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Agricultural Countermeasures in the Nordic Countries after a Nuclear Accident

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Abstract

This report by the NKS/BOK-1.4 project group describes agricultural countermeasures after a nuclear accident, aiming at the reduction of radiation doses to man from the ingestion of foodstuffs. The intention has been to collect information based on common understanding that can be used as a Nordic handbook and in further developments of the national preparedness systems. The report covers two areas: the gathering and dissemination of information before and during a nuclear emergency, and the development of a countermeasures strategy. A number of factors are discussed, which will affect the choice of countermeasure(s), and as a case study, a technical cost-benefit assessment of a specific countermeasure is described.

Key words

Agriculture; Decision Making; Emergency Plans; Food; Information Dissemination; Radiation Protection; Reactor Accidents; Remedial.

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Agricultural Countermeasures in the Nordic Countries after a Nuclear Accident

Report from the NKS/BOK-1.4 project group Countermeasures in Agriculture and Forestry

NKS

December, 2001

Preface

Nuclear accidents in the past have had far-reaching environmental and economic consequences. At the Chernobyl accident in 1986, radioactive material was dispersed over large areas of Europe, and fallout over farmland gave rise to contaminated foodstuffs. The Chernobyl accident demonstrated the need for an effective nuclear accident contingency plan to ensure a supply of safe foodstuffs, and prevent contaminated foodstuffs from reaching the consumer.

Among the Nordic countries, Finland, Sweden and Norway were most affected by the Chernobyl fallout, and restrictions were placed on the use of vast areas of agricultural land. In the early post-accident phase, the response from the Nordic authorities was poorly co-ordinated, and led to confusion.

The aim of this report is to provide a common base for countermeasures to mitigate the consequences to agriculture of radioactive fallout in the Nordic countries

Notwithstanding the fact that during the past 10 years most of the Nordic countries have built up their own national systems of preparedness to counteract or avoid radioactive contamination of the food chain, there was a need for a common agreed basis for the introduction of countermeasures, and to understand why different action might be taken in neighbouring Nordic countries. These views led to the NKS/EKO-3.4 project intended as a first step towards a regular collaboration on nuclear accident preparedness in agriculture and the food production area among the Nordic authorities within agriculture, food production and radiation protection. The project report should be the basis for a mainly joint handbook concerning consequence limiting measures within the agricultural and food producing area (Preuthun et al. 1997). The present document has been developed in this context, in order to clarify a common base for the application of countermeasures.

The target groups for this report are the Nordic authorities responsible for radiation protection, agriculture and food production, nuclear emergency preparedness systems, and people working in the agricultural sphere: farmers, farmers advisors, farmers associations and the food and feed industry. It has been the intention to collect information based on common understandings, which can be used as a Nordic handbook, and in further developments of the national preparedness systems.

The report is written as part of the NKS/BOK-1.4 project, “Countermeasures in Agriculture and Forestry”, as a collaboration between the national ministries of food and agriculture, the nuclear emergency preparedness authorities, and radiation protection authorities and experts in the Nordic countries.

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Contents

Summary

This report covers two key areas. They are:

(i) the gathering and dissemination of information in both normal conditions as well as under emergency; and
(ii) countermeasures and their application.

Section 2 is primarily a general memorandum directed to:

- the responsible authorities in agriculture and preparedness
- those disseminating and relaying information (e.g. the authorities and the media);
- the recipients of information (e.g. farmers, farmers' organisations and the public).

The need for adequate and coherent paths of communication, predetermined chains of command, and the necessary legal framework are discussed. In addition, there is a brief description of tools for monitoring and forecasts of dispersion of radioactive materials.

Section 3 covers: (i) criteria to be applied in making decisions on whether to employ countermeasures and (ii) strategies for the implementation of countermeasures. It is accepted that countermeasures can reduce, but not eliminate, dose from consumption of food products.

A number of factors of natural, technical, economical and political origin influence the final choice of the countermeasure(s). It is shown that the choice of a specific countermeasure may impact on the future ‘degrees of freedom’ to act. It is also important that resources are used cost-effectively, and it is necessary to take special care of high-risk groups (e.g. children). Finally, a brief explanation of the transport of radionuclides through the food chain with reference to key transport factors is given.

Section 4 covers countermeasures for (i) crops, (ii) livestock, and (iii) food processing. A list of specific countermeasures is given, together with details of how to obtain further information on details and applicability of each.

Section 5 (i) explains the ‘aggregated environmental transfer concept’ and (ii) through a simple case study, discusses how countermeasures for specific scenarios can be assessed. The case study: (a) takes into account the background situation; (b) discusses potential countermeasures, and (c) shows a procedure for optimisation by relating predicted averted dose to monetary cost. It is emphasised that this is a technical procedure for assessing countermeasures, but it is recognised that politics may also be taken into account and could be the deciding factor.

Section 6 covers conclusions and recommendations, and is essentially a memorandum for all the organisations mentioned in Section 2. It discusses the resources in terms of personnel, local and central government, universities, the media etc., the need for emergency exercises, the need for identification of responsibilities and co-ordination of the various players. A main conclusion is that the choice and implementation of countermeasures can be improved through adopting the systems described in Sections 4 and 5.

1 Introduction

The nuclear facilities and power plants in Finland, Sweden and in many countries around the Baltic Sea constitute a potential for a severe accident to result in the deposition of radioactive fallout on agricultural land in the Nordic countries. This document discusses contingency plans for mitigating the impact of such an event on the food chain.

Agricultural countermeasures are in this document defined as special actions taken to reduce radiation doses to man from the ingestion of foodstuff.

There are substantial amounts of radioactive sources in, and in the vicinity of, the Nordic countries

It is accepted that in the event of agricultural land being contaminated by radioactive fallout, it is likely that some of the population will be exposed to radiation; protection cannot be absolute. However, sound contingency planning, and the implementation of countermeasures, can go a long way to minimising exposure and reducing the impact on food production. It is also accepted that the level of emergency preparedness is a political and economic question, but that is not discussed further in this document.

For any emergency preparedness plan to be effective, it is essential that all parties be familiar with the details of the plan and its contents, and to be fully aware of individual responsibilities. Similarly, the maintenance of an emergency preparedness plan at an operational level calls for training exercises and updating as and when necessary.

A comprehensive description of the general nuclear preparedness systems in the Nordic countries is given in (Mærli 1996).

1.1 Scope

The scope of the report is to highlight the need for common regulations in the area of contingency plans and agriculture; it mentions the duties of the various authorities, the role of information systems and agricultural advisors. Possible restrictions on the activities of the farmers and the farming industry are discussed.

The report lists a range of countermeasures and describes intervention strategies for both the agricultural and the food production industries for minimising the impact of radioactive fallout on human health.

