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HUGINN

A late-phase nuclear emergency exercise

Edited by Bent Lauritzen
Risø National Laboratory, Denmark

February 2001

Abstract

The Huginn late-phase exercise was carried out by the NKS/BOK-1.4 project group in the spring 2000. National teams from Denmark, Finland, Norway and Sweden took part in the exercise. The objective of the exercise was to test the ability to calculate the radiological and economical consequences of various agricultural countermeasures following a nuclear accident. This report describes the findings of the four national teams, including the approaches made by the teams, selection of countermeasures and the results of the cost-benefit analyses that they performed. The methods used and findings by the four teams have been compared and recommendations issued based on the exercise results.

Key words

Agriculture; Cost Benefit Analysis; Fallout; Radiation Doses; Radioecological Concentration; Remedial Action

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HUGINN

A late-phase nuclear emergency exercise

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

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NKS

February, 2001

Preface

The NKS/BOK-1.4 project group on Countermeasures in Agriculture and Forestry carried out the Huginn exercise. This report is the result of the active participation by and many stimulating discussions with the BOK-1.4 project members,

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The conclusions and recommendations issued in this report are solely the responsibility of the authors and not of NKS.

Bent Lauritzen, BOK-1 project leader

HUGINN

A late-phase nuclear emergency exercise

Executive Summary

Nuclear accidents affecting food-producing areas require immediate resolutions on the use and treatment of foodstuffs that may be contaminated from the accident, and call for decisions on the future agricultural production. A number of agricultural countermeasures exist to mitigate the effects of nuclear fallout contaminating arable land. It is for the nuclear authorities to develop a strategy for intervention and to select the best agricultural countermeasures among the many possibilities.

In order to examine and promote decision making on agricultural countermeasures based on radiological principles of optimizing the effect of the measures, taking into account monetary costs and dose reduction, the late-phase exercise Huginn was designed[1]. The exercise aimed mainly at the group of experts and advisors within the NKS/BOK-1.4 project, Countermeasures in Agriculture and Forestry, and project members from Denmark, Finland, Norway, and Sweden took part in the exercise. The exercise was designed as a “table-top” exercise, in which the four national teams were given sufficient time to carry out the required work.

In the Huginn exercise, similar fallout situations were postulated for each of the Nordic countries: the accident taking place in the midst of the growing season and the fallout containing radioactive isotopes of iodine and cesium. Other radionuclides were omitted to keep the exercise simple. The four national teams were given the task, independent of each other, to identify appropriate countermeasures, and to carry out cost-benefit calculations for selected countermeasures.

The Huginn exercise demonstrated that it is possible based on existing information to carry out cost-benefit analysis for a number of agricultural countermeasures, e.g., administration of Prussian Blue to cattle and sheep. For other countermeasures, however, more detailed and scenario-specific information will be needed to assess the radiological and economical consequences of the countermeasures. In particular, the necessary information on transfer factors to plants was not readily accessible, and it was recommended that a study of transfer factors for nuclear emergency preparedness be undertaken.

The results of exercise showed that large differences exist among the national groups, both with respect to the choice of countermeasures, and in the cost-effectiveness estimates of the selected countermeasures. Such differences may hinder Nordic harmonization following nuclear accidents.

It was agreed that the Huginn exercise has been useful, but that it should be followed up by discussions on the decision process and methods employed by the Nordic countries for handling nuclear accidents. Furthermore, the exercise format using questionnaires was deemed to be useful for testing the response of the Nordic authorities to a nuclear accident.

[1] The Huginn exercise builds upon a previous NKS exercise, Odin. According to Nordic mythology, Huginn and Muninn are the two ravens of Odin.

The Huginn Exercise:

Evaluation and Recommendations

Bent Lauritzen
Risø National Laboratory

1 Background and Objectives

The Huginn exercise was conducted in the spring 2000, as part of the Nordic Nuclear Safety Research (NKS) project BOK-1.4, “Countermeasures in Agriculture and Forestry”. BOK-1.4 project members from Denmark, Finland, Norway, and Sweden formed national groups that took part in the exercise and the exercise was carried out concurrently in the four countries. The exercise scenario describes a fallout situation (i.e., a late-phase situation), in which food-producing areas in the Nordic countries are contaminated with radioactive isotopes of cesium and iodine.

