animal produce that will need to be disposed of. Normal animal management/grazing regimes can be used.
<b>Countermeasure description</b>	Clay minerals (i.e. bentonites, vermiculites, zeolites) can be added to fodder to reduce gut uptake of radiocaesium by farmed livestock.
<b>Target</b>	Meat and milk producing animals. Inappropriate for free grazing livestock because they are not gathered daily.
<b>Targeted radionuclides</b>	Radiocaesium.
<b>Scale of application</b>	Medium to large.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated meat and milk.
<b>Time of application</b>	Early to long term.
<b>Constraints</b>	
<b>Legal constraints</b>	The sale of milk and meat is subject to Council Food Intervention Levels (CFILs). Bentonite is a legal feed additive in some countries to prevent scouring.
<b>Social constraints</b>	Acceptability of method with respect to animal welfare issues.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Possible requirement for labelling products directly or indirectly affected by application of the countermeasure.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	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 0.5g/kg body weight per day. A maximum reduction of about fivefold can be achieved at a dose level of 1-2g/kg body weight per day.
<b>Factors influencing effectiveness of procedure (technical)</b>	Dose of clay minerals given to animal per day. As the dose increases the greater the reduction of the radionuclides in the milk or meat. However loss of appetite and weight has been observed if too higher dose is given. Clay minerals from different sources have different binding capacities. Availability of large quantities of clay minerals.
<b>Factors influencing effectiveness of procedure (social)</b>	Compliance/resistance to the countermeasure. Effective administration of the clay minerals.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	None.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Transportation of clay minerals from extraction site, and subsequent storage facilities. Ideally a factory to incorporate clay minerals into pelleted feed rations during manufacture.
<b>Required consumables</b>	Clay minerals. Fuel for transportation.
<b>Required skills</b>	Farmers would possess the necessary skills to add clay minerals to feed provided instructions were given.
<b>Required safety precautions</b>	None.

<b>Other limitations</b>	Cannot be fed on a daily basis to free grazing animals.
<b>Waste:</b>	
<b>Amount and type</b>	None
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	None.
<b>Intervention Costs:</b>	
<b>Equipment</b>	None.
<b>Consumables</b>	Clay minerals. Fuel for transportation of clay minerals.
<b>Operator time</b>	If clay minerals were not provided to the farmer already incorporated in feed, the farmer would need to mix the clay minerals with the feed. Additional time would be required to oversee that each animal ingested an appropriate amount.
<b>Factors influencing costs</b>	Availability of clay minerals at anyone time.
<b>Communication costs</b>	Possible cost of labelling.
<b>Compensation costs</b>	To the farmer to compensate for the extra costs associated with buying concentrates with clay minerals, or mixing of the clay minerals themselves.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Animal welfare issues associated with feeding atypically high quantities of clay minerals.
<b>Environmental impact</b>	Effect of extracting large quantities of clay minerals on the landscape if quarry is not already in operation. In early – medium phase clay minerals would be sourced from existing quarries for speed. Possible trace element deficiency in pasture if 'large' quantities of e.g. zeolite are spread to land with slurry
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Policing the countermeasure and averting growth of a black market. Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' resulting in loss of employment in local 'cottage' industries and leading to the need to maintain farming and associated communities. Potential for generating widespread mistrust of the farming practice in relation to food production. Although conversely, there may be a possible increase in public confidence that the problem of contamination is being effectively managed.
<b>Other side effects, pos. or neg.</b>	Can maintain the production of meat and milk without disrupting normal farming practices.
<b>UK Stakeholder opinion</b>	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.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<p><b>Practical experience</b></p>	<p>Bentonite was used in Sweden after Chernobyl, on 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.</p>
<p><b>Key references</b></p>	<p>Unsworth, E. F., Pearce, J., McMurray, C. H., Moss, B. W., Gordon, F. J., and Rice, D. (1989). Investigations of the use of clay minerals and Prussian Blue in reducing the transfer of dietary radiocaesium to milk. <i>The Science of the Total Environment</i>, 85, 339-347.</p> <p>Voigt, G. (1993). Chemical methods to reduce the radioactive contamination of animals and their products in agricultural ecosystems. <i>The Science of the Total Environment</i>, 137, 205-225.</p>
<p><b>Comments</b></p>	<p>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 from farm animals. Yet, this is not believed to reach levels of concern in practice.</p> <p>Live-monitoring prior to slaughtering can be a good supplement to control the effectiveness of the countermeasure for each animal or a selection within a herd/flock.</p> <p>Radiostrontium: Clay minerals have also been suggested as feed-additive binders for radiostrontium.</p> <p>In comparatively recent studies Hansen, Saether, Asper &amp; 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 0.5 g kg<sup>-1</sup> live weight d<sup>-1</sup> 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 countermeasure for Sr, further work would be required to determine if trace mineral metabolism was adversely affected.</p>

Table B3.8 Distribution of saltlicks containing AFCF

<b>Distribution of saltlicks containing AFCF</b>	
<b>Objective</b>	To reduce activity concentrations of radiocaesium in meat or milk of free-grazing animals to below intervention levels.
<b>Other Benefits</b>	Reduction in quantities of animal produce that will need to be disposed off. Normal animal management/grazing regimes can be maintained.
<b>Countermeasure description</b>	In salt deficient areas the intake of salt by grazing animals may be sub-optimal and saltlicks are placed on pastures to supplement their intake. Ammonium iron hexacyanoferrate (AFCF, Giese-salt) can be added to such licks (at 2.5%) to reduce the uptake of radiocaesium in the animal's gut. Since AFCF is an extremely effective radiocaesium binder this will greatly reduce the contamination of milk/meat.
<b>Target</b>	Milk and meat producing ruminants.
<b>Targeted radionuclides</b>	Radiocaesium.
<b>Scale of application</b>	Large.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre-intervention</b>	Ingestion of contaminated milk or meat.
<b>Time of application</b>	Can be distributed shortly after radioactive fallout if animals are grazing outdoors. Must be repeated seasonally/annually.
<b>Constraints</b>	
<b>Legal constraints</b>	The sale of milk and meat intended for human consumption are subject to Council Food Intervention Levels (CFILs). 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. May not be allowed under some organic production regimes.
<b>Social constraints</b>	Acceptability to farmers, food industry and consumers of using an additional feed additive to reduce uptake from the gut of livestock.
<b>Environmental constraints</b>	The pastures must be such that the animals are in need of the salt provided in the saltlicks. In coastal areas the pastures will naturally contain sodium, and the animals would not utilise the saltlicks.
<b>Communication constraints</b>	Possible requirement for labelling products directly or indirectly affected by application of the countermeasure.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Around 50% reduction in uptake of radiocaesium. However, there is considerable variation in effectiveness between animals within a given flock/herd (due to willingness to visit saltlicks).
<b>Factors influencing effectiveness of procedure (technical)</b>	Amount of salt on the pastures. Frequency of the animals' use of the saltlick. Biological half-life of animal breed.
<b>Factors influencing effectiveness of procedure (social)</b>	Compliance/resistance to the countermeasure. Effective administration of the saltlicks.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	None.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Saltlicks are distributed independent of whether AFCF is required or not. Manufacturing plants willing to incorporate AFCF into their products.
<b>Required consumables</b>	Saltlicks containing 2.5 % AFCF.
<b>Required skills</b>	None.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Required safety precautions</b>	None.
<b>Other limitations</b>	None.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	None.
<b>Intervention costs:</b>	
<b>Equipment</b>	None.
<b>Consumables</b>	An additional cost for incorporating the AFCF in the saltlicks. In Norway the normal saltlicks cost 4 EUR while saltlicks with AFCF are produced in Germany and cost 30.6 EUR (including delivery to Norway). The prices given are for 10 kg saltlicks. Each sheep will take up 2-10 g salt per day, a dairy cow 10 times more. Thus, as an example, one 10 kg saltlick is sufficient for 20 sheep during 3 months, or for 20 dairy cows during 10 days.
<b>Operator time</b>	None. The saltlicks are distributed on pastures independent of whether AFCF is needed or not.
<b>Factors influencing costs</b>	Production costs, transportation costs.
<b>Communication costs</b>	Possible cost of labelling.
<b>Compensation costs</b>	None.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Possible change in production status (i.e. organic farming).
<b>Environmental impact</b>	Whilst some soils may contain bacteria or fungi capable of degrading cyanide, toxic levels of HCN should not arise under field conditions.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Policing the countermeasure and averting growth of a black market. Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' resulting in loss of employment in local 'cottage' industries and leading to the need to maintain farming and associated communities. Potential for generating widespread mistrust of the farming practice in relation to food production. Although conversely, there may be a possible increase in public confidence that the problem of contamination is being effectively managed.
<b>Other side effects, pos. or neg.</b>	Can maintain the production of meat and milk without disrupting the normal farming practices.
<b>UK Stakeholder opinion</b>	Unlikely to be an option considered in the UK as most areas are not salt deficient.
<b>Practical experience</b>	Widely used in Norway since 1989 and still in use for cows, sheep, goats and reindeer grazing unimproved pastures. Has proven effective, easily practicable and cheap.

<b>Key references</b>	<p>Giese, W. W. (1988). Ammonium-ferric-cyano-ferrate(II) (AFCF) as an effective antidote against radiocaesium burdens in domestic animals and animal derived foods. <i>Br. Vet. Journal</i>, 144, 363.</p> <p>Hove, K. (1993). Chemical methods for reduction of the transfer of radionuclides to farm animals in semi-natural environments. <i>Science of the Total Environment</i>, 137, 235-248.</p> <p>Hove, K., Hansen, H.S. and Strand, P. (1990). Experience with the use of caesium binders to reduce radiocaesium contamination of grazing animals. In: S. Flitton and E.W. Katz (Eds.), <i>Environmental contamination following a major nuclear accident</i>. International Atomic Energy Agency, Vienna, IAEA-SM-306/36, 2 (1990), pp. 181-189.</p> <p>Pearce, J. (1994). Studies on any toxicological effects of Prussian Blue compounds in mammals – a review. <i>Food Chem. Toxicol.</i>, 32, 577-582.</p> <p>Tveten, U., Brynildsen, L. I., Amundsen, I., and Bergan, T. D. S. (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. <i>J. Environmental Radioactivity</i>, 41 (3), 233-255.</p>
<b>Comments</b>	<p>Detailed toxicological studies have shown that AFCF has no adverse effects on animal or human health. As noted AFCF-saltlicks are only appropriate in areas with a salt deficiency. However, licks are also used to supplement micronutrient supply and these could be used to provide an additional vehicle for the distribution of AFCF. Furthermore, supplementary feeding blocks are distributed in some areas of semi-natural pasture. AFCF has been successfully added to the formulation of these blocks without detrimentally affecting the longevity of the block.</p> <p>Such blocks (which have yet to be field- tested) could provide an alternative to salt licks. Powder containing AFCF gets lumpy when stored, so the Ministry of Trade and Industry in Norway keep a 3-year rolling stock of this. Live-monitoring of animals prior to slaughter is a good supplement in this case since there is a variation between animals in a herd/flock concerning use of the saltlick.</p> <p>Live-monitoring prior to slaughtering can be a good supplement to control the effectiveness of the countermeasure for each animal or a selection within a herd/flock.</p>

**Table B3.9 Administration of AFCF boli to ruminants**

<b>Administration of AFCF boli to ruminants</b>	
<b>Objective</b>	To reduce activity concentrations of radiocaesium in meat or milk of to below intervention levels.
<b>Other Benefits</b>	Reduction in quantities of animal produce that will need to be disposed off. Normal animal management/grazing regimes can be maintained.
<b>Countermeasure description</b>	Slow release boli containing ammonium iron hexacyano ferrate (AFCF, Giese salt) an effective radiocaesium binder, have been developed to reduce the gut uptake of <sup>137</sup> Cs in animals in agricultural and semi-natural environments. Boli are particularly favourable for infrequently handled free-grazing animals like sheep and semi-domesticated reindeer: they can be administered when animals are gathered for routine handling operations.
<b>Target</b>	Milk and meat producing ruminants.
<b>Targeted radionuclides</b>	Radiocaesium.
<b>Scale of application</b>	Distributed to all ruminants eating contaminated feed – especially suitable to free-grazing/infrequently handled animals.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk and meat.
<b>Time of application</b>	2-3 months prior to slaughter for meat producing animals. For milk producing animals every 2-3 months as long as contaminated feed is used.
<b>Constraints:</b>	
<b>Legal constraints</b>	After administration of boli, milk and meat subject to Council food Intervention levels (CFILs). 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. AFCF boli may not be permitted under some organic production regimes.
<b>Social constraints</b>	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 some reindeer herders in Norway, cattle owners in the FSU and sheep farmers in the UK.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Possible requirement for labelling products directly or indirectly affected by application of the countermeasure.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Highly effective: up to 80% reduction in lamb meat and reindeer meat. Up to 70% reduction in cow's milk and 80% reduction in goat's milk. Effectiveness can be variable – but a reduction of 50-65% over a period of 9-11 weeks can be expected for sheep administered 3 waxed boli.
<b>Factors influencing effectiveness of procedure (technical)</b>	Concentration of AFCF in boli and number of boli distributed. Presence of wax coating on the boli (wax coating increases the release period from 2 to 3 months). It is possible that some animals may not be collected for administration – and hence not administered boli. Marking treated animals (e.g. with lanolin based marker fluids) may provide reassurance that animals have been treated. However, treated animals can still regurgitate boli.
<b>Factors influencing effectiveness of procedure (social)</b>	Compliance/resistance to the countermeasure. Effective administration of the boli.

<b>Feasibility:</b>	
<b>Required specific equipment</b>	For sheep, cows and goats the farmer can administer by hand or adapt dosing guns used for other intra-ruminal devices. For reindeer a specifically designed instrument is needed for placing the bolus in the rumen.
<b>Required ancillary equipment</b>	When remote from farmstead, corrals and fences are needed for gathering free-ranging animals prior to distribution.
<b>Required utilities and infrastructure</b>	Factory to manufacture AFCF boli. Currently there are no commercial facilities making boli within western Europe. Roads for distributing the boli to farmers and reindeer herders. Car or snow scooter for veterinarian for reindeer boli use.
<b>Required consumables</b>	Boli with AFCF, fuel for car/snow scooter. Swallowing is eased by immersing boli in liquid paraffin prior to administration.
<b>Required skills</b>	Farmer would have required skills for sheep, cows and goats with little additional training. For reindeer it is important that a veterinarian using the specifically designed instrument for this purpose places the bolus in the rumen. Reindeer deaths have been reported in Norway due to wrong techniques.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	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.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	None.
<b>Intervention costs:</b>	
<b>Equipment</b>	Approximately 60 EUR per specific instrument for reindeer boli use.
<b>Consumables</b>	Approximately 2 EUR per bolus with AFCF for sheep. Fuel for veterinarian's car/snow scooter. Liquid paraffin.
<b>Operator time</b>	For ruminants: the bolus can be administered by the farmer. In Norway it is estimated that administration of 2 boli to sheep by a trained farmer takes 30 seconds per animal. For reindeer: a team of minimum three persons needed; two reindeer breeders holding the animal down, and one veterinarian placing the bolus in the rumen. The working time would be approximately 15 animals per person per hour (45 animals per team per hour) for experienced personnel.  The veterinarian can be paid either per hour or per animal. Additional time would be required to collect animals – although ideally this would be fitted into normal management practices.
<b>Factors influencing costs</b>	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 required.
<b>Communication costs</b>	Possible cost of labelling.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Compensation costs</b>	Authorities may take the view that compensation payments to animal owners for administration time is required. A compensation cost of 20 EUR per reindeer treated has been reported in Norway.
<b>Waste cost</b>	None.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Animal welfare: Reindeer deaths have been reported due to wrong techniques when administering the boli. Change in agricultural production status (especially organic). Interference in traditional practices for reindeer herders.
<b>Environmental impact</b>	Whilst some soils may contain bacteria or fungi capable of degrading cyanide, toxic levels of HCN should not arise under field conditions.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Policing the countermeasure and averting growth of a black market. Loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas is 'safe' resulting in loss of employment in local 'cottage' industries and leading to the need to maintain farming and associated communities. Potential for generating widespread mistrust of the farming practice in relation to food production. Although conversely, there may be a possible increase in public confidence that the problem of contamination is being effectively managed.
<b>Other side effects, pos. or neg.</b>	Can maintain the production of meat and milk without disrupting the normal farming practices.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Used in production systems in Norway and the FSU after the Chernobyl accident. (In FSU a different hexacyanoferrate compound was used).
<b>Key references</b>	Garmo, T. H. and Grønnerud, T. B. (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, W. W. (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, W.W. (1989). Countermeasures for reducing the transfer of radiocaesium to animal derived foods. The Science of the Total Environment, 85, 317-327.