The agricultural system, in which the report is foreseen to be used, is shown in the following scheme adapted from (Preuthun et al. 1997):

Crops	**Livestock**
Decontamination of land	
Reduce plant-uptake of radionuclides	Reduce intake of radionuclides by animals
Reduce activity in crops	Reduce activity in animals
Food processing	
Alternative usage of foodstuffs	
Change land use	Change production

The implementation of agricultural countermeasures will generally impose serious restrictions on the farmer's freedom, with respect to both his animals and his land. It should be borne in mind that the farm is the 'whole life' of the farmer (i.e., it is his home and his family's home as well as his place of work and leisure), and therefore the most extensive ethical and social considerations must be taken into account when considering countermeasures. The farmer will be anxious to preserve the well-being of his animals.

Note: The countermeasures in this report have been drawn up with only radiocaesium ($^{134+137}Cs$), radiostrontium ($^{89+90}Sr$) and radioiodine (^{131}I) contamination in mind. They are not designed to cover contamination from fuel fragments ('hot particles'), uranium or plutonium.

This generic report is not regarded as an operative tool, but might be used as a basis for translation into the various Nordic languages, taking into account both the national and local conditions.

1.2 Agricultural countermeasures and decision-support

In the event of a severe nuclear accident and contamination of farmland, the authorities will be called upon to make decisions to mitigate the impact on man. Selection of optimal countermeasures, and correct timing of response, requires information on the nature of the accident and conditions in the affected area. Decision-support aims to provide radiological data together with geographical, demographic and agricultural information. Analysis of the whole situation in the contaminated area will form the basis for assessing the potential impact and decisions on implementation of countermeasures. Decision-support systems are used to facilitate timely decisions in complex and changing situations.

Multi-national documents have provided guidelines on various types of countermeasures (IAEA 1994a, IAEA 1994b, Sandalls 1990), and the Nordic countries have produced Nordic-specific guidelines (Preuthun et al. 1997; Andersson 1996; Andersson et al. 2000). The purpose and scope of the publications were to provide assistance in the preparation of more detailed practical guidelines for agricultural countermeasures in the various countries. However, pre-planned strategies exist for only a limited number of situations because environmental conditions, the nature and size of the accidental release, the populace affected, and the social, economical, and agricultural conditions, vary from place to place.

Decisions made by the agricultural and foodstuffs authorities are based on the recommendations of the radiation safety authorities. Contacts and co-operation with the foodstuffs industry and with farmers (through agricultural organisations) are important when considering acceptability of countermeasures. Farmers have the key role in implementation of countermeasures. Connections between authorities and co-operating organisations form a network for decision-support systems.

Decisions made by the agricultural and foodstuffs authorities are based on recommendations from the radiation safety authorities

Emergency preparedness plans include actions to predict/identify areas of land affected, and to map the contamination. Assessments of the consequences of the radioactive contamination must be made as soon as the necessary information is available. This information includes data on the nature of the accident, weather forecasts, and information collected from the national radiation monitoring networks. Computer-based decision support systems are available to help with this requirement (e.g. the European RODOS (Real-time On-line DecisiOn Support system) and the Danish ARGOS (Accident Reporting and Guiding Operational System) systems.

RODOS is an integrated framework developed for models, methods and data, which are necessary for evaluating and presenting information required in decision-making following a nuclear accident. The main elements of RODOS include analysis and prognosis of the radiation situation based on meteorological forecasts. The area scales covered are local, national and European; RODOS covers both early and late phases of an accident.

Although the existing guidelines and decision-support systems are useful in preliminary assessment of the contamination situation and its potential consequences, it should be borne in mind that such assessments may carry large uncertainties, and actual measurements in the field will eventually be required for a more reliable assessment.

1.3 Electronic manual of countermeasures

To facilitate the use of data sheets for nuclear emergency preparedness, a user-friendly electronic manual with countermeasures for contaminated agriculture land/systems is provided on the NKS home page **http://www.nks.org/** (Salbu et al. 2001) for the user groups. Various countermeasures are described for a range of scenarios. The countermeasures include actions, which can be taken:

(i) after the incident has occurred but before any fallout arrives;
(ii) a short-time after deposition of fallout;
(iii) in the first growing season following deposition of fallout; and
(iv) for the longer term.

The web version can be used to identify various countermeasures options and to compare their potential effectiveness for given contamination scenarios. The facility may be used in conjunction with exercises as shown in Section 3, and in calculations for emergency preparedness (Section 5.2).

2 Emergency preparedness in agriculture

Although the fine details of national contingency plans will vary from country to country, there are many components of the plans, which will be common to all the Nordic countries. It is the core components of the plans, which are discussed in this section.

2.1 Administration, the media and the agricultural organisations

2.1.1 The central administration

The government and the ministries are responsible for providing the legislation, which will permit enforcement of countermeasures as and when necessary. Where the provision and maintenance of mobile laboratories, tools, equipment, computers, protective clothing etc. are part of the contingency plan, the funding must be made available to those designated to make such provisions.

2.1.2 Government agencies and specialist institutions

The detailed scientific knowledge and expertise (e.g. of nuclear physics, radioecology, nuclear medicine, meteorology, botany, animal husbandry, production statistics etc.) required to formulate and implement the preparedness plans lie within specialist institutions such as government ministries, government research laboratories, universities and meteorological offices. Responsibilities for the various components of the contingency plan will lie largely with these specialist institutions, and the preparedness plan must make provision for unambiguous delineation of responsibilities and chains of command. Reliable 'hot-lines' of communication should always be available for those with key roles to play in the event of an emergency. The appointment of departments (or persons) responsible for carrying out calculations and recommending countermeasures (as shown in Section 5) lies with these specialist institutions. Annex 1 shows the authorities responsible for various branches of agriculture (including nuclear emergency preparedness and radiation protection) in each of the Nordic countries.

2.1.3 Consultation with individual experts

Apart from the expertise that lies within the official institutions involved in the emergency actions, there may well be a need to seek urgent advice from individual independent experts and from the private organisations. These experts, and routes for contacting them, should be an integral part of the contingency plan.

2.1.4 Scientific and Educational Institutions

The scientific and educational institutions are responsible for streamlining the contingency plans and offering improvements in terms of greater efficiency, technical advances, time-saving, simplification of procedures, and cost benefits.

2.1.5 Dissemination of information to the general public

Television, radio and the electronic and printed press, represent ready-made routes for rapid dissemination of information to the general public in the event of an emergency. Contingency plans should include agreements between the authorities and the media on how to communicate official statements to the public through the media and through Internet portals. Security checks should be in place to ensure that hoax information is not broadcast.

2.2 Information

2.2.1 Information networks

In the event of an emergency, it will be necessary to consider what information should be transmitted, and to whom. Some data will be for transmission to the general public, other data will be for official use only.

If public confidence and trust in the authorities are to be maintained, it is imperative that the general public receives reliable, high quality information, and through a direct channel. A list of information systems and communications routes between central authorities, government agencies, expert institutes and the media, would be valuable.

Many organisations have their own information systems (magazines, Internet home pages), which could be used for dissemination of information. There is, among farmers and consumers, a clear order of confidence in information given from different sources, which has to be taken into account, when information sources and routes are chosen. The authorities should ensure that these channels may be used as an integrated part of the information system.