The main exercise objective was to test the ability to calculate the radiological and economical consequences of agricultural countermeasures. Background material for the exercise is a survey of agricultural, dose-reducing countermeasures carried out as part of the BOK-1.4 project (NKS, 2000). In this survey, the agricultural countermeasures are described on separate data sheets, containing estimates of dose reduction factors and monetary costs associated with each countermeasure.

The data sheets are intended to provide decision support in a nuclear emergency, by facilitating a rapid cost-benefit assessment of each countermeasure and giving guidance to an optimal strategy for managing contaminated farmland. The aim of the Huginn exercise has been to evaluate the data sheets in this capacity, i.e., in their ability to provide decision support. Specifically, the participants were asked,

- to consider the usefulness of the data sheets in the process of identifying possible agricultural countermeasures and calculating the radiological and economical consequences of such countermeasures;
- to determine and describe supplementary information required for assessing the radiological and economical consequences of the agricultural countermeasures;
- to describe useful revisions/additions to the data sheets, that would facilitate decision making on agricultural countermeasures in a radiological emergency.

A secondary objective of the exercise was to study how the Nordic countries would handle similar fallout situations. The exercise format was chosen such that the results obtained by the four national groups could be directly compared, for the purpose of analyzing the different approaches, methods and parameter values, and to examine whether harmonized intervention measures in the Nordic countries could apply following a nuclear accident.

1.1 Exercise format and scenario

The Huginn exercise was designed as a “table top” exercise, in which the four national teams were given two months to carry out the exercise and report their findings.

In the exercise, similar fallout situations were postulated in the four Nordic countries. The fallout contained the radiological important isotopes of cesium and iodine, while other radionuclides were left out to keep the exercise simple. The fallout took place around July 1st, in the midst of the growing season, with severe consequences for the agriculture as a result. Events preceding the fallout had no bearing on the scenario.

A central task for the participants was to evaluate which countermeasures were applicable, given the scenario, and to estimate the dose reduction and the monetary costs associated with selected countermeasures. As guidance towards the evaluation of the countermeasures, the participants were asked to answer questions on relevance, practicability, legality, and acceptability of these. No instruction was provided on how to select countermeasures for the cost-benefit assessment. However, the participants were instructed to make rather simple estimates of the costs and benefits and to report on the methodology used and to provide references. Finally, the participants were asked to issue conclusions and recommendations based on the exercise objectives.

The exercise was carried out independently by the four national teams, and their reports are included in this document. The exercise format, exercise scenario and instructions to the participants are described in more detail in the annex.

2 Exercise results

2.1 Evaluation of countermeasures

In Schedule 1 below, countermeasures found by the national teams to be both r*elevant* and *practicable*, and in Schedule 2, to be *relevant*, *practicable*, as well as *acceptable* are shown. More elaborate schedules can be found in the national reports. *Legality* of the countermeasures was in general found not to be an issue, with the exception of application of Prussian Blue boli, which is illegal in Finland. Compliance with regulations on activity concentrations in foodstuffs, however, played an important role in evaluating the countermeasures. In all cases, the findings were based on expert judgements.

The results are somewhat surprising, as most of the countermeasures investigated have been ruled out by at least one of the teams, as either being irrelevant, impracticable or unacceptable. However, the experience of other nuclear emergency exercises indicate that the Nordic countries often will choose different intervention strategies after a nuclear accident (NKS, 1995b).

The Nordic consensus on a short-list of possible countermeasures, considering the accident scenario, is shown in Table 1.

Table 1. Nordic consensus on possible countermeasures. Data sheet numbers are provided in the annex, Table 6, cf. also (NKS, 2000).