<b>Key references (cont.)</b>	<p>Harbitz, O. and Skuterud, L. (1999). Radioaktiv forurensning – betydning for landbruk, miljø og befolkning. Landbruksforlaget, Oslo, 1999. Radioactive contamination – consequences for agriculture, environment and population. Oslo, 1999 (in Norwegian).</p> <p>Howard, B.J., Beresford, N.A. and Hove, K. (1991). Transfer of radiocaesium to ruminants in unimproved natural and semi-natural ecosystems and appropriate countermeasures. <i>Health Physics</i>, 61, 715-725.</p> <p>Nisbet, A. F. and Woodman, R. F. M. (2000). Options for the Management of Chernobyl-restricted areas in England and Wales. <i>J. Environmental Radioactivity</i>, 51, 239-254.</p> <p>Pearce, J. (1994). Studies on any toxicological effects of Prussian Blue compounds in mammals – a review. <i>Food Chem. Toxicol.</i>, 32, 577-582.</p> <p>Tveten, U., Brynildsen, L. I., Amundsen, I., and Bergan, T. D. S. (1998). Economic consequences of the Chernobyl accident in Norway in the decade 1986-1995. <i>J. Environmental Radioactivity</i>, 41 (3), 233-255.</p>
<b>Comments</b>	<p>Live-monitoring prior to slaughtering can be a good supplement to control the effectiveness of the countermeasure for each animal or a selection within a herd/flock. No known toxicological studies have shown that AFCF has adverse affects on animal or human health</p>

**Table B3.10 Manipulation of slaughter times**

<b>Manipulation of slaughter times</b>	
<b>Objective</b>	To reduce activity concentrations of radionuclides in meat to below intervention levels.
<b>Other Benefits</b>	Reduces quantities of contaminated meat requiring disposal.
<b>Countermeasure description</b>	Immediate slaughter, prior to or soon after deposition, may be considered to prevent contamination reaching the meat. Conversely, the fattening period for farmed animals may be prolonged until activity concentrations in meat decline. Free grazing animals have a seasonal variation in diet and thus a seasonal variation in radiocaesium contamination in meat. By changing the slaughter time to a season of the year when the contamination level is at its lowest, there will be a reduction in activity concentrations in the meat.
<b>Target</b>	Meat producing livestock including farmed animals, free grazing sheep and domesticated reindeer.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large scale.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated meat.
<b>Time of application</b>	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.
<b>Constraints:</b>	
<b>Legal constraints</b>	Meat intended for human consumption is subject to Council Food Intervention Levels (CFILs). Some environmental protection schemes limit grazing intensity at times through the year.
<b>Social constraints</b>	Farmer resistance and disruption to farming practice. Altering slaughtering periods can have profound consequences for annual cycles of farming/herding activity e.g. with respect to availability of manpower, provision of feed over longer periods etc. Markets may be prone to seasonal gluts and shortages.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Dialogue with farmers/herders is necessary to a) ensure understanding of the reasons and conduct of slaughter, and b) identify means of ameliorating negative consequences of countermeasure on other farming and related activities.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Up to 100% for immediate slaughter before contamination. Much more variable following prolonged fattening period. For 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. This can give 75-80% reduction in sheep meat contamination in mushroom rich years. For reindeer: a reduction in meat contamination of up to 85% if the animals are slaughtered in September instead of the traditional winter slaughter in Dec/Jan when lichens form the majority of the diet.

<b>Factors influencing effectiveness of procedure (technical)</b>	Timing of slaughter compared to deposition. Activity concentrations in feed provided over fattening period, including fungi if present. Rate of change of activity concentrations in grazed herbage. Biological half-life, which is animal and radionuclide specific.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of, and compliance with the countermeasure.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Abattoir or slaughtering equipment on farm for immediate slaughter.
<b>Required ancillary equipment</b>	Extra fencing of areas for animal collection.
<b>Required utilities and infrastructure</b>	Transport to take animals to abattoir. Storage/deep freeze facilities could be required if large numbers of animals are slaughtered at the same time.
<b>Required consumables</b>	Additional feed for prolonged fattening period.
<b>Required skills</b>	Slaughtering would be carried out by licensed slaughtermen with necessary skills.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	<p>Immediate slaughter. Capacity of local slaughterhouses to cope with large numbers of animals presented for slaughter before or shortly after deposition. Attention must be paid to any drugs administered to the animals. For every animal drug, there is a specified period between its administration and when the animal can be slaughtered for human consumption. This period ranges from zero to about 60 days. If an immediate slaughter policy is adopted it is possible that some of the slaughtered animals would be unfit for human consumption because of recently administered drugs.</p> <p>Planned delay in slaughtering time. The increase in animal numbers on the farm could cause logistical problems with regard to accommodation and also have implications for animal welfare.</p>
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	None.
<b>Intervention Costs:</b>	
<b>Equipment</b>	None.
<b>Consumables</b>	Additional feed for prolonged fattening. Cartridges for captive bolts etc.
<b>Operator time</b>	Extra work by farmer arranging immediate slaughter or prolonged fattening period. Additional work by abattoir operators or on-farm slaughtermen.
<b>Factors influencing costs</b>	Scale of revised slaughtering programme. Shortage of clean feed. Age of animal following delay to slaughter.
<b>Communication costs</b>	Explaining countermeasure to farmers and those involved in slaughtering of affected livestock.

<b>Compensation costs</b>	<p>Compensation to farmer/reindeer breeder for:</p> <p>(i) 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.</p> <p>(ii) Planned delay in slaughtering time. Poorer meat quality if the slaughter is performed later than usual – it will be fatty and tough. There may be a need to change product description, e.g. lamb may have to be classified as mutton. For both younger and older animals, it is likely that a greater than normal proportion of the carcass would have to be used for low grade meat products, such as mince, sausages and pies, than for prime cuts. Lower price for fur/pelt if the slaughter is performed at a time when the quality is poorer. Additional feed over prolonged fattening period if necessary. Extra work.</p>
<b>Waste cost</b>	None.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Animal welfare must not be compromised by extra time spent at slaughterhouses prior to slaughter, or in travelling long distances to remote slaughterhouses.
<b>Environmental impact</b>	Possible changes in landscape due to changes in grazing pressure.
<b>Agricultural impact</b>	Reduced grazing on fields if immediate slaughter or increased grazing if fattening period prolonged.
<b>Social impact</b>	Disruption to people's image/perception of 'countryside' e.g. if there are no animals or overcrowding of animals in the fields, with potential impacts on tourism etc. Disruption to farming and other related activities. Policing the countermeasure and averting growth of a black market. Disruption to the supply of meat to food industry and market shortages. Appropriate selection of priority areas for application of the countermeasure. Loss of traditional activities.
<b>Other side effects, pos. or neg.</b>	Possible positive impact on biodiversity if grazing period is shortened. Possible negative impact if grazing too intense.
<b>UK Stakeholder opinion</b>	Reassurance, via monitoring programmes, would be necessary to show that livestock have radionuclide concentrations less than intervention limits.
<b>Practical experience</b>	Used in Norway after the Chernobyl accident for sheep, but other countermeasures like the use of saltlicks/boli with AFCF and clean feeding are now dominating. Still in use in Norway for reindeer.
<b>Key references</b>	<p>Dahlgaard, H. (Ed.) (1994). Nordic radioecology – The transfer of radionuclides through Nordic ecosystems to man. Studies in Environmental Science 62, Elsevier, Oxford.</p> <p>Howard, B. J. (1993). Management methods for reducing radionuclide contamination of animal food production semi-natural ecosystems. Science of the Total Environment, 137, 249-260.</p> <p>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.</p>

<b>Comments</b>	<p>For a policy of immediate slaughter to be adopted, there must be contingency plans in place to cope with the legal and practical logistics of transporting thousands of animals at short notice. The possible consequences of a short delay in slaughtering time could be very serious if animals had already become directly contaminated by the deposit or ingested newly contaminated vegetation. In the UK, it is very unlikely that thousands of animals could be slaughtered within a few hours notice, under humane conditions that allow the carcasses to enter the human food chain. Pigs reared and fattened outdoors would be subject to similar constraints as those of ruminant livestock described above. However, the early or late slaughter of pigs may not result in the same penalties with regard to the cash value of the carcass since there are a number of economically viable conventional slaughter weights (i.e. porkers, cutters, baconers and heavy hogs). Thus bringing forward or prolonging the age of slaughter may simply mean changing the slaughter weight category.</p>
-----------------	---

**Table B3.11 Change of hunting season**

<b>Change of hunting season</b>	
<b>Objective</b>	To reduce internal dose to consumers by changing/restricting the hunting season to a period when the contamination levels in game meat are low.
<b>Other Benefits</b>	Traditional hunting for game can be preserved; the amount of condemned meat will be reduced.
<b>Countermeasure description</b>	Hunting is usually restricted to certain periods of the year. Due to seasonal variation in diet the contamination levels in some game species will vary significantly with season. By changing or restricting the hunting season to the time of year when the contamination levels in the game meat will be lowest, the internal dose to humans consuming game meat will be reduced.
<b>Target</b>	Game.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Can be imposed on any scale necessary.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway</b>	Ingestion of contaminated meat.
<b>Time of application</b>	Annually, from short to long term.
<b>Constraints:</b>	
<b>Legal constraints</b>	Existing hunting seasons have a legal status in most countries. In EU countries hunting seasons are strictly based on biological factors by categories of game animals and therefore prolonged seasons do not apply.
<b>Social constraints</b>	Variable depending on local hunting practices. Acceptability of changing hunting seasons raises wildlife issues, which are likely to be contested if seasons would start earlier or last longer than normally. Acceptability to hunters.
<b>Environmental constraints</b>	Changed hunting season must not coincide with breeding; different hunting seasons for male and female animals could be used (as is now the case for many species).
<b>Communication constraints</b>	Debate and dialogue may be required on the ethical premises of countermeasure. Guidelines for hunters.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Up to 65% lower level of radiocaesium in moose meat if optimised hunting practice. Up to 80% reduction in meat contamination for roe deer. Up to 85% reduction in meat contamination for wild reindeer.
<b>Factors influencing effectiveness of procedure (technical)</b>	Mushroom availability to game before and during hunting (varies by year, time of hunting and site). If season is shortened, hunting intensity throughout the season must be considered (e.g. cutting the last days or weeks of hunting season of, for instance, deer animals would not have much effect as the hunting is almost over by then).
<b>Factors influencing effectiveness of procedure (social)</b>	Hunters` compliance and individual willingness to submit to restrictions. Acceptability of the implementation of the countermeasure to the public.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Different seasons may require alternative equipment, for instance when game is transported out of the hunting area.
<b>Required ancillary equipment</b>	None.
<b>Required utilities and infrastructure</b>	Communication lines.
<b>Required consumables</b>	Dependent on communication method.
<b>Required skills</b>	Communication skills.

<b>Required safety precautions</b>	None.
<b>Other limitations</b>	None.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	None.
<b>Intervention costs:</b>	
<b>Equipment</b>	Alternative equipment due to seasonal differences.
<b>Consumables</b>	Production of leaflets.
<b>Operator time</b>	In connection with decision-making, clarifying legislative uncertainties and implementation at a regional level. Design of leaflets. Labour involved in the distribution of leaflets will be minimal, as they can be distributed by post to hunters (e.g. via listings from hunting societies or fire-arms registration certificates).
<b>Factors influencing costs</b>	Scale of the problem connected with hunting. Infrastructure available for communication and exchange of information during processing of information, decision-making and implementation of countermeasure.
<b>Communication costs</b>	Potential need to facilitate widespread debate regarding the ethics and practice of countermeasure. Design and production of leaflets.
<b>Compensation costs</b>	The payments for unused hunting licences must be returned, if restrictions are the reason for cancelling of hunting.
<b>Waste cost</b>	None.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	If implemented successfully, low ethical impact. If unsuccessful (i.e. hunters simply avoiding the contaminated area) possible negative consequences for the community or owner (for private hunting lands) or ecosystem.
<b>Environmental impact</b>	The impact of changes in hunting season on breeding should be considered for each species. The continuous management of large game animals through hunting licenses is of utmost importance to keep the number of animals at as sustainable level. It is thus important to continue the hunting under all circumstances.
<b>Agricultural impact</b>	Possible increased grazing on agricultural lands if hunting season delayed, especially if extended over winter when food sources may be low.
<b>Social impact</b>	Changed relationship to land/forests and potential change of behaviour resulting from changes in people's perceptions of land as a 'natural' resource, to being 'unnatural' or in some way its resources damaged/polluted. Loss of traditional activities.
<b>Other side effects, pos. or neg.</b>	Lower slaughter weights if the hunting is performed earlier than usual. If hunting takes place in summer, hygienic 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. Reduced financing of game management due to cancellation of hunting licences of big mammals.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<b>UK Stakeholder opinion</b>	Unlikely to be an option considered in the UK as game is not a major component of the British diet. However, the public should be able to make an informed choice for game hunted for personal consumption. There should be a ban on the subsequent selling of this meat for entry into the foodchain.
<b>Practical experience</b>	Has been tested/used in Sweden after the Chernobyl accident for moose and roe deer with positive effect, especially for roe deer (see Johanson, 1994).
<b>Key references</b>	<p>Avila, R. (1999). Radiocaesium transfer to roe deer and moose, SSI-news (a newsletter from the Swedish radiation protection institute), volume 7, number 2; Nov 1999</p> <p>Johanson, K.J. (1994). Radiocaesium in game animals in the Nordic countries. In: Dahlgard, H. (Ed.). Nordic radioecology – The transfer of radionuclides through Nordic ecosystems to man. Studies in Environmental Science 62, Elsevier, Oxford, 1994, pp.287-301.</p> <p>Howard B. J, Wright S. M, and Barnett C. L (eds.), (1999). Spatial analysis of vulnerable ecosystems in Europe: Spatial and dynamic prediction of radiocaesium fluxes into European foods (SAVE), Summary &amp; final report, Contract FI4PCT950015, European Commission.</p>
<b>Comments</b>	If only shortening of hunting season is possible, then, if applied, hunting may be less safe due to increasing number of hunters visiting forests during a shorter season. Restrictions in hunting would obviously reduce the number of hunted deer animals. The number of living animals would remain greater than optimal, and that would cause increasing number of road accidents and other damages. Similar consequences have appeared during occurrence of dense elk population (for instance in spring 2002) in Finland.