Agreements covering exchange of information (e.g. monitoring data) among preparedness authorities in the European countries, in the event of a nuclear emergency, already exist. Similar agreements for exchange of information among the foodstuff and agricultural authorities, at least within the Nordic countries, would be valuable. An agreement should include a list of contact points in terms of organisations and personnel.

2.2.2 Information systems and chains. Communication routes

Information relating to emergency situations can be divided into two categories:

a) active-phase information which relates to ‘alert’ situations and actual accidents, or which deal with say the impact on food production and supply in a given situation;

b) passive-phase information which is used to at least maintain the system, and whenever possible, to introduce improvements and upgrades.

Information broadcast must be consistent at all levels. It is imperative that information is not manipulated by the media: Preferably, the media should relay prepared statements. Authorities and organisations may agree upon which types of information should be relayed, and on the communication routes (open or closed networks, television, radio, newspapers, periodicals, magazines, Internet, E-mail).

2.2.3 Active-phase information

In the event of an accidental release from a nuclear site, the information transmitted to the farmer will depend on the situation at that moment in time. The information may be:

(i) a warning that fallout may deposit on his farm;
(ii) that fallout is depositing, or has deposited, on his farm;
(iii) the nature of the fallout;
(iv) how long the fallout will last;
(v) what countermeasures he should employ;
(vi) any restriction orders or recommendations.

The first the farmer hears of an emergency will probably be through the radio, television or telephone, later followed up on the Internet. The early news of a potential or actual contamination problem should be concise, and transmitted as early as possible. Later, following a detailed appraisal of the situation, the farmer should receive an updated and probably improved picture. It is important to ensure that communication channels are available for the farmers' questions to be answered.

The contingency plan must make provision for responding promptly to farmers who will have questions relating to their own specific problems

Apart from the impact on farmers whose land is contaminated, all other farmers and the food industry in the Nordic countries (and possibly even further afield) will need to know about restriction orders because animals and farm produce are traded nationally and internationally.

Where it is necessary to place restriction orders on say sale, slaughter and movement of livestock, the farmer should, if possible, be given an indication as to when the restriction orders are likely to be lifted.

2.2.4 Passive-phase information

Passive-phase information relates to preparedness activities, which are on-going, and not just actions taking place at the time of an emergency. Passive-phase information concerns maintaining and improving the emergency network, training exercises, checking channels of communication, updating lists of names and contact points of key personnel, improving countermeasures, informing and educating the farmers etc.

The authorities have the possibility to pass information to the farmers and farming organisations via the Internet. Farming journals and periodicals can be a means of providing non-urgent information for the farmer. It is a fact that most farmers trust their own organisations and the people they know, they may have less trust in remote government bodies.

2.3 Education and training of personnel

2.3.1 Officers

Within the emergency-planning organisations, certain personnel will carry responsibility for formulating actions, making decisions, transmitting information, training personnel etc. These 'officers' will themselves need to be trained and to learn who is responsible for what in the overall contingency plan.

The channels of command both nationally and internationally must be defined unambiguously and relevant contact points (persons) in other institutions and countries must be appointed. Co-ordination of responsibilities and collaboration between the officers is essential.

2.3.2 Scientists

In an emergency, the decision-makers and the information transmitted will rely heavily on the efforts of the scientists. The scientists representing different disciplines will be involved in evaluating the situation, predicting the path of the radioactive cloud, predicting the likely environmental consequences, recommending countermeasures, and answering questions from decision-makers. It is important that the data be reliable and available at short notice. Such a high degree of preparedness calls for high calibre personnel and state-of-the-art support facilities (e.g. computer models). The educational institutions should recognise the need for high calibre scientists to work in this field.

2.3.3 The media

Staff members representing the press in radio, television, magazines and the news agencies ought to be well informed on common terms and on possible consequences of a nuclear accident on the food chain.

2.3.4 The private sector

People working in the private sector having impact on the flow of information to the farmers and the food industry ought to be held on a suitable level of education. When carrying out measurements under contracted conditions in private companies, the level of education of the staff should be part of the contract.

2.3.5 Exercises and inter-comparison tests

From time to time, limited scale and full-scale training exercises will need to be carried out to test and maintain the contingency plans. At laboratory level, inter-comparison exercises should be carried out. These exercises should test both laboratory quality and the speed required in an emergency situation.

2.4 Environmental monitoring and forecasts

In the immediate aftermath of the contaminating event, the deposition picture is likely to be seen in simplistic terms, as will be the early assessment of the potential impact. Later, incoming information will permit a refinement of the picture and a more reliable assessment of the actual and potential impacts.

Radiation monitoring systems in the various countries will give early warning about increased environmental radiation levels and the nature of the radiation, thus permitting the construction of maps showing the levels and spatial distribution of the contamination.

The data will be continually up-dated and analysed as a basis for making further decisions, which might be further countermeasures, or cessation of countermeasures, or lifting restriction orders.

The Nordic emergency monitoring systems have been described in (Devell and Lauritzen, 2001). Automatic gamma dose-rate monitoring stations form the most important part of the early warning system. Mobile monitoring systems, which can be despatched to areas of special interest, may play an important role in ascertaining the levels and nature of the deposited materials. Aerial survey is also a useful means of determining spatial distribution and radiation levels. Air sampling is used for detection and measurement of relatively small concentrations of airborne radionuclides. Analysis of rainwater or snow and soil will also contribute to enhancement of the deposition picture, which will be the basis for assessing the potential hazard to man from the deposited radionuclides. Assessments of the likely contamination of the food chain will take seasonality into account.

Although in the early stages of the emergency the levels of contamination likely to appear in the food chain will be predicted through calculation, it will be the monitoring of samples of fodder, milk, meat, grain, fruit, edible fungi, vegetables etc. which will provide the most reliable data. The foodstuffs available for monitoring will vary according to the season, and the items for monitoring are likely to be chosen according to the time elapsed since the deposition of fallout.

Annex 2 is a guide as to when measurements of dose and contamination should be carried out, and the radionuclides of most concern.

3 Developing a countermeasures strategy

3.1 Objectives of countermeasures

In the event of an accident leading to significant radioactive contamination of farmland, there are a number of different reasons for introducing agricultural countermeasures. The International Commission on Radiological Protection (ICRP 1990) defines the objectives in their widest sense as ‘the justification of any action, so that more good than harm arises, and optimisation of the action, so that the net benefit of introducing a countermeasure is maximised’.

The main reason for the deployment of countermeasures is to reduce the radiation dose (hereafter referred to as ‘the dose’) to the population in order to mitigate any potential adverse health effects. The doses received by people consuming contaminated food should be reduced as far as reasonably achievable. It is made clear in (ICRP 1999) that countermeasures may also have other important objectives apart from reduction of dose. These include reassurance for the populace, lessening anxiety (stress can adversely affect the health and well-being of people) and prevention of social disruption. The disadvantages of countermeasures may be both financial and social.