Data sheet	Countermeasure
A1	Early removal of vegetation
A6	Ploughing
A8	Ploughing and K-fertilization
B2	Change slaughter time
B4	Clean fodder to animals before slaughter*

* The Finnish team did not consider application of clean fodder to animals before slaughter to be acceptable to consumers and to the public.

2.2 Selection of countermeasures for cost-benefit analysis

The national teams selected different countermeasures for the cost-benefit analysis, as indicated in Table 2. All teams opted to investigate countermeasures that they found to be relevant, practicable as well as acceptable, cf. the discussion above.

The Danish team chose countermeasures to present different types of intervention, i.e., chemical (A5) and physical (A10) treatment of contaminated land areas, animal chain countermeasures (B5), and foodstuff processing (C5).

The Finnish, Norwegian and Swedish teams all chose countermeasures from a perceived ranking of "importance" of these, taking into account the agriculture production in the fallout area. The Finnish team used expert judgement and experience gained from recent national exercises, while Norway based its choice on expert judgement based on experience gained from the Chernobyl accident, but in accordance with the results of the countermeasure evaluation, cf. Schedule 2. Only two countermeasures however, namely "Early removal of vegetation" (A1), and "Ploughing and K-fertilization" (A8), were selected for further investigation by more than one of these three teams.

Table 2. Countermeasures selected for cost-benefit analysis.

Country	Data sheet numbers
Denmark	A5, A10, B5, C5
Finland	A1, A8 (A13, A14, C1) **
Norway	B4, B5
Sweden	A1, A5, A6, A8

** Cost estimates have only been carried out for countermeasures A1, A8.

Compliance with national and international regulations on activity concentrations in foodstuffs played an important role in deciding on the scale of each countermeasure. It is worth noticing however, that the four teams quoted different regulations with different limits on activity concentrations in foodstuffs: The Codex Alimentarius Commission regulation of foodstuffs in international trade (Denmark), EU-regulation for future accidents (Finland), Norwegian national limits/ EU-regulation for post-Chernobyl import from affected areas (Norway), and Swedish national limits on activity concentrations in foodstuffs for sale (Sweden).

2.3 Cost-benefit results

The results of the cost-benefit calculations are summarized in Table 3, with more details provided in Schedule 3 and in the national reports. The results are related to the affected areas and the specific agricultural production.

Cost-effectiveness is evaluated as the monetary costs per unit of averted collective dose. The cost-effectiveness values will assist ranking the different countermeasures, favoring those with small values of cost-effectiveness. The cost-effectiveness values should be compared to the α-value of dose reduction, i.e., the monetary worth of a unit of averted dose. This amounts to a differential cost-benefit assessment: If the cost per unit of averted dose is less than the α-value, the method will be justified in the sense that the benefits (dose reduction) outweigh the (monetary) costs. With α-values in the range of 10,000 – 30,000 Euro/manSv (NKS, 1995a; IAEA, 1994), many of the countermeasures considered would be justified given the accident scenario.

Table 3. Cost-effectiveness estimates. Rounded values.

Counter-measure	Description	Cost-effectiveness Euro/manSv	Country
A1	Early removal of vegetation	1,000 – 10,000	FI, SE
A5	Potassium fertilization	3,000 – 15,000	DK, SE
A6	Ploughing	20,000	SE
A8	Ploughing and K-fertilization	3,000 – 30,000	FI, SE
A10	Skim-and-burial ploughing	1,000	DK
B4	Clean fodder to animals before slaughter	80,000 – 150,000	NO
B5	Prussian Blue salt licks/boli/additives	1,000 – 40,000	DK, NO
C5	Light salting of meat	2,000,000	DK

Some of the monetary costs appear difficult to assess. The cost-effectiveness estimate of the A1 countermeasure ranges from 1000 Euro/manSv (FI) to 10,000 Euro/manSv (SE). The wide span foremost reflect differences in the estimated price of cutting vegetation, but also differences in the time period considered (the fallout year, or the year following the fallout year), and in transfer factors, cf. Section 3.1. Similarly, for the A5 and A8 countermeasures, the Swedish, Danish and the Finnish estimates differ by up to an order of magnitude, the Swedish estimates being the largest.