Table B3.12 Decontamination techniques for milk

<b>Decontamination techniques for milk</b>	
<b>Objective</b>	To remove contamination from milk and return this milk to the foodchain.
<b>Other Benefits</b>	To reduce quantity of contaminated milk to be disposed of. Maintenance of farming communities.
<b>Countermeasure description</b>	Techniques are available for removing radionuclides from milk on a large scale, these include magnetic separation, ion exchange, electrodialysis, ultrafiltration. A relatively new method 'MAG*SEP <sup>SM</sup> ', uses specially coated magnetic particles that selectively remove radioactive contaminants from aqueous liquids, through selective adsorption and magnetic filtration. It has been used on an industrial scale in the Ukraine to decontaminate milk following the Chernobyl accident: the nutritional quality, colour and smell of the milk have not been affected.
<b>Target</b>	Milk.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small to medium.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk.
<b>Time of application</b>	Medium to long term if decontamination equipment not stored for contingency purposes.
<b>Constraints:</b>	
<b>Legal constraints</b>	After treatment, milk intended for human consumption is subject to Council Food Intervention Levels (CFILs). There will be legal constraints on the fate of used exchange resins/ MAG*SEP <sup>SM</sup> resins / ultrafiltration membranes / electrodialysis membranes and salt solutions.
<b>Social constraints</b>	Economic viability. The consumer's perception of decontamination of milk may be similar to that of the practice of food irradiation which consumers have firmly rejected over the years. Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade/consumers when foodstuffs can be obtained from other sources.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Labelling of milk produced by decontamination procedures may be required.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Ion exchange can result in the removal of up to 90% of the radionuclides. Ultrafiltration can result in the removal of over 99% of caesium. Electrodialysis can result in the removal of up to 90% of the radionuclides. MAG*SEP <sup>SM</sup> resins can remove over 99% of caesium.
<b>Factors influencing effectiveness of procedure (technical)</b>	The decontamination process selected. Radionuclide(s) present.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability to farmers and the public.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Decontamination unit.
<b>Required ancillary equipment</b>	None.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Required utilities and infrastructure</b>	Somewhere to site the decontamination unit, i.e. a dairy.
<b>Required consumables</b>	Exchange resins/ MAG*SEP <sup>SM</sup> resins / ultrafiltration membranes / electro dialysis membranes and salt solutions as required.
<b>Required skills</b>	Specific training in the techniques would be required for dairy personnel using the decontamination units. Specific training on the handling of waste would also be required.
<b>Required safety precautions</b>	Dose monitoring of workers handling spent resins/sorbents/filters might be necessary.
<b>Other limitations</b>	There are at present no decontamination units available for use outside the Ukraine. Unless stored as part of contingency plans, such units would need to be imported which would result in delays in implementation. The manufacturers suggest that it would take a further three weeks for a separation unit to be set up to treat milk on an industrial scale.
<b>Waste:</b>	
<b>Amount and type</b>	Used exchange resins/ MAG*SEP <sup>SM</sup> resins / ultrafiltration membranes / electro dialysis membranes and salt solutions. Aqueous waste may also arise from regeneration of exchange resins and sorbents.
<b>Possible transport, treatment and storage routes</b>	Disposal to landfill.
<b>Factors influencing waste issues</b>	Dependent on quantity of resins used. Typically for <sup>137</sup> Cs 20kg of resins are used to treat 100 batches of milk (each batch representing 1 metric ton of milk). If radionuclide concentrations are well in excess of the CFIL, waste stream may be very contaminated. Disposal of such materials would be subject to individual national regulations but might require licensing.
<b>Doses:</b>	
<b>Additional dose</b> <i>(There is a separate datasheet describing the additional dose pathways associated with landfill as a disposal option for the used resins.)</i>	Driver: <ul style="list-style-type: none"> <li>External exposure while transporting contaminated milk to decontamination unit</li> </ul> Operative at decontamination unit: <ul style="list-style-type: none"> <li>External exposure from decontamination unit and disposing of resins</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Decontamination units.
<b>Consumables</b>	Exchange resins/ MAG*SEP <sup>SM</sup> resins/ultrafiltration membranes/ electro dialysis membranes and salt solutions.
<b>Operator time</b>	Tanker driver (10 hour shifts). Installation and operation of decontamination units and disposal of consumables.
<b>Factors influencing costs</b>	Volume of resins/membranes required. Quantities of milk. Contamination levels in milk.
<b>Communication costs</b>	Information and training for operators. Product labelling.
<b>Compensation costs</b>	To farmer or milk purchaser if there is a loss of market value for decontaminated milk. To dairy for handling contaminated milk.
<b>Waste cost</b>	Landfill costs and tax.
<b>Assumptions</b>	That there is a market for the end product. That appropriate monitoring is carried out at dairy.

<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Redistribution of dose from consumers to operators of decontamination units and those involved in the disposal of resins etc., including populations around waste facilities. Distribution of costs and benefits (e.g., possible inequity due to change in prices of decontaminated milk with lower income populations buying the treated milk). Loss of profit to producers if the treated milk is not accepted by consumers. Informed consent may be required.
<b>Environmental impact</b>	Minimal.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Maintenance of farming and associated communities. Possible loss of confidence in products/potential for generating mistrust of food production system. Social rejection of the treated milk or high decrease in market price. Conversely, possible increase in public confidence that the problem of contamination is being effectively managed. Disruption/adjustment of farming and related industrial activities. Disruption to the supply of milk to food industry and potential for market shortages.
<b>Other side effects, pos. or neg.</b>	Ion exchange and electro dialysis can result in adverse effects on the nutritional quality or organoleptic properties of the milk. MAG*SEP <sup>SM</sup> does not adversely affect milk quality.
<b>UK Stakeholder opinion</b>	Unlikely to be an option considered in the UK for all but the most severe and unlikely accidents. The dairy industry and British Retail Consortium consider that it would be unacceptable from a consumer's perspective to produce clean milk from contaminated raw milk. Furthermore, dairies would be unwilling to accept contaminated milk into their processing plants.
<b>Practical experience</b>	MAG*SEP <sup>SM</sup> was used in the Ukraine following Chernobyl.
<b>Key references</b>	<p>Long, S., Pollard, D., Cunningham, J. D., Astasheva, N. P., Donskaya, G.A. and Labetsky, E. V. (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. <i>Journal of Radioecology</i>, 3 (1), 15-30.</p> <p>Mercer, J., Nisbet, A. F. and Wilkins, B. T. (2002). Management options for food production systems affected by a nuclear accident: 4 Emergency monitoring and processing of milk. NRPB-W15.</p> <p>Patel, A. A. and Prasad, S. R. (1993). Decontamination of radioactive milk – a review. <i>International Journal of Radiation Biology</i>, 63 (3), 405-412.</p>

**Table 3.13 Processing of milk for subsequent human consumption**

<b>Processing of milk for subsequent human consumption</b>	
<b>Objective</b>	To produce milk products with activity concentrations less than intervention levels from contaminated liquid milk that would be suitable for human consumption with or without a period of storage.
<b>Other Benefits</b>	To reduce quantity of contaminated milk for disposal.
<b>Countermeasure description</b>	Processing would permit milk contaminated at levels above the CFIL to be used for human consumption. Processing raw milk into butter, standard cheese and processed cheese may be used to reduce activity concentration of radiocaesium and radiostrontium. For <sup>131</sup> I, transformation into products with longer shelf-life such as cheese, UHT milk and canned goods is effective due to short physical half life of this radionuclide. Processing nevertheless produces contaminated by-products.
<b>Target</b>	Milk.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small to medium scale.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated milk.
<b>Time of application</b>	Early to medium term.
<b>Constraints:</b>	
<b>Legal constraints</b>	The sale of dairy products intended for human consumption is subject to Council Food Intervention Levels (CFILs).
<b>Social constraints</b>	Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade when foodstuffs can be obtained from other sources. The principle of informed consent suggests that such foodstuffs should have their origins labelled, and consumers are likely to prefer 'clean' foodstuffs. If prices are lowered in response to this demand pattern, there is an inequitable distribution of the residual contamination to poorer populations, and the possibility of their consuming a higher than average dose from residual contamination. Reluctance of driver to transport contaminated milk. Reluctance of processing plant to accept contaminated milk.
<b>Environmental constraints</b>	None, although there could be an indirect environmental impact depending on disposal route chosen for by-products.
<b>Communication constraints</b>	Labelling of treated products.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Milk products prepared by isolating the fat and/or protein components from the aqueous fraction tend to be depleted in radiocaesium and radioiodine compared with raw whole milk. Examples would be butter, cream, hard cheese, cottage cheese, casein and whey protein concentrates. Radiostrontium closely follows the behaviour of calcium. Hence, products such as cottage cheese, cream and butter, which are relatively low in calcium, tend to have low levels of radiostrontium while high calcium products such as skim milk and cheese have higher levels of radiostrontium.

<p><b>Countermeasure effectiveness (cont.)</b></p>	<p>However, the transfer of radiostrontium during cheese making is affected by the method of coagulation used. If rennet coagulation is used the transfer of radiostrontium to the cheese is usually increased. If acid coagulation is used the transfer of radiostrontium to the cheese whey is increased.</p> <p>The change in radionuclide content of a foodstuff due to processing may be assessed by calculating the food processing retention factor. This indicates the fraction of the radionuclide which remains in the food following processing and is shown by the equation below:</p> $\text{Processing retention factor} = \frac{\text{Total activity of the factor radionuclide in the processed food (Bq)}}{\text{Total activity of the radionuclide in the raw material (Bq)}}$ <p>The processing retention factors of various milk products are:</p> <p><b>Radiocaesium</b></p> <table border="0"> <tr><td>Milk powder</td><td>1.00</td></tr> <tr><td>Cheese (rennet)</td><td>0.04-0.23</td></tr> <tr><td>Cheese whey (rennet)</td><td>0.75-0.95</td></tr> <tr><td>Cheese (acid)</td><td>0.11-0.12</td></tr> <tr><td>Cheese whey (acid)</td><td>0.75-0.90</td></tr> <tr><td>Cream</td><td>0.02-0.16</td></tr> <tr><td>Butter</td><td>0.003-0.49</td></tr> <tr><td>Skim milk</td><td>0.85-0.99</td></tr> <tr><td>Cottage cheese (rennet)</td><td>0.01-0.1</td></tr> <tr><td>Cottage cheese (acid)</td><td>0.1</td></tr> </table> <p><b>Radiostrontium</b></p> <table border="0"> <tr><td>Milk powder</td><td>1.00</td></tr> <tr><td>Cheese (rennet)</td><td>0.1-0.8</td></tr> <tr><td>Cheese whey (rennet)</td><td>0.2-0.8</td></tr> <tr><td>Cheese (acid)</td><td>0.04-0.08</td></tr> <tr><td>Cheese whey (acid)</td><td>0.7-0.9</td></tr> <tr><td>Cream</td><td>0.07</td></tr> <tr><td>Butter</td><td>0.02-0.15</td></tr> <tr><td>Skim milk</td><td>0.89-0.95</td></tr> <tr><td>Cottage cheese (rennet)</td><td>0.03-0.3</td></tr> <tr><td>Cottage cheese (acid)</td><td>0.07-0.2</td></tr> </table>	Milk powder	1.00	Cheese (rennet)	0.04-0.23	Cheese whey (rennet)	0.75-0.95	Cheese (acid)	0.11-0.12	Cheese whey (acid)	0.75-0.90	Cream	0.02-0.16	Butter	0.003-0.49	Skim milk	0.85-0.99	Cottage cheese (rennet)	0.01-0.1	Cottage cheese (acid)	0.1	Milk powder	1.00	Cheese (rennet)	0.1-0.8	Cheese whey (rennet)	0.2-0.8	Cheese (acid)	0.04-0.08	Cheese whey (acid)	0.7-0.9	Cream	0.07	Butter	0.02-0.15	Skim milk	0.89-0.95	Cottage cheese (rennet)	0.03-0.3	Cottage cheese (acid)	0.07-0.2
Milk powder	1.00																																								
Cheese (rennet)	0.04-0.23																																								
Cheese whey (rennet)	0.75-0.95																																								
Cheese (acid)	0.11-0.12																																								
Cheese whey (acid)	0.75-0.90																																								
Cream	0.02-0.16																																								
Butter	0.003-0.49																																								
Skim milk	0.85-0.99																																								
Cottage cheese (rennet)	0.01-0.1																																								
Cottage cheese (acid)	0.1																																								
Milk powder	1.00																																								
Cheese (rennet)	0.1-0.8																																								
Cheese whey (rennet)	0.2-0.8																																								
Cheese (acid)	0.04-0.08																																								
Cheese whey (acid)	0.7-0.9																																								
Cream	0.07																																								
Butter	0.02-0.15																																								
Skim milk	0.89-0.95																																								
Cottage cheese (rennet)	0.03-0.3																																								
Cottage cheese (acid)	0.07-0.2																																								
<p><b>Factors influencing effectiveness of procedure (technical)</b></p>	<p>Radionuclide(s) present, fat content of milk, process selected. In the making of cheese, radiostrontium transfer is affected by the method of coagulation used: if rennet coagulation is used the transfer of radiostrontium is usually increased.</p>																																								
<p><b>Factors influencing effectiveness of procedure (social)</b></p>	<p>Acceptability and marketability of end product.</p>																																								
<p><b>Feasibility:</b></p>																																									
<p><b>Required specific equipment</b></p>	<p>Milk processing plant, special facilities may be required for milk products undergoing storage.</p>																																								
<p><b>Required ancillary equipment</b></p>	<p>Milk tankers.</p>																																								

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Required utilities and infrastructure</b>	Waste treatment facilities licensed to accept contaminated by-products.
<b>Required consumables</b>	Fuel for tankers.
<b>Required skills</b>	Operators at milk processing plants will have the required skills.
<b>Required safety precautions</b>	Consider respiratory protection if appropriate for operators (e.g. production of skim milk powder).
<b>Other limitations</b>	Capacity of processing plants within the affected area to accept additional raw milk for processing. There might be reluctance to move contaminated milk to a processing plant located outside a contaminated area that would affect total capacity.
<b>Waste:</b>	
<b>Amount and type</b>	Percentage by mass of waste by-products generated in the production of various milk products for consumption: Cheese = 88% is cheese whey. Butter = 52% is buttermilk Cream=90% is skim milk Cottage cheese=85% cottage cheese whey Milk powder/skim milk powder = no contaminated by-product just 80-90% water Contaminated water from washing and rinsing of tankers.
<b>Possible transport, treatment and storage routes</b>	Dairy effluent plant & sewage treatment works.
<b>Factors influencing waste issues</b>	Type of milk processing undertaken. High biological oxygen demand (BOD) associated with milk.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Pathways in italics are for the subsequent transportation of waste for storage or disposal. The waste by-products from processing would undergo biological treatment: there is a separate datasheets for the biological treatment of milk that outlines the additional dose pathways.)</i>	Driver: <ul style="list-style-type: none"> <li>External exposure while transporting contaminated milk to processing plant</li> <li><i>External exposure while transporting milk products to storage facility</i></li> <li><i>External exposure while transporting contaminated waste by-products for storage and disposal</i></li> </ul> Dairy operative: <ul style="list-style-type: none"> <li>External exposure to milk (dependant on the location of the control room from the machinery) at processing plant</li> </ul> Operative at milk powder storage facility: <ul style="list-style-type: none"> <li><i>External exposure from stored milk products</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Minimal. Processing equipment already available.
<b>Consumables</b>	Additional consumables required to process raw milk. Fuel for transportation.
<b>Operator time</b>	Tanker driver (10 hour shifts). Operators at processing plant if additional manpower required.
<b>Factors influencing costs</b>	Distance to processing plant, quantity of milk for processing, length of storage time.
<b>Communication costs</b>	Possible cost of labelling.
<b>Compensation costs</b>	To farmer or milk purchaser if there is a loss of market value for processed milk products. To processing plants for handling contaminated milk and if equipment required decontamination.

<b>Waste cost</b>	Cost of disposal of by-products to sewage treatment plants if not carried out <i>in situ</i> at a dairy effluent plant.
<b>Assumptions</b>	That there is a market for the end products. That appropriate monitoring is carried out at processing plant.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Informed consent. Distribution of costs and benefits (e.g., possible inequity due to change in prices of processed milk with lower income populations buying the treated food). Loss of profit to producers if the treated food is not accepted by consumers.
<b>Environmental impact</b>	None, although there could be an indirect environmental impact depending on disposal route chosen for by-products.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Maintenance of farming and associated communities. Possible loss of confidence in products/potential for generating mistrust of food production system. Disruption/adjustment of farming and related industrial activities. Disruption to the supply of milk to food industry and potential for market shortages.
<b>Other side effects, pos. or neg.</b>	Parts of the processing plant may become contaminated.
<b>UK Stakeholder opinion</b>	Unlikely to be an option considered in the UK for all but the most severe and unlikely accidents. The dairy industry, the Meat and Livestock Commission and British Retail Consortium consider that it would be unacceptable from a consumers' perspective to produce milk products from contaminated raw milk. Furthermore, dairies would be unwilling to accept contaminated milk into their processing plants.
<b>Practical experience</b>	Existing commercial process.
<b>Key references</b>	<p>Long, S., Pollard, D., Cunningham, J. D., Astasheva, N. P., Donskaya, G. A. and Labetsky, E. V. (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. <i>Journal of Radioecology</i>, 3 (1), 15-30.</p> <p>Mercer, J., Nisbet, A. F. and Wilkins, B. T. (2002). Management options for food production systems affected by a nuclear accident: 4 Emergency monitoring and processing of milk. NRPB-W15.</p> <p>Wilson, L., Bottomley, R. and Sutton, P. (1988). Transfer of radioactive contamination from milk to commercial dairy products. <i>Journal of the Society of Dairy Technology</i>, 41 (1), 10-13.</p>
<b>Comments</b>	The processing of milk into dairy products suitable for the foodchain does not remove the need for disposal of other higher activity by-products. These like the liquid milk from which they were derived may also have high BODs.