The main aim of countermeasures is to reduce the radiation dose to humans

A social problem could be unwillingness to live or work in a contaminated area, even if the radiological risk is small. Information campaigns about the actual risk imposed by staying in the area, or consuming local food products, may diminish such perceived problems.

3.2 Factors influencing the choice of a countermeasures strategy

Because many different types of foodstuffs may be produced in a contaminated area, optimised strategies for reduction of dose from consumption of locally-produced food may call for the use of more than a single action. In order to choose the most appropriate procedure for the particular situation, it is essential to consider the many factors that may influence the strategy to be followed. These factors include:

(i) the avertable collective dose;
(ii) financial costs;
(iii) technical feasibility and requirements, e.g. machinery and personnel;
(iv) legal constraints, e.g. maximum allowed radionuclide concentrations of traded foodstuffs;
(v) environmental impact; and
(vi) social impact and acceptability.

3.2.1 Averted dose and its monetary value

Equating in monetary terms the total dose (external and internal) that can be averted by implementation of countermeasures should be an integral part of a countermeasures strategy. The calculation of collective dose may be complex, since contributions to dose may follow many different pathways and be dependent on many case-specific factors. Also the radiological effectiveness of a dose-reducing countermeasure (i.e. the fraction of a specific dose contribution averted by introduction of a countermeasure) is to some extent case-specific.

Doses to some groups of the population may be significantly above the average due to different diet, these 'critical groups' call for special consideration. Children are seen as a critical group because they are more susceptible than adults to developing radiation-induced cancer. Even personnel deployed to carry out countermeasures in contaminated areas constitute a critical group, and at some stage a judgement will need to be made as to whether this additional risk is acceptable.

The equating of dose-averted in terms of monetary value is a political decision. One authority may equate dose averted and monetary cost through reference to other types of accidents (e.g. traffic), combined with the state-of-the-art estimate of the probability of developing fatal cancer per unit of dose received. Various approaches for valuation of averted dose have been suggested (French et al. 1993; Guenther & Thein 1997; Eged et al. 2001).

It should be stressed that the value of the averted dose must be balanced against factors such as the monetary value of the product, the cost of providing a substitute product, and the costs that would be incurred if the product were to be dumped.

Annex 3 describes a number of factors influencing dose from consumption of contaminated food.

3.2.2 Direct costs and other economical perspectives

The direct monetary costs of implementing a countermeasure must take into account many factors including purchase and hire of equipment, cost of consumables, labour, transport, and treatment and disposal of any wastes arising.

The potential influence of countermeasures on land quality and value must be considered. The countermeasure action itself may have a positive or negative effect on the future productivity of the land. For example, where fertiliser is added to nutrient-deficient soil to reduce soil-to-plant transfer of radionuclides, a substantial increase in crop yield would be expected at least in the short term. On the other hand, deep ploughing may bring less fertile soil to the surface and productivity could be adversely affected for many years.

Where the countermeasure proposed is a change in land use, the market for the new crop/product should be considered together with the availability of facilities for harvesting and processing the new product. It may even be necessary to buy-in or import the 'lost' crop/product from overseas, thus incurring additional monetary costs.

Countermeasures have advantages and disadvantages, and both must be weighed

Indirect costs or benefits associated with the chosen countermeasure strategy may, as described in the following sections, also incur other socially or environmentally related problems (e.g., stress, decrease in working capacity, change in land value).

3.2.3 Seasonality and technical feasibility/requirements

The contamination scenario, the potential for contamination of the food chain, and therefore the countermeasures options, will be largely governed by the time of year and this seasonal dependence is termed 'seasonality'. Contamination of say bare soil in winter may not present the same potential hazard as contamination of a standing crop about to be harvested. Similarly, removing contaminated snow and the concomitant contamination is another season-specific option. Some countermeasures will need to be implemented very soon after the fallout event (e.g. disposal of a standing crop) whereas others could easily be delayed (e.g. ploughing).

The choice of countermeasure(s) may be limited by the availability of specialised hardware; similarly, the availability of even non-specialist hardware and resources will need to match the area of land to be treated. Where say normal ploughing is the countermeasure of choice, this should rarely present a problem, but more specialised equipment such as the skim-and-burial plough may not be available locally, or indeed in sufficient numbers.

The physical and chemical properties of the fallout will be a factor to consider when selecting the countermeasure(s). For example, if the fallout is essentially ^{131}I (half-life 8 days), a short-term prohibition of consumption of milk, fruit and leafy vegetables may suffice. The situation would be very different for ^{137}Cs (half-life 30 years) with its potential for contaminating the food chain for many years to come.

Checklists should be issued to ensure that the technical requirements for carrying out countermeasures are satisfied. Also, the availability of personnel with the required skills to carry out the countermeasures must be secured.

Countermeasures have to be chosen with care

3.2.4 Legal constraints

Some countermeasures may be illegal in certain countries. For instance, placing solid boli containing the caesium-binding agent Prussian Blue in the gut of farm animals as a means of obtaining less contaminated meat and milk, is illegal in Finland.

Radioactive waste generated by countermeasures must be disposed of in accordance with the law.

The effectiveness of countermeasures should be assessed bearing in mind possible restrictions concerning the acceptable contamination levels of foodstuffs placed on the market.

3.2.5 Environmental impact

Some countermeasures may impact adversely on the environment in both the short and long term. For example, deep ploughing brings sub-soil to the surface and soil fertility may be impaired. Radical treatments such as ploughing and reseeding of pastureland may change the natural ecosystem and result in the loss of valuable plant species.

A change of land use from say arable to forestry is likely to be to the advantage of the natural environment; a habitat for both fauna and flora will be created, the organic layer at the soil surface will build up, and soil erosion may be reduced or eliminated. Overall, there will be a marked increase in biodiversity.

3.2.6 Social impact, acceptability and credibility

When deciding whether countermeasures are to be implemented in a given area, the impact on the local populace must be taken into account: for example, it might not make sense to ban consumption of an essential constituent of diet if a contamination-free replacement or substitute is not available. Experience has shown that the public will be particularly concerned with environmental issues and, especially in farming areas, animal welfare.

All the persons who will be affected by the countermeasures must be in possession of all the necessary information so that they can participate in the process. Dialogues between the authorities/decision-makers, the public and non-governmental organisations (such as the farmers' associations), are essential even in the active phase, (see Section

2.2.3). Such dialogues should increase the public's trust in the authorities dealing with the situation and reduce mental stress.

People living in a contaminated area must be made aware of the risks of staying in that area

Harmonisation of countermeasures applied within different Nordic areas is desirable. If similar situations are handled in different ways, it is necessary that such differences can be reasoned on local conditions, in order to maintain credibility.

The public acceptability of a countermeasure is important; burying contaminated soil will be less expensive, quicker and easier than removing the soil, but the public may accept only total removal.

Finally, it is good psychology to encourage the local populace to take their own personal countermeasures. For example, people can perhaps avoid consuming those elements of the diet that contribute most to dose - a 'self-help' leaflet on this subject may be beneficial.