The B5 countermeasure displays a very large variation in the cost-effectiveness, from the application of salt licks to grazing oxen and sheep (1,000 Euro/manSv), to the administration of Prussian Blue boli to lamb (40,000 Euro/manSv). The low cost-effectiveness of B4 is associated with price on fodder and high labor cost. The low cost-effectiveness of C5 hinges upon the costs ascribed to food preparation (salting of meat) in private households.

3 Elements of dose assessment

The dose arising from ingestion of contaminated foodstuffs takes the general form,

$$\begin{aligned}\text{ingestion dose (Sv)} = {} & \text{deposited activity (Bq m}^{-2}\text{)} \\ & \times \text{transfer factor (m}^{2}\text{ kg}^{-1}\text{)} \\ & \times \eta \times \text{food production (kg)} \\ & \times \text{dose conversion factor (Sv Bq}^{-1}\text{)},\end{aligned}$$

where η is the fraction of food production that is used for human consumption. When several radionuclides are present, the total ingestion dose is the sum over separate contributions from each radionuclide. In addition, account must be taken for the time delay between deposition and consumption of foodstuffs, which allows for the decay of short-lived radionuclides.

Dose-reducing agricultural countermeasures may effect the deposited activity (e.g., pre-accident measures, removal of contamination), transfer factors (e.g., potassium fertilization), food production (e.g., food treatment, change of land use), η (discarding foodstuffs) or the time delay (storage of foodstuffs). The overall radiological effect of a countermeasure is quantified through a dose reduction factor, defined as the ratio of ingestion dose without and with the countermeasure implemented. The data sheets in most cases, but not all, provide information on expected dose reduction factors.

3.1 Transfer factors

The transfer factors quantify the complex transport processes involved in the transfer of radionuclides from deposition to food product, including retention of radionuclides on the plant surface, transfer from soil to plant, translocation to the edible parts of plants, and transfer coefficients from fodder to animal products. Rather simplifying assumptions are often invoked in estimating transfer factors, such as assuming a stationary flow of radionuclides through the ecosystem.

The four teams assumed rather different transfer factors, resulting in very different estimates of the activity concentration in vegetation. In areas of the four countries with similar deposition of cesium (activity per unit area), Denmark obtains an activity concentration of ^{137}Cs in grass of 360 Bq/kg and Finland has 240-2400 Bq/kg, values based on transfer from soil to plant. Sweden has 9,000 Bq/kg, while Norway obtains the activity concentration of 30,000 – 60,000 Bq/kg, based on direct deposition assuming that the soil-to-plant transfer (root uptake) is low during the first 2 months after deposition. The values quoted, however, apply to somewhat different periods, ranging from the fallout year to the following year.

In estimating (averted) doses from ingestion, transfer factors play a crucial role. The factors depend on local conditions, such as chemical form of the radionuclides, mode of deposition, soil type, season, agricultural produce, etc. Also, the transfer factors are associated with large uncertainties, as much of this information is unknown during the early phases of a nuclear accident. The large variation in the reported transfer factors is a consequence both of the local variability of these, and in the associated uncertainties.

3.2 Agricultural production data

The second element in estimating the collective dose from the ingestion pathway, is to obtain information on the agricultural production in the affected areas. The monetary costs and the dose averted are both proportional to the volume of food produced. Cost-effectiveness on the other hand, being the ratio of the monetary costs to the dose averted, will not be sensitive to the food volume, and the size of the food production should not be an important factor in deciding whether a countermeasure is justified based on radiological grounds. Different countermeasure strategies may still apply for areas with a small food production and a large food production, e.g. because of limited resources.

The four teams reported agricultural data with rather different levels of specification. This may reflect different prioritization by the four teams, or difficulties in obtaining relevant data during the exercise. The data reported were of sufficient level of detail to carry out the cost-benefit calculations.