**Table B3.14 Salting of meat for subsequent human consumption**

<b>Salting of meat for subsequent human consumption</b>	
<b>Objective</b>	To produce meat products with activity concentrations less than intervention levels from contaminated raw meat. The meat would be suitable for human consumption with or without a period of storage.
<b>Other Benefits</b>	To reduce quantity of meat requiring disposal.
<b>Countermeasure description</b>	Meat producing livestock that have been slaughtered with activity concentrations of radiocaesium above intervention levels may undergo salting either at commercial facilities or in the home. Salting of meat can achieve some reductions in the final activity concentration of radiocaesium in meat. Meat pieces (200g) are soaked in dilute NaCl brine (5%) using two successive treatments of 2 days each.
<b>Target</b>	Meat (Livestock & Game).
<b>Targeted radionuclides</b>	Radiocaesium.
<b>Scale of application</b>	Small to medium.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway pre intervention</b>	Ingestion of contaminated meat.
<b>Time of application</b>	Early to medium term.
<b>Constraints:</b>	
<b>Legal constraints</b>	The sale of meat intended for human consumption is subject to Council Food Intervention Levels (CFILs).
<b>Social constraints</b>	Foodstuffs with activity concentrations that have been brought below the relevant CFIL by processing may not be acceptable to the retail trade. Given consumer choice and the multiplicity of supply, consumers may also not wish to purchase 'decontaminated' meat. The principle of informed consent suggests that such foodstuffs should have their origins labelled, and consumers are likely to prefer 'clean' foodstuffs. If prices are lowered in response to this demand pattern, there is an inequitable distribution of the residual contamination to poorer populations, and the possibility of their consuming a higher than average dose from residual contamination. Markets for processed meat. Reluctance of processing plants to accept contaminated meat.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Labelling of treated meat.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	After soaking in salt solution, radiocaesium contamination of meat is reduced by up to 80%.
<b>Factors influencing effectiveness of procedure (technical)</b>	Size of the meat pieces treated - if large pieces a maximum reduction in radiocaesium contamination of 40-50% can be expected. Concentration of salt solution. Length of treatment.
<b>Factors influencing effectiveness of procedure (social)</b>	None.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Food processing plant to carry out salting of meat.
<b>Required ancillary equipment</b>	Vehicles to transport contaminated meat to processing plant.
<b>Required utilities and infrastructure</b>	Waste treatment facilities for disposal of by-products.
<b>Required consumables</b>	Fuel for vehicles, additional salt.

<b>Required skills</b>	Operators at processing plants should have the required skills.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	Capacity of processing plants, willingness to accept contaminated meat.
<b>Waste:</b>	
<b>Amount and type</b>	Large volumes of contaminated salt solution.
<b>Possible transport, treatment and storage routes</b>	On-site treatment plants & sewage treatment works.
<b>Factors influencing waste issues</b>	Quantity of meat being treated and its level of contamination.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Dose pathways in italics are indirectly incurred as a result of transportation of wastewater. Any waste water generated during processing will either be treated on site or at a Sewage Treatment Works (STW): the relevant dose pathways for this disposal route are given in Table C2: Landfill.)</i>	<p>Driver:</p> <ul style="list-style-type: none"> <li>External exposure while transporting contaminated meat to the processing plant</li> <li><i>External exposure while transporting wastewater to STW</i></li> </ul> <p>Meat processing plant operatives:</p> <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and hand skin exposure from meat at processing plant</li> <li>Inadvertent ingestion of meat juices while cutting up meat</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Commercial processing equipment is already available.
<b>Consumables</b>	Fuel to transport meat. Additional salt/brine to process additional volumes of meat.
<b>Operator time</b>	Drivers for transporting contaminated meat to commercial facilities. Operators at processing plant if additional manpower required.
<b>Factors influencing costs</b>	Quantity of meat. Distance to processing plant
<b>Communication costs</b>	Possible cost of labelling.
<b>Compensation costs</b>	To farmers if receive reduction in income because processed meat has a lower value. To processing plants for handling contaminated meat and if equipment subsequently requires decontamination.
<b>Waste cost</b>	Cost of disposal of salt solutions to sewage treatment plant.
<b>Assumptions</b>	That there is a market for the end products. That appropriate monitoring is carried out at processing plant.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Informed consent. Distribution of costs and benefits (e.g., possible inequity due to change in price of salted meat, with lower income populations buying the treated food). Loss of profit to producers if the treated food is not accepted by consumers.
<b>Environmental impact</b>	Disposal of salt solution should have minimal environmental impact.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Maintenance of farming and associated communities. Possible loss of confidence in products/potential for generating mistrust of food production system. Disruption/adjustment of farming and related industrial activities. Disruption to the supply of meat to food industry and potential for market shortages.

<b>Other side effects, pos. or neg.</b>	Soaking meat in brine can affect its nutritional value removing water-soluble vitamins, water-soluble proteins and salt soluble proteins. It may also affect the flavour of the meat.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	None.
<b>Key references</b>	Petajsa, E., Rantavaara, A., Paakkola, O. and Puolanne, E. (1992). Reduction of radioactive caesium in meat and fish by soaking. <i>Journal of Environmental Radioactivity</i> , 16, 273-285.
<b>Comments</b>	The texture of meat is not altered significantly and the salt content is only increased slightly. The technique is also applicable to contaminated fish

Table B3.15 Live monitoring

<b>Live monitoring</b>	
<b>Objective</b>	To determine whether activity concentration in animals are below the intervention limits.
<b>Other Benefits</b>	Reassurance. Optimisation of other countermeasure techniques.
<b>Countermeasure description</b>	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, 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, countermeasures such as clean feeding, or administration of AFCF in concentrates can then be used to lower the activity concentration before slaughter. The practice of live monitoring will thus reduce the need for meat condemnation.
<b>Target</b>	Meat-producing livestock (e.g. cattle, sheep, goat and reindeer)
<b>Targeted radionuclides</b>	Radiocaesium, radiodine.
<b>Scale of application</b>	Large scale when monitors are available.
<b>Contamination pathway</b>	Plant to animal transfer.
<b>Exposure pathway</b>	Ingestion of contaminated meat.
<b>Time of application</b>	Early to long term. At times when livestock are being moved from a restricted area or just before slaughter.
<b>Constraints:</b>	
<b>Legal constraints</b>	Meat intended for human consumption is subject to Council Food Intervention Levels (CFILs). Guidelines for animal welfare must be followed.
<b>Social constraints</b>	Disruption to farming practice. Resistance by farmer.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	Possible requirement for labelling products that have been subject to live monitoring.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	Highly effective (near 100 %) at excluding meat above intervention level from food chain.
<b>Factors influencing effectiveness of procedure (technical)</b>	Accuracy of conversion factors of activity concentration in live animals to those in the meat. Adequate shielding of monitors will be required in highly contaminated areas or areas with high natural background. Duration of counting time. Weather conditions – equipment needs to be weatherproof (i.e. resistant to low temperatures, snow etc under field conditions).
<b>Factors influencing effectiveness of procedure (social)</b>	Divergence from standard practice. Efficient use of equipment/good administrative system.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Portable, lead-shielded, NaI detector linked to single- or multi- channel analysers – calibrated for animals being monitored.
<b>Required ancillary equipment</b>	Restraints for livestock (e.g. cattle crush) will probably be required whilst monitoring being carried out.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Required utilities and infrastructure</b>	Penned area to contain livestock before monitoring.
<b>Required consumables</b>	Paint and ear tags to mark failed animals.
<b>Required skills</b>	Monitoring would be carried out by trained personnel. Animal handling experience/training would also be preferred. Ideally team would consist of two people with farmer providing assistance (catching animals etc.). More people may be required if large animal (e.g. cattle, horses, reindeer) are being monitored.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	Depending on scale of accident, availability of NaI detectors may be limited. Consider time required to manufacture/repair existing kits. Similarly, there may be a shortage of trained personnel. Consider time required to carry out training.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Monitoring operative: <ul style="list-style-type: none"> <li>External exposure, inadvertent ingestion and hand skin exposure from livestock while monitoring</li> <li>External exposure from land while working in a contaminated area</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Portable, lead-shielded, NaI detector linked to single- or multi- channel analysers. New equipment will need to be purchased to meet demand.
<b>Consumables</b>	Fuel for monitoring vehicles. Running costs for repairs and maintenance of detectors.
<b>Operator time</b>	Work rates should take into account: travel time to/from an area and between farms; time required to set up equipment, including taking background readings; time required to monitor livestock; number of staff per team.
<b>Factors influencing costs</b>	Distances to farms, numbers of animals.
<b>Communication costs</b>	Farmer needs to be aware of the implications of the measurement data, particularly for those animals exceeding intervention levels. Possible cost of labelling.
<b>Compensation costs</b>	To farmers for assisting during monitoring and for livestock unable to go to market because activity concentrations in the meat are in excess of the intervention level
<b>Waste cost</b>	None.
<b>Assumptions</b>	None.
<b>Side-effect evaluation</b>	
<b>Ethical considerations</b>	Precautionary and reduces uncertainties. Partially self-help for farmer, especially if performed with training.
<b>Environmental impact</b>	None.
<b>Agricultural impact</b>	No direct impact. However, slaughter times could be delayed until activity concentrations fall below intervention levels. This represents a loss of flexibility in marketing practice. Delay may also result in the production of overfat lambs and beef cattle.

<b>Social impact</b>	Depending on results, the countermeasure could be either reassuring or depressing for the farmer. The farmer may need counselling. Possible increase in public confidence that the problem of contamination is being effectively managed.
<b>Other side effects, pos. or neg.</b>	Information on activity levels in livestock and how this changes between years.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Used in the UK from 1986 until present (2004) for monitoring lambs from Chernobyl restricted areas. Used in Norway from 1987 until present (2004) to monitor lambs and reindeer from Chernobyl restricted areas. In the early years, also used for monitoring cattle and goats. Ireland and Sweden monitor carcasses at slaughterhouses.
<b>Key references</b>	<p>Brynildsen, L. and Strand, P. (1994). A rapid method for the determination of radioactive caesium in live animals and carcasses and its practical application in Norway after the Chernobyl accident. <i>Acta Vetrinaria Scandinavica</i>, 35, 401-408.</p> <p>Meredith, R. C. K., Mondon, K. J. and Sherlock, J. C. (1988). A rapid method for the in vivo monitoring of radiocaesium activity in sheep. <i>J. Environ. Radioactivity</i>, 7, 209-214.</p> <p>Nisbet, A. F. and Woodman, R. F. M. (1999). Options for the management of Chernobyl restricted areas in England and Wales. NRPB-R305.</p>

## **APPENDIX C WASTE DISPOSAL OPTIONS**

Table C1: Incineration

<b>Incineration</b>	
<b>Objective</b>	To reduce volume of contaminated food products prior to disposal and to produce a stable end product.
<b>Other Benefits</b>	None.
<b>Countermeasure description</b>	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.
<b>Target</b>	Contaminated cereals, vegetables, fruit, fish, rendered meat, eggs, milk powder, honey, mushrooms, berries, grass.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Medium to large.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	Early to late.
<b>Constraints:</b>	
<b>Legal constraints</b>	Possible need for radiation protection training of workers. Relevant EC legislation is given below: Waste Incineration Directive 2000/76/EC Animal Waste Directive 90/667/EC Integrated Pollution Prevention and Control Directive 96/61/EC
<b>Social constraints</b>	Unlikely to be acceptable to the public if the crops/carcasses have to be incinerated outside the affected area. Local opposition to incinerators due to negative perception of health effects, particularly dioxins. Opposition to disposal of radioactively contaminated material by incineration very likely. Local opposition to building new incinerators. However 2000/76/EC allows public to comment before decision is made.
<b>Environmental constraints</b>	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.
<b>Communication constraints</b>	Operators require information on the incineration of contaminated material. Likely requirement to monitor air/water quality in area neighbouring the incinerator and publish results.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A.
<b>Factors influencing effectiveness of procedure (technical)</b>	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.

<p><b>Factors influencing effectiveness of procedure (technical) (cont.)</b></p>	<p>To produce a feedstock that will sustain combustion the feedstock should have the following characteristics:</p> <p>Energy value: minimum 6 MJ kg<sup>-1</sup>  Moisture content: maximum 35%  Combustibles content: minimum 30%</p> <p>In addition, the operating temperature of incinerator, combustion conditions and physio-chemical form of the radionuclides and the waste also affect this procedure. The temperature of a municipal waste incinerator furnace must be maintained above 900°C. Nuclides which volatilise at temperatures below the operating temperatures of the furnace would be found in the exhaust gases (i.e. iodine volatilises at 184°C, caesium at 671°C and selenium at 685°C). It would therefore be expected that some fraction of these elements activity would be released in the exhaust gases. Elements that volatilise at temperatures higher than 900°C will be retained in the ash.</p> <p>The majority of carcass incineration plants burn less than one tonne per hour and are not large enough to accommodate a whole bovine carcass. During the Foot and Mouth (FMD) crisis all facilities capable of taking whole bovine carcasses were fully committed to the disposal of either BSE infected cattle, Specified Risk Material (SRM) or cattle destroyed under the Over Thirty Months Scheme (OTMS).</p>
<p><b>Factors influencing effectiveness of procedure (social)</b></p>	<p>Compliance/resistance to incineration. There is potential for a black market in slaughtered meat/condemned crops.</p>
<p><b>Feasibility:</b></p>	
<p><b>Required specific equipment</b></p>	<p>Commercial incinerators, on-farm incinerators and mobile air-curtain incinerators capable of disposing of crops and/or mammalian carcasses.</p>
<p><b>Required ancillary equipment</b></p>	<p>Vehicles for transporting crops/carcasses to incineration site and ash to landfill site.</p>
<p><b>Required utilities and infrastructure</b></p>	<p>Disposal route for ash. If ash can't immediately be sent to landfill it must be safely stored.</p>
<p><b>Required consumables</b></p>	<p>Fuel for transporting crops/carcasses to incineration site and to run incinerator. Mobile air-curtain incinerators only work effectively when fed with dry seasoned timber.</p>
<p><b>Required skills</b></p>	<p>Trained personnel will be available at incineration facilities.</p>
<p><b>Required safety precautions</b></p>	<p>Respiratory equipment. Protective clothing and equipment.</p>
<p><b>Other limitations</b></p>	<p>Foodstuffs need to be mixed with other materials to produce feedstock that will sustain combustion. Typical incinerator feedstock should have the following characteristics:</p> <ul style="list-style-type: none"> <li>• Energy value: minimum 6 MJ kg<sup>-1</sup></li> <li>• Moisture content: maximum 35%</li> <li>• Combustibles content: minimum 30%</li> </ul>

<b>Other limitations (cont.)</b>	The majority of carcass incineration plants burn less than one tonne per hour and are not large enough to accommodate a whole bovine carcass. The majority of small on-farm incinerators burn less than 50 kg per hour and can not accommodate large animals.
<b>Waste:</b>	
<b>Amount and type</b>	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.
<b>Possible transport, treatment and storage routes</b>	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.
<b>Factors influencing waste issues</b>	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.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Dose pathways in italics are indirectly incurred as a result of incineration.</i> <i>There is a separate datasheet for landfill as a disposal option for the residual ash.)</i>	Incineration Plant Operative: <ul style="list-style-type: none"> <li>External, inhalation, inadvertent ingestion and facial skin exposure to fly ash while cleaning the incinerator</li> </ul> Drivers (External exposure): <ul style="list-style-type: none"> <li>Transporting residual ash to landfill site</li> </ul> Farmer Ploughing Land: <ul style="list-style-type: none"> <li>External, inhalation and inadvertent ingestion of material deposited by incinerator stack while ploughing</li> </ul> Public: <ul style="list-style-type: none"> <li>External and inhalation exposure from material deposited by incinerator stack</li> <li><i>Ingestion of food grown on land where material from incinerator stack is deposited</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Incineration facility.
<b>Consumables</b>	Fuel for transporting food products to incineration plant and to run incinerator.
<b>Operator time</b>	Time to transport food products. Incineration plant operatives for processing additional material.
<b>Factors influencing costs</b>	Volumes of food products and requirements for pre-treatment. Distance between farm and incinerator. Calorific value of material (costs increase with calorific value).