3.3 Contaminant mobility and transfer to humans

In agriculture, both the physicochemical form of radionuclides, and the type of soil contaminated influence the potential for the contaminant(s) to enter the food chain. Following a severe nuclear accident, radionuclides such as caesium and strontium can be present in different physicochemical forms, ranging from ions, to particles or large fuel-fragments. After deposition particles are relatively inert and ecosystem transfer is delayed. Within time, however, particle weathering occurs and the radionuclides become mobilised.

Much of the caesium fallout on soils becomes strongly attached to clay minerals, and its mobility and availability for root-uptake is therefore limited. Conversely, caesium on organic soils remains relatively mobile and relatively more available for root-uptake, and this can persist for many years. In the wake of the 1986 Chernobyl accident, it was the rough grazing land on the organic soils where the contamination of lamb meat necessitated restriction on the movement and slaughter of sheep in some parts of Europe. The presence of potassium (a chemical analogue of caesium) will also affect root-uptake of caesium; the higher the concentration of potassium in the soil water, the lower the root-uptake of the caesium. Adding potassium to soil can be an effective means of reducing root-uptake of caesium.

Generally, the fractional amount of radiostrontium in the soil taken up by plants exceeds that of radiocaesium. Strontium is less strongly held than caesium because it is predominantly bound to organic matter. The calcium content of the soil will largely determine the strontium mobility, and the degree of soil-to-plant transfer; the higher the calcium levels in the soil, the lower the strontium uptake by plants. Indeed, the addition of calcium to calcium-deficient soils can be a particularly effective countermeasure to reduce root-uptake of strontium. Sandy soils generally contain less calcium than loamy and peat soils.

Controlling contamination levels in the diet is a valuable means of controlling dose

Various crops, and even different species of the same crop, may have very different transfer factors for a given chemical element. For the choice of appropriate countermeasures to limit the transfer of contaminants to humans via the food chain, it is necessary to focus on the total amount of contamination transferred. The most highly contaminated foodstuffs may perhaps be consumed in relatively small quantities and therefore contribute very little to the total dose; on the other hand, items of diet contaminated at relatively low levels may perhaps be consumed in relatively large quantities. Clearly, both the individual components of the human diet and the amounts consumed are important. Factors influencing the environmental mobility of contaminants in the food chain are described in Section 5.1.

4 Categorisation and list of agricultural countermeasures

4.1 Categorisation of countermeasures

In the event of an accident contaminating a food-producing area, a number of countermeasures are likely to be considered. It is generally advantageous to reduce the contaminant transfer as much as possible in the first steps of the production line, i.e. literally 'in the field'. Other countermeasures may reduce the transfer of contaminant(s) at various stages of the animal- or plant-food production line.

It is essential that the chosen countermeasure(s) be implemented during the appropriate time-frame following the contaminating event. Given sufficient warning, it may even be possible to take preventive measures before fallout. Such countermeasures may prevent the direct contamination of crops, land and animals, but this should not be at the expense of exposure of personnel implementing the countermeasure(s).

There are a number of 'prompt' countermeasures available for implementation immediately after the fallout has deposited on the ground. Some of these are aimed at limiting dose from short-lived radionuclides such as ^{131}I (half-life 8 days). Although the total dose from ^{131}I may be highly significant, most of it is received within a few weeks after the contamination. To be effective, countermeasures aimed at reducing dose from the short-lived radionuclides must be implemented at an early stage.

Some countermeasures can be effective only if introduced soon after the contamination has occurred

If vegetation in the field is harvested soon after the contamination has occurred, it can largely prevent contamination of the underlying soil, thus reducing any long-term soil problems. However, this countermeasure must be carried out early if the contamination on the crop is to be prevented from reaching the soil; rainfall can accelerate the rate of transfer from crop to soil. It may be necessary to dispose of the harvested crop.

When considering the countermeasures options for contaminated land, knowledge of the vertical distribution of the contamination may be useful. If removal of a shallow layer of soil is an option, then only the contaminated soil should be removed if the cost, effort and disposal problems are to be kept to a minimum. Rarely does caesium or strontium migrate more than a few centimetres down the soil profile, even in a period of several months.

4.2 List of countermeasures

This section gives a list of the many countermeasures, which may be employed to reduce dose from consumption of agricultural crops and products. The countermeasures are shown in arbitrary order and a brief description of each action is given. Some of the countermeasures are simple and inexpensive, but others, such as radical changes of land use, should only be considered in very severe contamination situations. More detailed descriptions of countermeasures options are given in (Andersson et al. 2000) and at the NKS home page, **http://www.nks.org/**.

4.2.1 Countermeasures for land and crops

(1) covering land and crops to protect against imminent fallout. If standing or harvested crops can be protected (e.g. with plastic sheets) during the deposition phase, contamination can be limited,

(2) harvesting crops before fallout. If sufficient notice of an accident is given, it may be possible to harvest standing crops before the fallout,

(3) harvesting and disposing of vegetation/crops soon after contamination. Removal of surface-contaminated herbage soon after deposition of the fallout can prevent contamination of the underlying soil, and new crops will be less contaminated,

(4) removal of contaminated snow. Removal of contaminated snow may prevent contamination of the underlying grassland and soil,

(5) removal of surface soil. Removal of contaminated surface soil prevents contamination of subsoil.

(6) liming of soil to attenuate root-uptake of strontium. Liming of calcium-deficient soils will also reduce uptake of caesium,

(7) potassium fertilisation to reduce root-uptake of caesium,

(8) phosphate fertilisation to reduce root-uptake of strontium,

(9) ploughing to reduce the contamination to shallow-rooted plants,

(10) deep ploughing to place the contamination out of reach of plant roots,

(11) ploughing and potassium-fertilisation to reduce uptake of caesium. The combination of ploughing and addition of potassium fertiliser is effective in reducing root-uptake of caesium,

(12) repeated ploughing to increase fixation of caesium in soil,

(13) skim-and-burial ploughing to place the contamination at a depth in the soil, where it will be inaccessible to most arable crops and farm machinery,

(14) turf harvesting. Mechanical cutting of contaminated sods will remove roots and top-soil layer,

(15) cultivating alternative crops with low radionuclide uptake, for instance cereals in stead of grass,

(16) change of production from edible crops to fodder plants, to reduce the activity in the food,

(17) using contaminated vegetation as fertiliser. Contaminated plants, which are unfit for human or animal consumption, may be applied as fertiliser without significantly raising soil contamination levels,

(18) growing industrial crops. If the levels of contamination in soil are such that food crops can no longer be grown, industrial crops, such as fibres for clothing or rapeseed for oil-production, may be an alternative,

(19) change of land use to forestry. If foodstuffs can no longer be grown, afforestation may be an option.

4.2.2 Countermeasures for animals

(1) placing animals under cover before the fallout. By moving animals indoors, or at least under cover, direct contamination can be limited.