4 Conclusions and recommendations

4.1 Huginn results

A basic principle of intervention is that countermeasures should be optimized, to ensure a maximum net benefit (the benefits minus the costs) of intervention. This can only be achieved if based on a proper cost-benefit calculation. The agricultural data sheets and the Huginn exercise were developed to facilitate and to test such calculations.

Non-radiological factors that are difficult to quantify should enter the cost-benefit calculations, or rather act as constraints in the optimization process: For instance, it may be important to secure continued agricultural production in the affected areas, and to assert that countermeasures are practicable, legal and generally acceptable.

The Huginn exercise has been successful in testing this “constrained cost-benefit” calculation: All teams evaluated the countermeasures for relevance, practicability and acceptability, producing a shortlist of possible measures, and carried out cost-benefit calculations for selected countermeasures.

However, large differences were found, both in the generated shortlists of applicable countermeasures and in calculated costs and benefits. The different shortlists obtained could be due to different farming conditions, agricultural practices or attitudes towards environmental pollutants in the Nordic countries, or it might simply reflect differences in the subjective assessments made by the actual teams. The basis for cost calculations was different in the four countries. For example, some participants did not consider the price of machinery and some included the costs of using extra fertilizers.

In either case, issuing different recommendations on agricultural countermeasures may be a serious obstacle to harmonization: If the competent authorities in the Nordic countries receive conflicting advice, and with limited time for consultation in a nuclear emergency, decisions on intervention measures may end up differently in the Nordic countries.

The results of the Huginn exercise, hereunder the methods and principles employed by the different countries, should be further investigated for the purpose of analyzing how different recommendations on agricultural countermeasures may result from similar fallout situations.

4.2 Exercise objectives: data sheets as decision support

The Huginn exercise demonstrated that data sheets are useful elements in evaluating countermeasures and in performing cost-benefit calculations. The teams were largely satisfied with the form and content of the data sheets, with only few suggestions for improvements. One recommendation was the inclusion in countermeasure B5 the administration of Prussian Blue in concentrate for milch cows, and more generally, that dose reduction factors and estimates of monetary costs be provided in more of the data sheets.

However, the process also pointed towards some limitations:

1) The calculations were to a large degree carried out by the authors of the data sheets themselves, while people not experts on radiological protection played a minor role in the exercise. In this context the Huginn exercise did not offer an independent test of the usefulness of the data sheets.

2) Only countermeasures for which the corresponding data sheets contain quantitative information on dose reduction and monetary costs were selected for the exercise, and only relatively few calculations were actually performed. The task of calculating costs and benefits appears not to have been easy, and methods to further assist performing such calculations should be considered.

3) The cost-benefit calculations are subject to uncertainties, which may be important for making decisions on individual countermeasures and for developing an intervention strategy. Some of the data sheets used contain information on uncertainties, e.g., in the form of a range of dose reduction factors. The national teams however, did not present any uncertainty estimate.

4) For decision support, advice ought to be issued on the scale of countermeasures (the intervention area). In the Huginn exercise, teams were not requested to give such advice, and only few teams issued recommendations on the size of intervention areas. When recommendations were issued, they were based on compliance with activity limits and not based on a cost-benefit analysis.

The second objective of the Huginn exercise was to determine and describe information needed for the cost-benefit calculations. Radioecological data, in particular transfer factors, was obtained from different sources, covering different transfer routes, seasons and agricultural production. Most reliable information pertains to the year following the fallout year. One conclusion from the exercise was the need for a survey of transfer factors for the fallout year (the growing season), with default values that can be used for emergency preparedness.

Agricultural production data were obtained from annual reviews on farm statistics, available in all four countries. Such data appear sufficient for making a first assessment of possible countermeasures. More detailed information might be requested in an actual nuclear emergency, although it is not obvious how such information would be a factor in decisions on intervention.