<b>Communication costs</b>	Dissemination of information about incineration of contaminated produce to farmers and the public.
<b>Compensation costs</b>	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.
<b>Waste cost</b>	Transportation of ash to disposal site. Cost of landfill - charges/tax if appropriate.
<b>Assumptions</b>	Fly ash and gases are collected by filtering system and not released into the atmosphere.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Additional dose to incinerator operators and populations living close to incineration plants. Consent of incinerator workers. Environmental risk.
<b>Environmental impact</b>	<p>Atmospheric emissions from incineration include</p> <ul style="list-style-type: none"> <li>• Gases: CO, CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, etc.</li> <li>• Mineral dust: fly ash (PM10).</li> <li>• Heavy metals: Pb, Cu, Hg, Cd, etc.</li> <li>• Organic molecules: dioxins, furans, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs).</li> </ul> <p>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.</p>
<b>Agricultural impact</b>	Ash has high concentrations of micro and macronutrients that will fertilise the soil.
<b>Social impact</b>	Selection of incinerators.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	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.
<b>Key references</b>	Bontoux, L. (1999). The Incineration of Waste in Europe: Issues and Perspectives, IPTS, March 1999.

<b>Key references (cont.)</b>	<p>Environment Agency (2001). Waste Incineration, November 2001. Website last viewed 6 May 2004: <a href="http://www.environment-agency.gov.uk/yourenv/eff/resources_waste/213982/203410/?version=1&amp;lang=e">http://www.environment-agency.gov.uk/yourenv/eff/resources_waste/213982/203410/?version=1&amp;lang=e</a></p> <p>Stanners, D. and Bourdeau, P. (Eds.) (1995). Europe's Environment: The Dobris Assessment - An overview. European Environment Agency, Copenhagen</p> <p>Woodman, R. F. M., Nisbet, A. F. and Penfold, J. S. S. (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.</p>
<b>Comments</b>	A valuable option when landfill space is scarce.

**Table C2: Landfill**

<b>Landfill</b>	
<b>Objective</b>	To dispose of contaminated food products before or after volume reduction techniques.
<b>Other Benefits</b>	None.
<b>Countermeasure description</b>	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.
<b>Target</b>	Contaminated cereals, vegetables, fruit, compost, fish, rendered meat, eggs, milk powder, honey, mushrooms, berries, incinerator ash, topsoil.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	Early to late phase.
<b>Constraints:</b>	
<b>Legal constraints</b>	Limits on radioactive wastes that can be disposed of to landfill. Limits on amounts of organic wastes that can be disposed of to landfill. Training/consent of workers for handling radioactive wastes. Relevant EC legislation is listed below: EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC) EC Landfill Directive 1999/31/EC. EC Groundwater Directive (80/68/EEC)
<b>Social constraints</b>	Local opposition to use of particular landfill sites e.g. where contaminated crops are disposed of in previously uncontaminated areas.
<b>Environmental constraints</b>	None provided landfill site is fully engineered.
<b>Communication constraints</b>	Likely requirement to monitor area around landfill site and publish results.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A.
<b>Factors influencing effectiveness of procedure (technical)</b>	Large quantities of putrescible wastes can cause instability and uneven settlement in a landfill. These effects mean that it is necessary to restrict the proportion of foodstuffs entering a landfill. The maximum proportion of putrescible wastes which could practicably be disposed of to landfill is estimated to be 50% by weight of the inventory. The contaminated organic waste should only be disposed of to a fully engineered sanitary landfill licensed to accept putrescible waste.
<b>Factors influencing effectiveness of procedure (social)</b>	Willingness of privately owned landfill sites and local populations to accept the wastes. Maintenance of correct landfill procedures.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Landfill site.
<b>Required ancillary equipment</b>	Vehicles for transport of food products, compost, soil and ash to landfill.

<b>Required utilities and infrastructure</b>	Appropriate transport network.
<b>Required consumables</b>	Fuel for transport of food products, compost, soil and ash to landfill.
<b>Required skills</b>	At landfill sites the necessary skills will be available.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions.
<b>Other limitations</b>	Putrescible waste must be thoroughly mixed with inert wastes to provide a suitable medium to allow continuation of normal landfill operations e.g. waste spreading and compaction. Future management of landfills may further restrict quantities of putrescible wastes admitted.
<b>Waste:</b>	
<b>Amount and type</b>	Leachate, landfill gas (methane and carbon dioxide).
<b>Possible transport, treatment and storage routes</b>	<p>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.</p> <p>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</p>
<b>Factors influencing waste issues</b>	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.
<b>Doses:</b>	
<p><b>Additional dose</b></p> <p><i>(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.)</i></p>	<p>Landfill Site Operative:</p> <ul style="list-style-type: none"> <li>• External exposure, inhalation of dust and inadvertent ingestion of dirt while landfilling contaminated material</li> </ul> <p><i>Sewage Treatment Works Operative:</i></p> <ul style="list-style-type: none"> <li>• <i>External exposure and inadvertent ingestion of leachate and sludge during treatment</i></li> <li>• <i>External, inhalation and inadvertent ingestion exposure loading cake onto wagons</i></li> </ul> <p>Drivers (External Exposure):</p> <ul style="list-style-type: none"> <li>• Transporting leachate to STW's</li> <li>• <i>Transporting sludge and cake to place of disposal (e.g. farmland)</i></li> </ul> <p><i>Farmer Applying Sludge or Cake to Land:</i></p> <ul style="list-style-type: none"> <li>• <i>External exposure, inadvertent ingestion and inhalation of sludge or cake while loading spreader</i></li> <li>• <i>External exposure while spreading sludge or cake</i></li> <li>• <i>External exposure, inhalation and inadvertent ingestion while ploughing sludge or cake</i></li> </ul>

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Additional dose (cont.)</b>	<p><i>Public:</i></p> <ul style="list-style-type: none"> <li><i>Ingestion of food grown on land spread with sludge or cake</i></li> <li><i>Ingestion of drinking water and freshwater fish extracted from rivers to which STW's effluent is discharged</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Landfill site – costs for disposing of waste to landfill (including landfill tax). Suitable vehicle for transport.
<b>Consumables</b>	Fuel for transport (depending on distance).
<b>Operator time</b>	Additional work by landfill operator as required. Additional journeys made by lorry driver.
<b>Factors influencing costs</b>	Volume of material to be disposed of. Distance to landfill site. Future increases in landfill tax.
<b>Communication costs</b>	Dialogue and dissemination of information about this waste disposal option (its rationale and possible alternatives) within affected communities.
<b>Compensation costs</b>	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.
<b>Waste cost</b>	Included in landfill costs. Treatment of leachate at STW's.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Additional dose to site operators and populations living close to disposal sites. Consent of landfill workers. Environmental risk.
<b>Environmental impact</b>	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.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Potential for dispute regarding waste disposal sites and selection of areas for disposal. Stigma associated with areas surrounding designated landfill sites.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Landfill is a current practice.
<b>Key references</b>	Woodman, R. F. M., Nisbet, A. F. and Penfold, J. S. S. (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.

Table C3: Ploughing in of a standing crop

Ploughing in of a standing crop	
<b>Objective</b>	To dispose of a contaminated crop <i>in situ</i> .
<b>Other Benefits</b>	Provides a source of organic matter and nutrients to the soil.
<b>Countermeasure description</b>	This is the direct incorporation of crops at any stage of development up to maturity. Crops are destroyed and do not enter the foodchain. Subsequent ploughing dilutes activity e.g. the activity concentration of radiocaesium or radiostrontium in the soil following incorporation of a mature cereal crop would be at least 10 <sup>3</sup> 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.
<b>Target</b>	Contaminated crops.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	Soil-plant transfer.
<b>Time of application</b>	Early to medium phase, although to reduce the amount of biomass to be incorporated ploughing in is best carried out in the early phase.
<b>Constraints:</b>	
<b>Legal constraints</b>	There may be some legal restrictions under environmental schemes. Also, herbicides would not be permitted under organic farming systems. Relevant EC legislation is listed below: EC Nitrate Directive 91/676/EEC
<b>Social constraints</b>	Acceptability of incorporating contamination into the soil, rather than removing crops and disposing elsewhere.
<b>Environmental constraints</b>	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.
<b>Communication constraints</b>	Need for dialogue regarding selection of areas for treatment.
<b>Effectiveness:</b>	
<b>Effectiveness of procedure</b>	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.
<b>Factors influencing effectiveness of procedure (technical)</b>	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.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of the implementation of the countermeasure to farmers and the public.

<b>Feasibility:</b>	
<b>Required specific equipment</b>	Tractor and tractor-driven mouldboard plough (widely available).
<b>Required ancillary equipment</b>	Disc or skim coulters, trash boards, forage harvester, rotary cultivator.
<b>Required utilities and infrastructure</b>	None.
<b>Required consumables</b>	Fuel, desiccants such as glyphosate or diquat.
<b>Required skills</b>	Farmers and agricultural workers would have the required skills, but must be instructed carefully about the objectives.
<b>Required safety precautions</b>	Consider respiratory protection if very dry conditions and protective clothing.
<b>Other limitations</b>	The availability of alternative food supplies should be considered before a crop is ploughed in. Dose limits for farmers/agricultural workers.
<b>Waste:</b>	
<b>Amount and type</b>	None.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b>	Farmer using forage harvester or rotary cultivator: <ul style="list-style-type: none"> <li>• External exposure from desiccating crops</li> <li>• External exposure, inadvertent ingestion and inhalation using forage harvester or rotary cultivator</li> <li>• External exposure, inhalation and inadvertent ingestion of material during ploughing</li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Tractor and mouldboard plough already available. Forage harvester and rotovators. Field crop sprayer for application of desiccants, already available.
<b>Consumables</b>	Fuel (ca. 15 l ha <sup>-1</sup> ). Glyphosate (ca. 6 l ha <sup>-1</sup> ).
<b>Operator time</b>	One operator per plough. 4 h ha <sup>-1</sup> mouldboard plough; 1h ha <sup>-1</sup> forage harvester; 2h ha <sup>-1</sup> rotovator; 0.3 h ha <sup>-1</sup> field crop sprayer
<b>Factors influencing costs</b>	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.
<b>Communication costs</b>	Dialogue regarding selection of areas considered suitable for application of this countermeasure. Provision of information to operators on correct operation of procedure.
<b>Compensation costs</b>	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.

<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	<i>In situ</i> treatment of contaminated crop and soil. Self-help for farmer. Free informed consent and compensation for operators. Depending on scenario (i.e. radionuclides are largely on the crop) there may be negative consequences to contaminating the soil beneath the crop.
<b>Environmental impact</b>	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.
<b>Agricultural impact</b>	Incomplete breakdown of incorporated crops may make subsequent cultivation difficult.
<b>Social impact</b>	Appropriate selection of priority areas for application of the countermeasure. Disruption to farming practices on the farm. Stigma associated with food products where the countermeasure has been applied. Disruption to the supply of crops with subsequent market shortages.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Ploughing in of crop residues is a standard practice on arable farms, particularly for cereal straw.
<b>Key references</b>	Watts, C. W., Cope, R. E. and Dexter, A. R. (1996). Harvesting and Ploughing in of crops at various stages of growth. Contract report, Silsoe Research Institute, Bedford, UK.  Woodman, R. F. M., Nisbet, A. F. and Penfold, J. S. S. (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.

**Table C4: Composting**

<b>Composting</b>	
<b>Objective</b>	To reduce mass and volume of contaminated biomass requiring disposal.
<b>Other Benefits</b>	Final compost useful as a fertiliser or soil conditioner.
<b>Countermeasure description</b>	Composting may be considered where it is impractical to plough contaminated crops back into the soil and/or when contaminated grass needs to be disposed of. Composting achieves a mass reduction of 50% and a volume reduction of 50-90%. It may be carried out at commercial facilities or <i>in situ</i> 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 microorganisms, to produce stable humus.
<b>Target</b>	Contaminated crops and grass.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	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.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	Early to late. For contaminated crops it is best carried out in the early phase to reduce the amount of biomass to be composted.
<b>Constraints:</b>	
<b>Legal constraints</b>	Composting on agricultural land may require an authorisation. Relevant EC legislation is listed below: EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC) Integrated Pollution Prevention and Control Directive 96/61/EC Nitrate Directive 91/676/EEC (if compost is landspread)
<b>Social constraints</b>	Willingness of farmer to carry out composting if this is not usual practice. Possible perception of causing additional contamination of the soil when compost spread on farmland. In particular, there is likely to be resistance if compost is applied to previously uncontaminated areas. Acceptability to food industry/consumers of residual levels of contamination in food produced on land where compost is spread.
<b>Environmental constraints</b>	Spreading of compost should not be conducted near water courses. Consideration needs to be given to underlying geology, particularly aquifers.
<b>Communication constraints</b>	Need for dialogue regarding selection of areas for composting. Need for dialogue between land owners/farmers, environmentalists and public. Farmers/operators require information on how to carry out the countermeasure, including its objective.

<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A.
<b>Factors influencing effectiveness of procedure (technical)</b>	Climatic conditions affect speed and efficiency with which material is broken down. Availability of green (woody) waste for dilution. Quantity of precipitation.
<b>Factors influencing effectiveness of procedure (social)</b>	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.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Commercial composting facilities. On farms, composting can be carried out directly on agricultural land.
<b>Required ancillary equipment</b>	Dedicated front end loaders or other material handling vehicles may be required. Windrow turners and screens may also be required. Temporary compost heaps such as those that a farmer might set up on open ground would benefit from temporary covering e.g. Dutch barn.
<b>Required utilities and infrastructure</b>	Area of hard-standing (e.g. concrete) on farm. Storage for compost.
<b>Required consumables</b>	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.
<b>Required skills</b>	At commercial composting facilities the necessary skills will be available. Many farmers will be able to carry out composting, but some may need instruction.
<b>Required safety precautions</b>	Consider protective clothing. Respiratory protection is recommended whenever materials are handled or moved. Aerosolisation of micro-organisms (bioaerosols) and small fragments of vegetation can be problematic if inhaled or in contact with eyes.
<b>Other limitations</b>	None.
<b>Waste:</b>	
<b>Amount and type</b>	Any compost that might not be considered suitable as a soil conditioner. As a rule of thumb, 1 m <sup>3</sup> of leachate may be generated for every 20 m <sup>2</sup> 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.
<b>Possible transport, treatment and storage routes</b>	Landfill or incineration of unusable compost. Leachate should be returned to the compost or if necessary disposed of to a sewage treatment works.
<b>Factors influencing waste issues</b>	The application of the compost to arable land is dependent on the time of year and state of land (i.e. do not apply when frozen, waterlogged, or to land on a steep slope). Dependant on whether carried out at composting facility or on farms, if carried out on open ground on farms leachate will not be collected.

<b>Doses:</b>	
<p><b>Additional dose</b></p> <p><i>(Dose pathways in italics are indirectly incurred as a result of composting.</i></p> <p><i>Any unused compost may have to be disposed of to landfill or 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 Table C2: Landfill.)</i></p>	<p>Composting Facility Operative or Farmer:</p> <ul style="list-style-type: none"> <li>• External exposure during daily inspection</li> <li>• Inadvertent ingestion while turning compost</li> <li>• Inhalation of dust while turning compost</li> </ul> <p>Drivers (External Exposure):</p> <ul style="list-style-type: none"> <li>• Transporting crops to composting facilities</li> <li>• <i>Transporting leachate to STW's</i></li> </ul> <p>Public:</p> <ul style="list-style-type: none"> <li>• <i>Ingestion of food grown on land spread with compost</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Already available at commercial facilities. Transport for crops/grass if destined for commercial facilities.
<b>Consumables</b>	Fuel for transport (depending on distance). Fuel for operating equipment on site.
<b>Operator time</b>	Time to establish a composting system on farm. Time to inspect and turn compost. Time to transport crops/grass to commercial facility.
<b>Factors influencing costs</b>	Volumes of crops and grass to be composted. Whether composting carried out <i>in situ</i> or at commercial facilities.
<b>Communication costs</b>	Provision of information to farmers on rationale of this waste treatment option. Provision of information to operators on correct application of the procedure on farm so as to avoid pollution.
<b>Compensation costs</b>	Possible decontamination of equipment at commercial composting facilities.
<b>Waste cost</b>	Landfill charges and landfill tax. Leachate treatment.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	<i>In situ</i> 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.
<b>Environmental impact</b>	Large volumes of carbon dioxide and water vapour are released. Trace gases such as ammonia and hydrogen sulphide may be produced if excess nitrogen or sulphide are present in the feedstock. These gases would cause odour problems at the composting site. Large quantities of leachate are produced, typically 30 litres of leachate per tonne of waste. If carried out on open ground the leachate might result in some contamination of land and groundwater. There may also be a release of bioaerosols. Inappropriate application of compost to land may cause pollution of watercourses.
<b>Agricultural impact</b>	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.