(2) removal of animals from contaminated grazing land and supply clean fodder,

(3) storage of fodder crops until short-lived radionuclides has decayed (such as ^{131}I),

(4) supplying animals with stable iodine to prevent accumulation of radioiodine in the thyroid gland,

(5) adding caesium adsorbents (micas and zeolites) to animal feed to attenuate gut-uptake,

(6) adding calcium to fodder to reduce gut uptake of strontium and reduce transfer to milk,

(7) supplying Prussian Blue to bind caesium in the gut and reduce transfer to meat and milk. Prussian Blue may be administered as salt licks, in fodder, or as bolus placed in the gut of the animal,

(8) replacing sheep/goats with cattle to reduce radionuclide concentration in milk and meat. Small ruminants like sheep and goats accumulate higher levels of radionuclides than cattle,

(9) changing from milk to meat production. Changing production from milk to beef can reduce the transfer of radionuclides,

(10) cutting forage plants at sufficiently great height to reduce amounts of contaminated soil ingested by animals,

(11) changing slaughter time. The time of slaughtering can be changed to periods with low intake of radionuclides,

(12) supplying clean fodder to animals in the weeks before slaughter,

(13) changing from feed animals to non-feed animals, e.g. wool-production.

4.2.3 Food processing

(1) mechanical decontamination (e.g. peeling, washing, removal of outer leaves) of fresh vegetables, fruit and cereal grains,

(2) light salting of meat and fish. Soaking meat or meat pieces in dilute sodium chloride brine reduces caesium content by 50 - 80 %

(3) parboiling mushrooms removes 90 - 95 % caesium,

(4) soaking dried mushrooms in water removes 80-90 % caesium,

(5) changing grinding mill yield, using only least contaminated grain fractions (different contaminant concentrations are found in flour, dark meal and bran),

(6) making cheese by the rennet method. This concentrate caesium in the whey, whereas the cheese contains little caesium (but relatively much strontium),

(7) using Prussian Blue filters to remove caesium from milk,

(8) cultivating crops that can be processed. Cultivation of sugar beets or oil-seeds crops, which, after processing, gives nearly uncontaminated food products,

(9) manufacturing food-products that can be stored to allow short-lived radionuclides to decay (e.g. ^{131}I).

5 Transfer factors and countermeasures assessment

In this section, the transfer factor concept is explained briefly and the principles for evaluation of countermeasures for a specific situation is illustrated by an example using the information given in Sections 3, 4 and 5.

5.1 Transfer factors

After an accidental release and deposition to the ground, the radionuclides tend to move from compartment to compartment in the environment and in the food chain. In many cases, only a small fraction of the radionuclides migrates from one compartment to another. For example, the amount of caesium and strontium appearing in cow milk will be only a small fraction of that ingested by the animal in fodder. However, it is the fractional amounts transferred which must be known in order to predict how a fallout event will affect the food chain, and ultimately the dose to humans.

Transfer factors quantify the complex processes involved in the transfer of radionuclides from one environmental compartment to another. The various links in the chain by which fallout on soil arrives in the human diet include transfer from soil to plant, translocation within the plant, transfer from fodder through the gut wall of food animals, transfer to meat and milk within the animal, and culinary preparation and food processing, and each can be represented by its own characteristic transfer factor/coefficient.

In practice, it is simpler and more convenient to make use of the aggregated transfer factor (T_{ag}) in which all the individual compartment-to-compartment transfers in a chain are represented by a single factor. We can, for example, use T_{ag} to express the fractional amount of ^{131}I deposited on unit area of grazing land to what appears in unit volume of cow milk. The aggregated transfer factor (T_{ag}) may be defined as:

$$T_{ag} = \frac{\textbf{concentration of radionuclide in given food item (Bq kg}^{-1}\textbf{)}}{\textbf{activity of radionuclide per unit area of land (Bq m}^{-2}\textbf{)}}$$

Aggregated transfer factors relate the amount of radionuclides appearing in plants and animals to the amount deposited. Most tabulated aggregated transfer factors only consider transfer from soil to plant/animals, and care must be taken when direct contamination is not negligible. This include continuous fallout, and the initial period after deposition when there is direct contamination of say pasture land, and transfer is affected by interception and weathering. Transfer factors are not a constant but vary with time.

The impact of the contamination depends largely on the season at the time of deposition. The Nordic farming year can be divided into five periods:

(i) start of the growing season;

(ii) early summer hay harvest;

(iii) late summer hay harvest and;

(iv) late summer or early autumn cereal harvest; and

(v) outdoor season for grazing dairy animals. Fallout on grazing land will have the greatest impact in the summer when the animals are grazing outdoors or being fed freshly harvested fodder.

With the exception of leafy vegetables, the consequences of direct contamination of young plants in the early phase of growth may not be severe. Where fallout levels on mature grass ready for harvesting are unacceptably high, the best option is usually to cut the grass and dispose of it. In August and September, direct contamination of mature cereal crops may be a cause for concern.

The most important factors determining the soil-to-plant transfer factor are the soil type and the crop species (as mentioned in Section 3.3). Transfer factors for various crops on various types of soil are given in (Eriksson 1997; Nisbet and Woodman 2000; and Andersson et al. 2000). A survey of transfer factors for Cs, Sr and I to be used in contingency plans in the Nordic countries, can be found in (Kostiainen et al. 2001).

Some examples of soil-to-foodstuffs/fodder aggregated transfer factors for ^{137}Cs and ^{90}Sr are given in Table 1. It can be seen that for caesium, the levels are highest in the crops/foodstuffs from the soils with the highest content of organic matter. Root-uptake of ^{137}Cs on peaty soil is about an order of magnitude greater than on sandy soil. The soil-to-pasture transfer factors for ^{137}Cs are about two orders of magnitude higher than soil-to-bread and soil-to-fodder grain on all soil types. Transfer to hay is also significantly higher than to cereals.

Table 1. Aggregated transfer factors (m^2 kg^{-1} dry weight) of ^{137}Cs and ^{90}Sr to crop products by root-uptake during the first growing season after fallout. Loam, sand (<15% clay) and peat (Eriksson 1997).

Caesium-137	**Soil Class**		
Crop/product	Loam	Sand (<15% clay)	Peat (>20% organic matter d.w.)
Bread & fodder grain	0.05×10^{-3}	0.2×10^{-3}	2×10^{-3}
Potatoes	0.3×10^{-3}	1.2×10^{-3}	12×10^{-3}
Hay, grass and cultivated pasture	5×10^{-3}	10×10^{-3}	100×10^{-3}
Natural pasture	10×10^{-3}	20×10^{-3}	200×10^{-3}

Strontium-90	**Soil Class**		
Crop/product	Loam	Sand (<15% clay)	Peat (>20% organic matter d.w.)
Bread & fodder grain	0.05×10^{-3}	1×10^{-3}	0.5×10^{-3}
Potatoes	1×10^{-3}	2×10^{-3}	1×10^{-3}
Hay, grass and cultivated pasture	10×10^{-3}	20×10^{-3}	10×10^{-3}
Natural pasture	20×10^{-3}	40×10^{-3}	20×10^{-3}

5.2 Countermeasure assessment. An example of how to assess dose averted and expenditure

Generally, in any countermeasures action, the benefits should be justified by the expenditure. As mentioned in Sections 3.2.1 and 3.2.2, the costs and benefits of implementing a countermeasure may be manifold. Many of the contributions to costs and benefits (e.g. socially and environmentally related components) may be complex. It is more straightforward to estimate the radiological benefit and the direct costs (see Section 3.2.2) of implementing a countermeasure.

Consider an accident, which results in ^{137}Cs in heavy rain falling on large areas of Western Jutland in Denmark at the beginning of July, see details in (Lauritzen 2001). It is assumed that with respect to potential dose, systemic contamination through root-uptake will be dominant over plant surface contamination. Assume that a field survey has shown 62,000 ha of land covered with cereals to be contaminated at a level of about 80 kBq per m^{-2}. Both plant and animal produce are produced in the area and countermeasures are called for in both cases. The arable products in the area consist of wheat (60%) and barley (40%), and the annual yield is 7.0 t ha^{-1} for wheat and 5.0 t ha^{-1}

Method for estimating the averted collective dose and the monetary costs and benefits

The collective dose averted by implementing a countermeasure for reduction of dose from consumption of a food-product can, in general terms, be calculated from the formula:

$$\Delta E = C \cdot DRF \cdot T_{ag} \cdot Y \cdot e(70)$$

where

ΔE is the averted collective dose (Sv)

C is the activity of the contaminant (^{137}Cs in this case) per unit area of land (Bq m^{-2})

DRF is the fraction of the dose that is avertable through implementation of the countermeasure (in this case 2/3)

T_{ag} is the aggregated transfer factor ‘soil to consumer-ready food product’, cereals in this case (m^2 kg^{-1})

Y is the annual production of the food product in the area (kg). It is assumed that production equals consumption

e(70) is the conversion factor from food contamination to consumer dose (equal to 1.3×10^{-8} Sv Bq^{-1} for ^{137}Cs)

A detailed account of the parameter values applied in this calculation is given in (Lauritzen 2001). Using the above formula, the collective dose averted over the first year by introducing this countermeasure over 62,000 ha (the land covered by cereals) may be estimated as

$$\Delta E_{(1a)} = 80 \text{ kBq m}^{-2} \cdot 2/3 \cdot 0.2 \times 10^{-3} \text{ m}^2 \text{ kg}^{-1} \cdot$$
$$[(0.6 \cdot 0.7 \text{ kg m}^{-2} + 0.4 \cdot 0.5 \text{ kg m}^{-2}) \cdot 6.2 \times 10^8 \text{ m}^2] \cdot 1.3 \times 10^{-8} \text{ Sv Bq}^{-1}$$
$$\approx \underline{50 \text{ Sv}}$$

Taking into account an effective ecological half-life of ^{137}Cs of about 10 years (Aarkrog 1994), the total collective dose that can be averted over a lifetime (70 a), can be estimated as

$$\Delta E_{(70a)} \approx (30 / \ln 2) \cdot (1 - e^{-(70/30)\ln 2}) \cdot \Delta E_{(1a)}$$
$$\approx 800 \text{ Sv}.$$

In practice, the monetary value of dose averted will be decided by political rather than technical considerations. Valuing the averted dose of 1 Sv at DKK 300,000 the radiological benefit of implementing the countermeasure is approx.

DKK 200 mio.

The dose averted can be related to the direct costs of carrying out the countermeasure, which are based on the datasheet and current prices:

Potassium fertiliser	DKK	10	mio.
Diesel oil	DKK	2	mio.
Labour costs	DKK	2.5	mio.
Equipment	DKK	0.65	mio.

Potassium fertiliser costs are for one year only. Over the following years, maintenance of high potassium levels in the soil may well require further additions of potassium, but this may be part of the routine agricultural practice in the area. A comparatively small amount of money may need to be added for magnesium fertilisation, which may, according to the datasheet, be required as a consequence of the potassium fertilisation.

Thus, the total direct cost of implementing the countermeasure would be about

DKK 15 mio.

for barley. Finally, assume that the soil is sandy and potassium deficient, and the addition of potassium fertiliser to reduce root-uptake of radiocaesium is the method selected from the countermeasure data sheets (Andersson et al. 2000; **http://www.nks.org/**). According to the data sheet, a two-third reduction in caesium-to-plant transfer is achievable through the addition of potassium by an amount of 150 kg ha^{-1}.

It can be seen from the calculations in the boxes that, for a total cost of DKK 15 mio., the radiological benefit is about DKK 200 mio. So, strictly in terms of cost-benefit, the countermeasure is justified.

Other factors need to be considered in developing a countermeasure strategy. A countermeasure must be practicable, e.g. consumables and equipment of the selected countermeasure must be available (diesel and fertiliser in the example). As the implementation of this particular countermeasure is not restricted to any set time-frame, and potassium fertiliser and spreaders are normally available, there should be no problem in this case. But, this may not always be so.

Some countermeasures will have beneficial side-effects. When, in the wake of the Chernobyl accident, potassium fertiliser was widely used in the former Soviet Union to attenuate root-uptake of caesium on low-nutrient soils, the increase in crop yield alone justified the expenditure.

Only ^{137}Cs was considered in the example. It is possible that under real conditions other radionuclides will need to be considered and that more than a single countermeasure will be called for. The use of potassium fertiliser could be combined with other countermeasures such as ploughing, which might reduce the systemic contamination of the crop even further. But, because ploughing results in an irreversible distribution of the contaminant, this action should be considered very carefully before implementation.

6 Conclusions and recommendations

The authors of this report believe that the key points in a nuclear accident contingency plan in agriculture are

- to lay down a strategy, including a stringent method of selecting and assessing countermeasures; and
- to implement the plan in the relevant system of organisations.

It is evident that countermeasure strategies and their implementation will be different in the Nordic countries, reflecting local conditions. A strategy however, based on the procedures described in this report will allow for optimisation both of the selection and the scale of countermeasures, and will ensure that only justified countermeasures are carried out. The content of this report should be adapted to the national and local conditions.

To maintain and develop nuclear accident contingency plans, it is important that emergency exercises are carried out at all administrative levels (cf. Sections 2.3 and 2.4), and procedures be updated accordingly. The use of state-of-the-art information systems should be an integral part of a contingency plan.

The decision on when to activate a nuclear accident contingency plan in the Nordic community will be political. The plan will be effective only if there is a prior regulatory framework with defined responsibilities, agreed routes of communication, and chains of command. With this in mind, the authors of this report offer the following recommendations to those organisations mentioned in Section 2.

Central authorities (governments, ministries)

- ensure that all the measures required to counteract the potential adverse effects on man, animals and the environment in general in the aftermath of a severe nuclear accident are lawful;
- place the responsibilities for the implementation of the nuclear accident contingency plan, in individual branches of governmental agencies;
- provide a basis for collaboration between authorities and experts, nationally and internationally.