<b>Social impact</b>	The countermeasure will need policing. Contamination of soil may restrict subsequent uses (e.g. organic farming) where compost is spread on clean land. Stigma associated with areas and perceived contamination of food products (crops, dairy, meat) where the compost has been applied.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Composting is a current practice.
<b>Key references</b>	<p>Slater, R. A., Frederickson, J. and Gilbert, E. J. (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.</p> <p>Shaw, S., Green, N., Hammond, D. J. B. and Woodman, R. F. M. (2001). Management options for food production systems affected by a nuclear accident. 1. Radionuclide behaviour during composting NRPB-R328.</p> <p>Woodman, R. F. M., Nisbet, A. F. and Penfold, J. S. S. (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.</p>

**Table C5: Biological treatment (digestion) of crops**

<b>Biological treatment (digestion) of crops</b>	
<b>Objective</b>	To reduce the mass of solids derived from contaminated crops requiring disposal.
<b>Other Benefits</b>	Digested crops can be used as a fertiliser and biogas generated used as an energy source.
<b>Countermeasure description</b>	Biological treatment of crops is very effective at reducing the volume of material for disposal. Typically the volume is reduced by 40 to 60 %, but it can be as high as 80 % depending on type of anaerobic digester and crop. Anaerobic digestion (AD) is the fermentation of organic matter, such as green crop residues, to produce a methane-rich gas, which can be used for heating or electricity generation. Material is retained in an enclosed reactor at temperatures of 35-55°C for a period of 10-30 days. Around 50% of the organic matter is degraded during this process. The remainder forms a sludge/slurry (digestate) that can be used directly as a fertiliser or separated to produce a solid fertiliser (cake) which may be disposed of via landfill or incineration and a liquid fertiliser (liquor) which may be put back into the digestion system.
<b>Target</b>	Contaminated crops.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small scale – crops need to be macerated prior to digestion and the equipment for this is not generally available.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	Early to late phase.
<b>Constraints:</b>	
<b>Legal constraints</b>	Relate to management of waste arising from digestion of crops. Relevant EC legislation: EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). EC Nitrate Directive 91/676/EEC
<b>Social constraints</b>	Relate to disposal option selected for waste e.g. willingness of farmers to accept sludge from biological treatment of crops. Resistance if the resulting sludge is applied to previously uncontaminated areas. Perception of causing additional contamination of the soil when slurry spread on farmland. There may be local opposition to the use of particular landfill sites e.g. if contaminated sludge is disposed of in previously uncontaminated areas.
<b>Environmental constraints</b>	None for digestion of crops. Relate to subsequent fate of slurry, which should not be spread on land with a high risk of runoff or leaching, and high nutrient status.
<b>Communication constraints</b>	Farmers/operators require information on the biological treatment of crops.

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

<b>Doses:</b>	
<p><b>Additional dose</b></p> <p><i>(Dose pathways in italics are indirectly incurred as a result of the digestion of crops. There are separate datasheets for landfill and incineration as alternative disposal options for the digestate and cake. If liquor is not applied to land it may be put back into the digestion system.)</i></p>	<p>Anaerobic Digestion Facility Operative:</p> <ul style="list-style-type: none"> <li>• Inadvertent ingestion of digestate during anaerobic digestion of crops</li> <li>• External exposure, inhalation and inadvertent ingestion of cake when loading it onto wagons</li> </ul> <p>Drivers (External Exposure):</p> <ul style="list-style-type: none"> <li>• External exposure to driver while transporting crops to anaerobic digester</li> <li>• <i>External exposure to driver while transporting digestion products (digestate, liquor, cake) to place of disposal (e.g. farmland)</i></li> </ul> <p>Farmer:</p> <ul style="list-style-type: none"> <li>• <i>External exposure, inhalation and inadvertent ingestion while loading spreader/sprayer with digestate, cake or liquor</i></li> <li>• <i>External exposure while spreading/spraying digestate, cake or liquor</i></li> <li>• <i>External exposure, inadvertent ingestion and inhalation of digestate, cake or liquor while ploughing</i></li> </ul> <p>Public:</p> <ul style="list-style-type: none"> <li>• <i>Ingestion by public of food grown on land spread with digestate, liquor or cake</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Anaerobic digestion facility already available. Maceration equipment limited availability. Vehicles for transport.
<b>Consumables</b>	Fuel for transport (depending on distance).
<b>Operator time</b>	Operators' time for macerating crops. Operators' time at anaerobic digestion facilities for handling additional material.
<b>Factors influencing costs</b>	Amount of crops to be digested and disposal routes of digestion products. Volume of liquid effluent to be treated.
<b>Communication costs</b>	Dialogue with the operators and regulators needs to be established well in advance.
<b>Compensation costs</b>	To anaerobic digestion facilities for handling contaminated crops and decontamination of equipment. To transport companies for decontamination of vehicles.
<b>Waste cost</b>	Treatment and disposal of sludge/slurry and effluent.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Additional dose to anaerobic digester operators and populations living close to sewage treatment works. Consent of workers. Environmental risk.
<b>Environmental impact</b>	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.

<b>Environmental impact (cont.)</b>	Digestate or cake and liquor are used as soil conditioner and liquid fertiliser. They contain the nutrients of the initial waste so landspreading may be limited. Incineration of digestate can release acids, heavy metals and other noxious gases. Fly ash is generated as a result of incomplete combustion, but is normally prevented from release by use of filters or other gas cleaning systems. Ash is typically disposed of to landfill. Landfill of digestate and ash can result in contamination of ground and surface waters. This should be avoided using a properly maintained landfill site.
<b>Agricultural impact</b>	Application of digestate or cake provides additional nutrients for crop-uptake and could lead to reduced requirements for fertiliser. The cake also provides organic matter that improves the soil quality.
<b>Social impact</b>	Contamination of soil may restrict subsequent uses (e.g. organic farming) where sludge is spread on clean land.
<b>Other side effects, pos. or neg.</b>	BOD removal is usually between 70 and 80%. Reduced greenhouse gas emissions. Deactivation of plant and animal pathogens. Greatly reduces waste odours.
<b>UK Stakeholder opinion</b>	Technology not sufficiently developed or widespread to be a major option.
<b>Practical experience</b>	Anaerobic digestion is a current practice.
<b>Key references</b>	IEA Bioenergy (1996). Biogas from municipal solid waste. Published by Ministry of Energy/Danish Energy Agency, Copenhagen and Netherlands Agency for Energy and the Environment, Utrecht. IEA Bioenergy (2001). Biogas and more: Systems and markets overview of anaerobic digestion. Woodman, R. F. M., Nisbet, A. F. and Penfold, J. S. S. (1997). Options for the management of foodstuffs contaminated as a result of a nuclear accident. NRPB-R295.
<b>Comments</b>	Anaerobic digesters are commonly found at sewage treatment works.

**Table C6: Landspreading of milk and/or slurry**

<b>Landspreading of milk and/or slurry</b>	
<b>Objective</b>	To dispose of contaminated milk and/or slurry.
<b>Other Benefits</b>	Additional source of nutrients to soil.
<b>Countermeasure description</b>	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 <i>in situ</i> .
<b>Target</b>	Contaminated milk and/or contaminated slurry.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large scale application on most farms that stock dairy herds. Application may be more restricted on farms stocking alpine sheep and goats.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	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.
<b>Constraints:</b>	
<b>Legal constraints</b>	<p>Constraints under some environmental schemes. Relevant EC legislation is listed below:</p> <p>EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC)</p> <p>EC Nitrate Directive 91/676/EEC</p> <p>EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC) and EC Landfill Directive 1999/31/EC.</p> <p>Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972</p> <p>EC Groundwater Directive 80/68/EEC</p>
<b>Social constraints</b>	Variable depending on usual practice. Willingness of farmer to carry out landspreading if this is not usual practice. Possible perception of causing additional contamination of the soil if milk/slurry is spread on farmland. Acceptability to food industry/consumers of residual levels of contamination in food produced on land where spreading is practised.
<b>Environmental constraints</b>	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 <sup>3</sup> ha <sup>-1</sup> y <sup>-1</sup> 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.
<b>Communication constraints</b>	Need for dialogue regarding selection of areas for treatment. Need for dialogue between land owners/ farmers, environmentalists and public.

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

<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	<i>In situ</i> 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.
<b>Environmental impact</b>	Inappropriate disposal of milk to land could lead to pollution of water courses.
<b>Agricultural impact</b>	Additional nutrients provided for crop-uptake which could lead to reduced requirements for fertiliser.
<b>Social impact</b>	Stigma associated with food products where the countermeasure has been applied. Landspreading of contaminated milk may restrict subsequent use of the land (e.g. organic farming).
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Landspreading of milk is carried out on a small scale when farmers are over quota or there is evidence of microbiological contamination. It has not, however, been carried out on a large-scale in the past.
<b>Key references</b>	Marchant, J. K. and Nisbet, A. F. (2002). Management options for food production systems affected by a nuclear accident. 6. Landspreading as a waste disposal option for contaminated milk. NRPB-W11.

Table C7: Biological treatment (digestion) of milk

<b>Biological treatment (digestion) of milk</b>	
<b>Objective</b>	To reduce the mass of solids derived from contaminated milk requiring disposal.
<b>Other Benefits</b>	Reduction in BOD of treated milk. Digested milk can be used as a fertiliser and biogas generated used as an energy source.
<b>Countermeasure description</b>	Milk may be processed through aerobic (activated sludge or fixed-film systems) and anaerobic digestion (AD) facilities present in sewage treatment works (STW) and dairy effluent plants (DEP). In aerobic systems the provision of oxygen and bacteria accelerates processes that would naturally occur in oxygenated rivers. In anaerobic systems material is retained in an enclosed reactor at temperatures of 35-55°C for a period of 10-30 days. These biological treatments accelerate a series of natural processes and significantly reduce the mass of solids for disposal and the biological oxygen demand of the effluent. Sludge and cake produced can be used as fertiliser and biogas for heating and electricity generation.
<b>Target</b>	Contaminated milk.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Small.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A
<b>Time of application</b>	Early to late.
<b>Constraints:</b>	
<b>Legal constraints</b>	The treatment of milk at STW's and DEP's will be subject to the Urban Waste Water Directive 91/271/EEC and EC Framework Directive on Waste (74/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EC). Other relevant EC legislation includes: EC Framework Directive on Waste Sewage Sludge Directive 86/278/EEC EC Nitrate Directive 91/676/EEC EC Landfill Directive 1999/31/EC
<b>Social constraints</b>	Relate to disposal option selected for waste e.g. willingness of farmers to accept sludge from biological treatment of milk. Resistance if the resulting sludge is applied to previously uncontaminated areas. Perception of causing additional contamination of the soil when slurry spread on farmland. There may be local opposition to the use of particular landfill sites e.g. if contaminated sludge is disposed of in previously uncontaminated areas.
<b>Environmental constraints</b>	None for digestion of milk. Relate to subsequent fate of sludge, which should not be spread on land with a high risk of runoff or leaching, and high nutrient status.
<b>Communication constraints</b>	Farmers/operators require information on the biological treatment of milk.

<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A
<b>Factors influencing effectiveness of procedure (technical)</b>	Dairy wastes at sewage treatment works (aerobic) cause problems due to the inadequate size of the plant, insufficient balancing (maximum holding capacity of one days average flow), and are not designed for the high BOD of dairy waste. Water companies usually insist that the fat content should not exceed 150 mg/l, pH should be between 6 and 9 and BOD between 300 and 600 mg/l. The optimum dry matter content for anaerobic digestion is 6-8%. To reduce raw milk's dry matter content to 6-8% it has to be diluted with water to produce a 40% milk/60% water mixture. Long residence time of milk in anaerobic reactor. Capacity to treat contaminated milk depends on radiological impact of effluent. Partitioning of radionuclides between effluent and sludge.
<b>Factors influencing effectiveness of procedure (social)</b>	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.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Biological treatment facility.
<b>Required ancillary equipment</b>	Vehicles for transport. Equipment for spreading sludge and cake.
<b>Required utilities and infrastructure</b>	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.
<b>Required consumables</b>	Fuel for transport.
<b>Required skills</b>	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.
<b>Required safety precautions</b>	None.
<b>Other limitations</b>	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.
<b>Waste:</b>	
<b>Amount and type</b>	<p><i>Anaerobic</i></p> <p>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%.</p> <p><i>Aerobic</i></p> <p>Sludge is produced and the amounts depend on the micro-organisms present, BOD of milk, treatment method used etc. Excess sludge represents 1 to 5% of the volume of waste treated</p>

<p><b>Possible transport, treatment and storage routes</b></p>	<p><i>Anaerobic</i></p> <p>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</p> <p><i>Aerobic</i></p> <p>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.</p>
<p><b>Factors influencing waste issues</b></p>	<p>Biological treatment method used.</p> <p>Disposal option chosen for sludge.</p> <p>Level of radioactivity in the waste products.</p> <p>Radiological impact of effluent discharged to watercourses.</p>
<p><b>Doses:</b></p>	
<p><b>Additional dose</b></p> <p><i>(Dose pathways in italics are indirectly incurred as a result of the digestion of milk. They represent the exposure to the end products of biological treatment, i.e. sludge, cake and liquid effluent. There are datasheets outlining the additional dose pathways from the alternative disposal of sludge and cake to landfill or incineration.)</i></p>	<p>Anaerobic Digester Operative (STW)</p> <ul style="list-style-type: none"> <li>• Inadvertent ingestion of sludge during milk treatment</li> <li>• External, inhalation and inadvertent ingestion exposure loading cake</li> </ul> <p>Aerobic Digester Operative (DEP)</p> <ul style="list-style-type: none"> <li>• External exposure and inadvertent ingestion of milk during milk treatment</li> </ul> <p>Drivers (External Exposure):</p> <ul style="list-style-type: none"> <li>• Transporting milk to treatment plant</li> <li>• <i>Transporting sludge and cake to place of disposal (e.g. farmland)</i></li> </ul> <p><i>Farmer Applying Sludge or Cake to Land:</i></p> <ul style="list-style-type: none"> <li>• <i>External exposure, inadvertent ingestion and inhalation of sludge and cake while loading spreader.</i></li> <li>• <i>External exposure while spreading</i></li> <li>• <i>External exposure, inhalation and inadvertent ingestion of dirt while ploughing in sludge or cake</i></li> </ul> <p><i>Public:</i></p> <ul style="list-style-type: none"> <li>• <i>Ingestion of food grown on land spread with sludge or cake</i></li> <li>• <i>Ingestion of drinking water and freshwater fish extracted from rivers to which effluent is discharged</i></li> </ul>
<p><b>Intervention Costs:</b></p>	
<p><b>Equipment</b></p>	<p>Biological treatment facilities. Vehicles for transport. Equipment for spreading sludge and cake.</p>
<p><b>Consumables</b></p>	<p>Fuel for transport (depending on distance).</p>

<b>Operator time</b>	Additional work incurred by operators at biological treatment facilities and operators involved with disposal of wastes.
<b>Factors influencing costs</b>	Volume of milk to be treated and disposal routes of digestion products. Volume of liquid effluent to be treated.
<b>Communication costs</b>	Dialogue with the operators and regulators needs to be established well in advance.
<b>Compensation costs</b>	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.
<b>Waste cost</b>	Treatment and disposal of sludge and effluent.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Additional dose to digester operators and populations living close to biological treatment facilities. Consent of workers. Environmental risk.
<b>Environmental impact</b>	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.
<b>Agricultural impact</b>	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.
<b>Social impact</b>	Contamination of soil may restrict subsequent uses (e.g. organic farming) where sludge is spread on clean land.
<b>Other side effects, pos. or neg.</b>	<p><i>Aerobic</i></p> <ul style="list-style-type: none"> <li>• BOD removal in excess of 95%.</li> <li>• Pathogens are negligible in milk sludges.</li> <li>• Sludge odours are strong so quick disposal required.</li> </ul> <p><i>Anaerobic</i></p> <ul style="list-style-type: none"> <li>• BOD removal is usually between 80 and 95% at DEPs.</li> <li>• Reduced greenhouse gas emissions.</li> <li>• Deactivation of plant and animal pathogens.</li> <li>• Greatly reduces waste odours.</li> </ul>

<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	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.
<b>Key references</b>	<p>Nisbet, A. F., Marchant, J. K., Woodman, R. F. M., Wilkins, B. T. and Mercer, J.A. (2002). Management options for food production systems affected by a nuclear accident: (7) Biological treatment of contaminated milk. NRPB-W38.</p> <p>Marshall, K. R. and Harper, W. J. (1984). The Treatment of Wastes from the Dairy Industry. In Surveys in Industrial Wastewater Treatment. Barnes, D., Forster, C. F. and Hurdey, S. E. (eds). Pitman Publishing, London, 296-376.</p> <p>Wheatley, A. D. (2000). Food and Wastewater. In Food Industry and the Environment in the European Union. Practical Issues and Cost Implications. 2<sup>nd</sup> Edition. Dalzell, J. M. (ed). Aspen Publishers Inc. Maryland.</p>

**Table C8: Disposal of contaminated milk to sea**

<b>Disposal of contaminated milk to sea</b>	
<b>Objective</b>	To dispose of contaminated milk.
<b>Other Benefits</b>	None.
<b>Countermeasure description</b>	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.
<b>Target</b>	Contaminated milk.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Large scale application as long as practical arrangements are possible at power stations or sewage works.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	Early to late phase. Seasonal.
<b>Constraints:</b>	
<b>Legal constraints</b>	<p>The Oslo-Paris (OSPAR) Convention protects the marine environment within Europe. However, the requirements of the convention would not apply in the event of an emergency. The Euratom Treaty Article 37 (EEC, 1957) requires each member state to provide data on planned disposal of radioactive waste. The Commission decides within 6 months if the plan will cause radioactive contamination of water, soil or airspace to another member state. However, milk containing radionuclides may not be classed as radioactive waste.</p> <p>Milk discharged to sea via long sea outfalls at coastal sewage treatment works will be subject to regulations that implement the <i>Urban Waste Water Directive 91/271/EEC</i>. The regulations ensure certain standards of wastewater treatment are attained and limit the BOD concentration of all significant discharges of wastewaters to 25 mg O<sub>2</sub> l<sup>-1</sup>.</p>
<b>Social constraints</b>	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.
<b>Environmental constraints</b>	Limits on total BOD discharged by long sea outfalls. These vary according to the degree of mixing of water body receiving contaminated milk.
<b>Communication constraints</b>	Need for widespread dialogue to ascertain the acceptability of discharge to sea both nationally and internationally. Public consultation can be a lengthy process that might not be achievable on the timescales required for disposing of large volumes of milk. Requirement to monitor water quality in surrounding water body.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A.
<b>Factors influencing effectiveness of procedure (technical)</b>	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.

<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of the implementation of the countermeasure to operators, haulage companies and the public. Compliance/resistance to the countermeasure.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	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 <sup>-1</sup> .
<b>Required ancillary equipment</b>	At some nuclear installations pumps will be required to offload milk from tankers into holding pits.
<b>Required utilities and infrastructure</b>	Coolant water and liquid effluent outfalls at nuclear installations or long sea outfalls at sewage treatment works.
<b>Required consumables</b>	Fuel for transporting milk to outfalls.
<b>Required skills</b>	The vehicle drivers and operators at the power stations and sewage works should have the necessary skills. Little additional training would be needed.
<b>Required safety precautions</b>	Not necessary at the levels of contamination for which this method would be considered. However, the discharge of milk to sea is a non-standard practice that will require station managers to carry out a full risk assessment. Potential hazards need to be identified and controlled. A constant stream of tankers arriving at a nuclear or sewage treatment plant may require traffic management and parking.
<b>Other limitations</b>	Contingency plans for dealing with protestors at the gates need to be made.
<b>Waste:</b>	
<b>Amount and type</b>	N/A.
<b>Possible transport, treatment and storage routes</b>	N/A.
<b>Factors influencing waste issues</b>	N/A.
<b>Doses:</b>	
<b>Additional dose</b> <i>(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.)</i>	Drivers (External Exposure): <ul style="list-style-type: none"> <li>Transporting milk to nuclear sites and coastal sewage treatment works</li> </ul> Public: <ul style="list-style-type: none"> <li><i>Ingestion of marine foodstuffs due to milk being discharged to the sea.</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	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.
<b>Consumables</b>	Fuel for transport (depending on distance).
<b>Operator time</b>	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.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Factors influencing costs</b>	Distance from farms to sea outfalls.
<b>Communication costs</b>	Dialogue with the operators and regulators need to be established well in advance. This will involve considerable time and effort. Potential need to facilitate widespread debate regarding the ethics and practice of disposal at sea.
<b>Compensation costs</b>	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.
<b>Waste cost</b>	N/A.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Additional dose to tanker drivers, marine life and consumers of marine produce. Aesthetic/ecological effects from sea disposal.
<b>Environmental impact</b>	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.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Potential for dispute regarding selection of this waste disposal option. Stigma associated with areas or fish produce where milk has been disposed of to sea. Disruptions to people's image/perception of the 'seaside' e.g. milk flowing onto the beach from outflow pipes, with potential impacts on tourism etc.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Milk discharged to drains following Windscale fire.
<b>Key references</b>	EEC (1957). The Treaty establishing the European Atomic Energy Community (Euratom). Rome, 25 <sup>th</sup> March 1957.  Wilkins, B. T., Woodman, R. F. M., Nisbet, A. F. and Mansfield, P. A. (2001). Management options for food production systems affected by a nuclear accident. 5. Disposal of waste milk to sea. NRPB-R323.
<b>Comments</b>	Disposal of milk to sea will require pre-planning e.g. doing site specific modelling to check environmental impact, liaison with nuclear or sewage plant operators. It would be helpful to get arrangements established well in advance of an accident. The suitability of power stations and sewage works will be highly variable.

**Table C9: Processing and storage of milk products for disposal**

<b>Processing and storage of milk products for disposal</b>	
<b>Objective</b>	To convert contaminated milk into a more stable end product for storage and subsequent disposal.
<b>Other Benefits</b>	Storage offers the authorities more time to plan disposal options.
<b>Countermeasure description</b>	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.
<b>Target</b>	Milk.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Medium to large.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	Early to medium phase.
<b>Constraints:</b>	
<b>Legal constraints</b>	Dairy workers may have to be trained in the handling of radioactive waste. EC legislation relevant to the control of milk processing plants is listed below: Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC). Urban Waste Water Directive 91/271/EEC for the treatment of liquid wastes.
<b>Social constraints</b>	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.
<b>Environmental constraints</b>	None.
<b>Communication constraints</b>	None.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A.
<b>Factors influencing effectiveness of procedure (technical)</b>	Availability and capacity of facilities for processing.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of implementing the countermeasure to dairy operatives. Acceptability of siting of storage facilities and subsequent disposal routes.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Milk processing plant with freeze-drier.
<b>Required ancillary equipment</b>	Milk tankers.
<b>Required utilities and infrastructure</b>	Storage facilities for milk powder.
<b>Required consumables</b>	Fuel for tankers.
<b>Required skills</b>	Operatives at milk processing plants will have the required skills.
<b>Required safety precautions</b>	Consider respiratory protection.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Other limitations</b>	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.
<b>Waste:</b>	
<b>Amount and type</b>	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.
<b>Possible transport, treatment and storage routes</b>	Milk powder can be disposed of to landfill. The stability of milk powder permits a period of storage (i.e. supervised warehouse) in advance of a suitable disposal route being found. Disposal of contaminated washings can be made to dairy effluent plants or sewage treatment works.
<b>Factors influencing waste issues</b>	Disposal of processing wastes would be subject to individual national regulations and may require licensing.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Dose pathways in italics are indirectly incurred as a result of processing of milk. There are datasheets outlining the additional dose pathways from the disposal of milk powder to landfill.)</i>	<p>Dairy Operatives:</p> <ul style="list-style-type: none"> <li>External dose from milk during processing (dependant on the location of the control room from the machinery).</li> </ul> <p>Drivers (External Exposure):</p> <ul style="list-style-type: none"> <li>Transporting milk to milk processing plant</li> <li>Transporting milk powder to storage facility</li> </ul> <p><i>Milk Powder Storage Facility Operatives:</i></p> <ul style="list-style-type: none"> <li><i>External dose when overseeing loading and unloading of milk powder to storage.</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Milk processing plant.
<b>Consumables</b>	Processing consumables, including for example electricity. Fuel for transport.
<b>Operator time</b>	Tanker drivers on 10 hour shifts. Operators at processing plants for additional work. Security guard.
<b>Factors influencing costs</b>	Transportation costs depend on distance. Length of storage time. Disposal route.
<b>Communication costs</b>	None.
<b>Compensation costs</b>	To processing plants for accepting contaminated milk and for subsequent decontamination of equipment. To dairy operatives for handling contaminated milk.
<b>Waste cost</b>	Cost of storage of milk powder and disposal to landfill or other facility. Cost of disposal of rinsing waters to dairy effluent/sewage treatment plant if necessary.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Dairy workers will have to give informed consent to the treatment of contaminated milk.
<b>Environmental impact</b>	Minimal environmental impact when processing liquid milk into whole milk powder, provided the latter is disposed of properly.
<b>Agricultural impact</b>	None.

<b>Social impact</b>	Disruption to the supply of milk to the food industry and market shortages. Negative social and psychological impact that people's food/food supply is so contaminated that it requires disposal. Conversely, it may increase public confidence that contamination is being removed from the foodchain and the situation is being effectively managed.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	Processing of milk to whole milk powder is a current practice.
<b>Key references</b>	<p>Long, S., Pollard, D., Cunningham, J. D., Astasheva, N. P., Donskaya, G. A. and Labetsky, E. V. (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. <i>Journal of Radioecology</i>, 3 (1), 15-30.</p> <p>Mercer, J., Nisbet, A. F. and Wilkins, B. T. (2002). Management options for food production systems affected by a nuclear accident: 4 Emergency monitoring and processing of milk. NRPB-W15.</p>

**Table C10: Rendering**

<b>Rendering</b>	
<b>Objective</b>	To reduce volume of contaminated carcasses prior to disposal.
<b>Other Benefits</b>	None.
<b>Countermeasure description</b>	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.
<b>Target</b>	Meat and milk producing livestock.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Medium to large.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	Early to late phase.
<b>Constraints:</b>	
<b>Legal constraints</b>	Rendering is likely to be subject to specific legislation in each member state. Relevant EC legislation is listed below: Integrated Pollution Prevention and Control Directive 96/61/EC. Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972. Over Thirty Month Scheme as specified in EC Regulation (Reg 716/96).
<b>Social constraints</b>	Public or stakeholder acceptability. Most rendering plants have local protest groups due to odours. Low acceptance of radioactively contaminated material to these groups.
<b>Environmental constraints</b>	Rendering should result in minimal environmental impact provided all control measures and best practice is fully implemented.
<b>Communication constraints</b>	Operators require information on rendering contaminated carcasses.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A.
<b>Factors influencing effectiveness of procedure (technical)</b>	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.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of disposal/treatment procedures.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Rendering plants suitable for disposal of mammalian carcasses.
<b>Required ancillary equipment</b>	Transportation of carcasses from farm to rendering plant and waste products to landfill or incineration and waste water treatment plant.

<b>Required utilities and infrastructure</b>	Disposal route for waste products e.g. landfill, incineration, wastewater treatment.
<b>Required consumables</b>	Fuel for transportation of carcasses and waste products.
<b>Required skills</b>	Rendering operators should have the necessary skills.
<b>Required safety precautions</b>	Protective clothing.
<b>Other limitations</b>	Capacity of rendering plants.
<b>Waste:</b>	
<b>Amount and type</b>	<p>The main products of rendering are:-</p> <ul style="list-style-type: none"> <li>• MBM (Meat and Bone Meal) - dust like end product containing 60-65% protein.</li> <li>• Tallow – solid hard fat.</li> <li>• Greaves - same material as MBM but the final grinding stage has been omitted.</li> <li>• Condensate - generated from the rendering process.</li> <li>• Blood - blood meal.</li> </ul> <p>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.</p>
<b>Possible transport, treatment and storage routes</b>	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.
<b>Factors influencing waste issues</b>	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.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Dose pathways in italics are indirectly incurred as a result of rendering. Rendering products are disposed of to landfill or 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 Table C2: Landfill.)</i>	<p>Rendering Plant Operative:</p> <ul style="list-style-type: none"> <li>• External exposure to carcasses</li> <li>• External exposure to rendering products (MBM, tallow, greaves) store</li> <li>• External exposure and inadvertent ingestion during treatment of condensate</li> </ul> <p>Drivers (External Exposure):</p> <ul style="list-style-type: none"> <li>• Transporting carcasses to rendering plants</li> <li>• <i>Transporting rendering products (MBM, tallow, greaves) to landfill or incineration</i></li> <li>• <i>Transporting sludge from rendering plant to STW</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Rendering plant.
<b>Consumables</b>	Fuel for transportation of carcasses and disposal of waste products.
<b>Operator time</b>	Rendering plant operators for additional work. Additional time to transport carcasses.
<b>Factors influencing costs</b>	Number of carcasses to be treated and disposal routes of rendered products. Risk of contaminating rendering plant and vehicles used to transport carcasses.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Communication costs</b>	Information and training for operators.
<b>Compensation costs</b>	To rendering plant owners for decontamination of the plant and vehicles.
<b>Waste cost</b>	Transportation of waste products to disposal site/plant. Costs of incineration or landfill and treating condensate. Compensation to landfill, incinerator and waste water treatment owners for decontamination of the plant and vehicles if necessary.
<b>Assumptions</b>	All the infrastructure needed is readily available.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Additional dose to operators and populations living close to rendering plants. Consent of plant operators.
<b>Environmental impact</b>	Minimal from rendering itself. Incinerating rendering wastes does not cause any particular air quality problems as standard flue gas cleaning systems minimise the formation of harmful by-products as well as meet the authorised emission levels. Minimal pollution risk to surface and groundwater arising from landfilling ash and rendering wastes.
<b>Agricultural impact</b>	None.
<b>Social impact</b>	Minimal.
<b>Other side effects, pos. or neg.</b>	None.
<b>UK Stakeholder opinion</b>	The Environment Agency's hierarchy of acceptance ranks rendering followed by incineration above landfill and burial.
<b>Practical experience</b>	Rendering was the preferred option for disposing of livestock during the FMD outbreak in the UK, although capacity was a limiting factor at the peak of the outbreak. Therefore, incineration, burial and burning disposal methods were also used. Rendering waste products were disposed of by incineration and landfill, depending on the rendering process used and age of cattle.
<b>Key references</b>	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, G. M., Tas, M. V., Varley, E. M. and Hickman, G. A. W. (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
<b>Comments</b>	Rendering is the preferred method of whole carcass disposal as it has the least disposal hazards associated with it.