Government agencies in agriculture and radiation protection

- ensure that the detailed regulation in their area of responsibility is in place;
- ensure that agreements and contracts with specialist organisations and individuals expected to operate the contingency plan are in place;
- ensure that plans for collaboration with other government agencies and authorities are operational at all levels

- ensure that the necessary numbers of skilled personnel are available at all operative levels;
- ensure that the necessary technical resources are available;
- ensure that the necessary agreements are contracted with the media.

Specialist institutions (agriculture, radioecology, etc.)

Universities and research institutions, etc. ought to be able to deliver a sufficient number of skilled scientists (PhD), and to carry out independent or contracted research. In an emergency situation, a sufficient laboratory capacity to perform radioactivity measurements, must be available.

The media

The public relations media must broadcast non-censored messages from the authorities. The media must be able to ensure that the information is genuine.

Agricultural organisations, etc.

- the organisations should collaborate with government departments and broadcast information to those who need it (e.g. farmers);
- farming organisations can help convince their members of the need for any action(s) in terms of countermeasures.

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Annex 1. Authorities in the Nordic countries with responsibilities for administration in agriculture

Authority for:	Denmark	Finland	Iceland	Norway	Sweden
Nuclear contingency plans.	Danish Emergency Management Agency (Beredskabs-styrelsen)	Radiation and Nuclear Safety Authority (Strålsäkerhets-centralen)	Icelandic Radiation Protection Institute (Geislavarnir ríkisins)	Norwegian Radiation Protection Authority (Statens Strålevern)	Swedish Nuclear Power Inspectorate (Statens Kärnkraft-inspektion)
Radiation protection	National Institute of Radiation Hygiene (Staten Institut for Strålehygiejne)	Radiation and Nuclear Safety Authority (Strålsäkerhets-centralen)	Icelandic Radiation Protection Institute (Geislavarnir ríkisins)	Norwegian Radiation Protection Authority (Statens Strålevern)	Swedish Radiation Protection Authority (Statens Stråskydds-institut)
Foodstuff	Danish Veterinary and Food Administration (Fødevare-direktoratet)	National Food Agency (Livsmedels-verket)	Environmental and Food Agency (Hollustuvernd rikisins)	Norwegian Food Control Authority (Statens Næringsmiddel-tilsyn)	Swedish National Food Administration (Statens Livsmedelsverk)
Plant growth and feeding-stuff	Danish Plant Directorate (Plante-direktoratet)	Ministry of Agriculture and Forestry (Jord og skogsbruks-ministeriet)	Ministry of Agriculture; Feed, Seed, and Fertilizer Inspectorate (Rannsóknastofnun landbúnaðarins)	Ministry of Agriculture (Landbruks-departementet)	Swedish Board of Agriculture (Statens Jordbruksverk)
Animal Husbandry	Danish Veterinary and Food Administration (Fødevare-direktoratet)	Ministry of Agriculture and Forestry (Jord og skogsbruks-ministeriet)	Ministry of Agriculture; Veterinary Services (Landbúnaðará-ðuneytið)	Norwegian Animal Health Authority (Statens Dyrehelse-tilsyn)	Swedish Board of Agriculture (Statens Jordbruksverk)

Comments:
The structure and responsibilities of the various organizations vary from country to country as they have evolved in line with needs and traditions.

The responsible authorities in the single administrative area are normally placed in governmental departments or agencies. The authority for the nuclear contingency plan, often has coordinating tasks in relation to the other authorities.

Annex 2. Measurements concerning agriculture and foodstuffs

The type of measurements that will need to be made at the alert stage, and during and after the fallout has arrived, are summarised in the following table.

	Prior to deposition	**During deposition**	**Short term after deposition**	**First growing season after deposition**
Aim	Background values from threatened areas	Identification of deposition	Rough estimation of deposition. Identification of areas where restrictions shall be introduced or maintained	Detailed mapping of contaminated areas. Control of countermeasures in contaminated areas. Release of areas from restrictions. Control of traded (transferable) foodstuffs. Improvement of predictions
Measure-ments to be carried out	"Old" mapping of fallout in the area. Data for soil and vegetation.		Surface measurements. Measurements from aircrafts. Measurements on air-filter samples. Measurements from cars. Field measurements. Measurements of samples of soil, vegetation and milk.	Field measurements. Measurements of samples of soil and vegetation. Measurements of various foodstuffs such as milk, vegetables, meat and fish.
Variables to be analysed	Cs, Sr, Pu	Dose rates (µGy/h, µSv/h). Gamma emitters Bq/m^3, Bq/m^2.	Dose rates. Gamma emitters, esp. ^{131}I. Cs–isotopes. Some ^{90}Sr-analyses. Few Pu-analyses. Few particle analyses	Cs- isotopes. Extended ^{90}Sr-analyses Some Pu-analyses.

Annex 3. Factors influencing doses from consumption of contaminated food

This annex gives a brief description of some factors that generally influence doses received from consumption of agricultural products. Many of the aspects described in Section 3.2 that influence the choice of agricultural countermeasures will be dependent on the specific case, and it may be difficult to recommend a generic method for their detailed analysis. For instance the environmental impact and public acceptability of a countermeasure are factors that cannot readily be quantified. Rather, the weighting that such factors impose will be subject to the judgement of the decision-maker. However, methods have been suggested for monetary valuation of changes to ecosystems (Hanley and Ruffell, 1993). The valuation of the dose-reduction effect of countermeasures is, ultimately determined by politics, but the political judgement should rely on expert analysis of the expected dose reduction.

A multitude of different radioactive contaminants may contribute to dose after a nuclear accident. The isotopes ^{134}Cs, ^{137}Cs, ^{90}Sr and ^{131}I are deemed to be of particular concern. The behaviour of caesium in the environment is similar to that of potassium. Following ingestion by humans and animals, caesium will become distributed throughout the soft tissues. In contrast, strontium, which behaves like calcium, will be assimilated into bone. Iodine will concentrate in the thyroid gland.

Contaminants released in the course of an accident may take a variety of physical and chemical forms. Radionuclides released from Chernobyl in 1986 were associated with particles of varying size. Larger particles deposited close to the reactor site while smaller particles travelled to Scandinavia more than 2000 km from the site. The mode of deposition (wet or dry) can affect the spatial deposition pattern on the ground, and the extent to which contamination is deposited on plant surfaces and on the underlying soil.

Particle weathering and solubility will influence the availability of contaminants in soil for uptake by plants. Particle solubility also influences the period over which contaminants are retained in the gastro-intestinal tract and the fraction of contaminants transferred to body tissue of humans and animals (Salbu 2000).

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Abstract	This report by the NKS/BOK-1.4 project group describes agricultural countermeasures after a nuclear accident, aiming at the reduction of radiation doses to man from the ingestion of foodstuffs. The intention has been to collect information based on common understanding that can be used as a Nordic handbook and in further developments of the national preparedness systems. The report covers two areas: the gathering and dissemination of information before and during a nuclear emergency, and the development of a countermeasures strategy. A number of factors are discussed, which will affect the choice of countermeasure(s), and as a case study, a technical cost-benefit assessment of a specific countermeasure is described.
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