Table C11: Burning of carcasses

<b>Burning of carcasses</b>	
<b>Objective</b>	To dispose of animal carcasses following slaughter.
<b>Other Benefits</b>	Limits the movement of contaminated carcasses.
<b>Countermeasure description</b>	After slaughter, animal carcasses may be completely destroyed to ash, at sites suitable for burning.
<b>Target</b>	Meat or milk producing livestock.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Medium to large.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A.
<b>Time of application</b>	Early to late phase.
<b>Constraints:</b>	
<b>Legal constraints</b>	The burning of animal carcasses is likely to be subject to specific water and air legislation in each Member State. Relevant EC legislation includes: Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972. EC Groundwater Directive 80/68/EEC.
<b>Social constraints</b>	Acceptability of changes to landscapes and of other environmental effects e.g. radionuclides released during burning, to relevant populations. Local opposition to the selection of burning sites. Aesthetic consequences of landscape/amenity changes.
<b>Environmental constraints</b>	Availability of suitable sites for burning large quantities of carcasses. Animal carcasses must be disposed of without endangering human health or harming the environment.
<b>Communication constraints</b>	Dialogue with land users. Media interest is likely to be high. Likely requirement to monitor air/water quality in area around burning site and publish results.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A.
<b>Factors influencing effectiveness of procedure (technical)</b>	Availability of suitable sites for burning. Availability of burning materials. Quantity of carcasses. Transportation of carcasses to site for burning. Poorly constructed pyre can burn for several weeks.
<b>Factors influencing effectiveness of procedure (social)</b>	Acceptability of implementing carcass burning to farmers and the public. There is potential for a black market in slaughtered meat. Willingness of private landowners and local populations to accept carcasses for burning.
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Excavators for digging trenches. JCB's, forklift trucks and tractors with bucket loaders for moving fire ingredients and carcasses. Lamps to allow night working.
<b>Required ancillary equipment</b>	Vehicles for the transportation of carcasses to site for burning and to the ash disposal site.
<b>Required utilities and infrastructure</b>	Burning site with good road network.
<b>Required consumables</b>	Fuel to aid combustion and for transportation.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

<b>Required skills</b>	Continued supervision of burning.
<b>Required safety precautions</b>	Respiratory equipment. Protective clothing and equipment.
<b>Other limitations</b>	Availability of labour to build pyres. Pyres are open to having illegal material (tyres, rubber and plastics) burned on them.
<b>Waste:</b>	
<b>Amount and type</b>	Ash. Approximately 350 kg is produced per tonne of animal.
<b>Possible transport, treatment and storage routes</b>	The ash produced may be disposed of via burial <i>in situ</i> or transported to a fully instrumented landfill site. In some situations the ash may have to be disposed of at an authorised incinerator prior to landfill disposal.
<b>Factors influencing waste issues</b>	Radionuclide concentration of waste product. Local opposition to disposal of ash via burial <i>in situ</i> .
<b>Doses:</b>	
<b>Additional dose</b> <i>(Dose pathways in italics are indirectly incurred as a result of burning carcasses. If burial of ash in situ is not possible the ash may be disposed of via incineration or landfill. There are separate datasheets for these disposal routes.)</i>	<p>Pyre Site Operatives:</p> <ul style="list-style-type: none"> <li>• External exposure from carcasses when loading on pyre</li> <li>• External exposure and inhalation of contaminated material emitted by pyre</li> <li>• External exposure and inadvertent ingestion of ash when collecting ash for transportation to incinerator or landfill site</li> </ul> <p>Driver:</p> <ul style="list-style-type: none"> <li>• External exposure while transporting animal carcasses to pyre site</li> <li>• External exposure while transporting ash to incinerator or landfill</li> </ul> <p><i>Farmer when ploughing in:</i></p> <ul style="list-style-type: none"> <li>• <i>External exposure from land when ploughing in ash</i></li> <li>• <i>Inadvertent ingestion of ash while ploughing in (as ash is wetted)</i></li> </ul> <p><i>Public:</i></p> <ul style="list-style-type: none"> <li>• <i>Inhalation of contaminated material deposited by the pyre</i></li> <li>• <i>External exposure from contaminated material deposited by the pyre</i></li> <li>• <i>Ingestion of foodstuffs grown on land which has had ash ploughed into it.</i></li> </ul>
<b>Intervention Costs:</b>	
<b>Equipment</b>	Hire of machinery and equipment.
<b>Consumables</b>	To destroy 250 carcasses the following are required; 250 railway sleepers, 250 bales of straw, 6,250 kg of kindling wood, 50,750 kg of coal, 1 gallon of diesel oil per metre length of pyre.
<b>Operator time</b>	Time to prepare pyres varies with the machinery and workforce available. Pyres burn continuously for 2 to 3 days. Transportation from farm to burial site. To monitor air and water pollution in surrounding area during and following burning.
<b>Factors influencing costs</b>	Numbers of livestock. Distance between farm and burning site. Availability of burning materials.

<b>Communication costs</b>	Dissemination of information about carcass burning to the general public.
<b>Compensation costs</b>	To transport and machinery hire companies for cleaning and decontamination of vehicles.
<b>Waste cost</b>	Cost of burial or landfill.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Highly disruptive effect on farmers. Additional dose to populations living close to burning sites.
<b>Environmental impact</b>	<p>Short term air quality and odour issues.</p> <p>Atmospheric emissions from pyres include</p> <ul style="list-style-type: none"> <li>• Gases: CO, CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, etc.</li> <li>• Mineral dust: fly ash (PM10).</li> <li>• Heavy metals: Pb, Cu, Hg, Cd, etc.</li> <li>• Organic molecules: dioxins, furans, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs).</li> <li>• Radionuclides</li> </ul> <p>All of these are damaging to human and animal health and the environment, and can enter the foodchain downwind. Critical air quality pollutant downwind of centre of pyre is SO<sub>2</sub>. Amounts will be reduced if coal with low S content (&lt; 2%) is used.</p> <p>It is recommended that populations downwind of pyre should be</p> <ul style="list-style-type: none"> <li>• 2km from small pyres (250 cattle equivalents over 3 days).</li> <li>• 3km from large pyres (1000 cattle equivalents over 3 days).</li> <li>• 4km from very large pyres (1000 cattle equivalents per day for 20 days).</li> </ul> <p>Ash will contain radionuclides, heavy metals and hydrocarbons. Leachate from ash can produce ammonia, phosphorous and potassium. Therefore there is a risk of surface and ground water pollution from ash associated contaminants, and to groundwater from fuels used.</p>
<b>Agricultural impact</b>	Ash has high concentrations of micro and macronutrients that will fertilise the soil.
<b>Social impact</b>	Disruption to farming and other related activities e.g. tourism. Policing the carcass burning and averting growth of a black market in slaughtered animals. Potential for dispute regarding burning sites (and) selection of areas for ash disposal. Stigma associated with areas surrounding designated burning sites.
<b>Other side effects, pos. or neg.</b>	There is a potential risk from carcasses awaiting burning to contaminate private and public water supplies. The extent of risk will depend on the state of decomposition of the carcasses and type of ground.
<b>UK Stakeholder opinion</b>	The Environment Agency considers that the high visibility of pyres and local air quality problems make this option unacceptable.

DATASHEETS ON COUNTERMEASURES AND WASTE DISPOSAL OPTIONS FOR THE MANAGEMENT OF FOOD PRODUCTION SYSTEMS CONTAMINATED FOLLOWING A NUCLEAR ACCIDENT

---

<b>Practical experience</b>	Over 950 pyres were built in England and Wales during the FMD outbreak to control the spread of the disease. A limit of 1000 cattle per pyre was introduced during the outbreak though the Department of Health recommends smaller ones to reduce the amounts of air pollutants.
<b>Key references</b>	<p>Environment Agency (2001). The environmental impact of the foot and mouth disease outbreak: An interim assessment. December 2001. Environment Agency, Bristol, UK.</p> <p>Environment Agency Wales (2001). Report to the National Assembly for Wales. Preliminary Assessment of Carcass Disposal sites at Mynydd Eppynt (Sennybridge Training Area, SEN. T. A). Internet version published 06/04/01. <a href="http://www.environment-agency.gov.uk/commodata/105385/127528">http://www.environment-agency.gov.uk/commodata/105385/127528</a></p> <p>MAFF (2001). Guidance Note on the Disposal of Animal By-Products and Catering Waste. January 2001.</p> <p>Trevelyan, G. M., Tas, M. V., Varley, E. M. and Hickman, G. A. W. (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</p>
<b>Comments</b>	Burning of carcasses maybe appropriate if the quantity of material or distance and access to premises in which disposal is otherwise permitted does not justify transporting it.

Table C12: Burial of carcasses

<b>Burial of carcasses</b>	
<b>Objective</b>	To dispose of animal carcasses following slaughter.
<b>Other Benefits</b>	No treatment of carcasses needed prior to burial, therefore, no risk of additional contamination of for example rendering plants, incinerators etc.
<b>Countermeasure description</b>	After slaughter animal carcasses may be disposed of in purpose built burial pits, on-farm or at mass burial sites.
<b>Target</b>	Meat and milk producing livestock.
<b>Targeted radionuclides</b>	All.
<b>Scale of application</b>	Medium to large.
<b>Contamination pathway</b>	N/A.
<b>Exposure pathway pre intervention</b>	N/A
<b>Time of application</b>	Early to late phase.
<b>Constraints:</b>	
<b>Legal constraints</b>	Under normal circumstances the burial of animals is prohibited by the Animal By-Products Regulations 2003, which enforce Regulation (EC) No. 1774/2002 made under the European Communities Act 1972. Other relevant EC legislation includes the <i>EC Groundwater Directive 80/68/EEC</i> .
<b>Social constraints</b>	Acceptability of changes to landscapes and of other environmental effects, to relevant populations. Local opposition to the selection of burial sites e.g. where contaminated carcasses are disposed of in previously uncontaminated areas. Aesthetic consequences of landscape/amenity changes.
<b>Environmental constraints</b>	Availability and capacity of suitable burial sites. Animal carcasses must be disposed of without endangering human health or harming the environment.
<b>Communication constraints</b>	Dialogue with land users. Media interest is likely to be high. Likely requirement to monitor area around burial pit and publish results.
<b>Effectiveness:</b>	
<b>Countermeasure effectiveness</b>	N/A
<b>Factors influencing effectiveness of procedure (technical)</b>	Engineering of burial pit, suitability and availability of land for burial pit i.e. away from water sources and not on land with high water table. On-Farm burial site: relies on the dispersal and dilution of animal leachate (fluids from carcasses) in the ground to protect water, so number of disposal sites are limited. Normally 8 tonnes of carcasses can be buried. This is equivalent to 16 adult cattle, 40 pigs or 100 sheep. More may be allowed in a crisis. Mass burial site: Sewage treatment works (STW) must have the capacity to treat the volumes of animal leachate produced. Time to construct mass burial sites. Transportation of carcasses to burial site.
<b>Factors influencing effectiveness of procedure (social)</b>	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.

<b>Factors influencing effectiveness of procedure (social) (cont.)</b>	Maintenance of correct burial pit procedures (e.g. clay lining) including burial of non-carcass material (e.g. sheep dip, paint diesel manure).
<b>Feasibility:</b>	
<b>Required specific equipment</b>	Excavators for digging pits. JCB's, bulldozers or tractors with bucket loaders for moving carcasses. Lamps to allow night working. For mass burial site: clay liner 1m thick, geoclay liner and geocomposite liner to prevent seepage. Vents to collect and burn off gasses produced by decomposition. Sumps/wells and pumps to collect and remove any animal leachate produced. Ideally on-site treatment facilities to pre-treat leachate and reduce biological strength (COD) before removal to sewage treatment works (either inland or coastal). Fencing to contain the site and prevent dumping of non-carcass material.
<b>Required ancillary equipment</b>	Transportation of carcasses to burial site and animal leachate to sewage treatment works.
<b>Required utilities and infrastructure</b>	Animal leachate has to be removed by tanker for treatment and disposal at sewage treatment works and on site gas control measures.
<b>Required consumables</b>	Fuel for transportation of carcasses to burial pit and animal leachate to sewage treatment works.
<b>Required skills</b>	Engineers and construction workers to build burial pit.
<b>Required safety precautions</b>	Risk assessment to be carried out before purpose-built burial pit constructed. Protective clothing and equipment for engineers, construction workers and sewage plant operators.
<b>Other limitations</b>	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.
<b>Waste:</b>	
<b>Amount and type</b>	Animal leachate e.g. body fluids from carcasses are released (about 0.1 m <sup>3</sup> per adult sheep and 1.0 m <sup>3</sup> per adult cow) within the first year, and gas.
<b>Possible transport, treatment and storage routes</b>	Animal leachate has to be removed by tanker for treatment and disposal at sewage treatment works and on site treatment of gas.
<b>Factors influencing waste issues</b>	Volume of leachate to be treated and the radionuclide concentration of the leachate.
<b>Doses:</b>	
<b>Additional dose</b> <i>(Dose pathways in italics are indirectly incurred as a result of burial. The leachate generated during burial will be disposed of at a Sewage Treatment Works (STW): the relevant dose pathways for this disposal route are given in Table C2: Landfill.)</i>	Burial Site Operative: <ul style="list-style-type: none"> <li>• External exposure to carcasses while burying</li> <li>• Inhalation and inadvertent ingestion of dirt while burying the carcasses</li> </ul> Drivers (External Exposure): <ul style="list-style-type: none"> <li>• Transporting carcasses to burial sites</li> <li>• <i>Transporting animal leachate to STW's</i></li> </ul>

<b>Intervention Costs:</b>	
<b>Equipment</b>	Civil engineering equipment required to dig pit (e.g. bulldozers, JCBs), clay, geoclay liner and geocomposite liner to line mass-burial pit, appropriate equipment to vent gas and collect animal leachate.
<b>Consumables</b>	Fuel for transporting carcasses to burial pit and animal leachate to sewage treatment works.
<b>Operator time</b>	Time to construct burial pit and transport carcasses and animal leachate. Time required to monitor groundwater after burial. Operator at sewage treatment works.
<b>Factors influencing costs</b>	Numbers of animals requiring burial. Size of pit required. Volume of animal leachate to be treated.
<b>Communication costs</b>	Dissemination of information about carcass burial to the general public.
<b>Compensation costs</b>	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
<b>Waste cost</b>	Treatment and disposal of animal leachate.
<b>Assumptions</b>	None.
<b>Side-effect evaluation:</b>	
<b>Ethical considerations</b>	Negative side-effects on populations living close to burial sites. Possible environmental and aesthetic consequences. Loss of amenity/change in public perception of land used for burial. Liability for potential negative effects from disposal site (e.g., leakage).
<b>Environmental impact</b>	Minimal risk of contamination of surface and groundwater from leachate from correctly designed and managed purpose built burial pits. However animal leachate may contain very high concentrations of ammonium ( $2000 \text{ mg l}^{-1}$ ), COD ( $100,000 \text{ mg l}^{-1}$ ) and potassium ( $3000 \text{ mg l}^{-1}$ ) as well as sheep dip chemicals, barbiturates and disinfectants. Animal leachate can contain pathogens such as <i>Escherichia coli</i> 0157, <i>Campylobacter</i> , <i>Salmonella</i> , <i>Leptospira</i> and protozoa <i>Cryptosporidium</i> and <i>Giardia</i> 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.
<b>Agricultural impact</b>	Potential risk of land becoming blighted.
<b>Social impact</b>	Changed relationship to the countryside and potential loss of amenity/social value resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Disruption to farming and other related activities e.g. tourism. Policing the carcass burial and averting growth of a black market. Contamination of the soil may restrict subsequent uses (e.g. organic farming). Potential for dispute regarding selection of burial pit sites. Stigma associated with areas surrounding designated burial pits.

<b>Other side effects, pos. or neg.</b>	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.
<b>UK Stakeholder opinion</b>	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.
<b>Practical experience</b>	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.
<b>Key references</b>	<p>Department of Health (2001). Foot and Mouth Disease. Measures to Minimise Risk to Public Health from Slaughter and Disposal of Animals—Further Guidance. 24<sup>th</sup> April 2001.</p> <p><a href="http://www.doh.gov.uk/fmdguidance/fmdsummary.pdf">http://www.doh.gov.uk/fmdguidance/fmdsummary.pdf</a></p> <p>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. <a href="http://www.foodstandards.gov.uk/press_releases/statements/fmd.htm#burial">www.foodstandards.gov.uk/press_releases/statements/fmd.htm#burial</a>.</p> <p>MAFF (2001). Guidance Note on the Disposal of Animal By-Products and Catering Waste. January 2001.</p> <p>Trevelyan, G. M., Tas, M. V., Varley, E. M. and Hickman, G. A. W. (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</p>
<b>Comments</b>	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.