4.3 Exercise perspectives

The Huginn exercise was designed foremost as an internal exercise of the BOK-1.4 project, and served to evaluate and to progress project work. The exercise provided valuable information on how this type of nuclear accident may be handled in the different Nordic countries. However, the exercise format and the exercise scenario could be used also for testing the response of competent authorities to a nuclear emergency.

In the exercise description, questionnaires were supplied to the participants for easier structuring and overview of the relevant countermeasures. The method of using questionnaires has generated positive response from the participants. In particular, questions on applicability of countermeasures (Annex, Schedules 1 and 2) may prove useful as a tool for developing an intervention strategy. In the context of the present exercise, the use of schedules has made it easier to compare the individual team reports, and also in drawing the conclusions of this report.

The four national teams used a range of different approaches and methods to derive recommendations on agricultural countermeasures. Using a systematic data-reporting format, including applied formulae, parameters, etc., would increase the clarity of reasoning for such recommendations. The national reports included in this document could be used as a basis for developing a standardized reporting format.

In case of a nuclear accident where similar situations are handled differently in the Nordic countries, a standardized reporting format would also help the competent authorities to understand and explain these differences and, possibly, better to decide whether a harmonized response to the accident is warranted.

A future late-phase exercise involving the Nordic agricultural and radiation protection authorities should be carried out to examine in a more realistic setting the usefulness of the data sheets as a decision support tool.

5 References

NKS, 1995a NKS/BER-3. Intervention Principles and Levels in the Event of a Nuclear Accident, Ed.: O. Walmod-Larsen, TemaNord 1995:507.

NKS, 1995b NKS/BER-5. Nordic Nuclear Emergency Exercises, Eds.: T. Bennerstedt, E. Stranden and A. Salo, TemaNord 1995:606.

NKS, 2000 K.G. Andersen et al.: A guide to Countermeasures for Implementation in the Event of a Nuclear Accident Affecting Nordic Food-Producing Areas (NKS-16, 2000).

IAEA, 1994 Intervention Criteria in a Nuclear or Radiation Emergency, Safety Series no. 109, International Atomic Energy Agency, Vienna, 1994.

Schedule 1. Countermeasures found to be both relevant and practicable. Data sheet numbers are provided in the Annex, Table 6, cf. also (NKS, 2000).

Counter-measure	Denmark	Finland	Norway	Sweden	Consensus
A1	X	X	X	X	X
A2					
A3	?	X		X	
A4					
A5	X	X		X	
A6	X	X	X	X	X
A7	X				
A8	X	X	X	X	X
A9	X	X	X		
A10	X				
A11					
A12	X				
A13	X	X			
A14	X	X			
A15	X				
A16	X	?		X	
A17	X	X			
A18	X				
B1	?			X	
B2	X	X	X	X	X
B3	X	X		?	
B4	X	X	X	X	X
B5	X	X	X	X	X
B6	X	X		?	
B7					
B8	X				
B9	X				
B10	X				
B11	X				
C1	X	X	X	X	X
C2	X	X			
C3	X	X	X		
C4	X	X			
C5	X	-			
C6	X		X		
C7	X	-	X		
C8	X	-	X		

Schedule 2. Countermeasures found to be both relevant, practicable, and acceptable.

Counter-measure	Denmark	Finland	Norway	Sweden	Consensus
A1	X	X	X	X	X
A2					
A3		?			
A4					
A5	X	X		X	
A6	X	X	X	X	X
A7	?	?			
A8	X	X	X	X	X
A9	X	X	X		
A10	X				
A11					
A12	X				
A13	X	X			
A14	X	X			
A15	?				
A16		X		X	
A17	?	X			
A18	?				
B1	X				
B2	X	X	X	X	X
B3	X	X			
B4	X		X	X	
B5	?		X	X	
B6	X				
B7					
B8	?				
B9	?				
B10	?				
B11	?				
C1	?				
C2	X	X			
C3	?				
C4	X				
C5	X				
C6	X				
C7	X				
C8	X				

Schedule 3. Cost-benefit analysis for selected countermeasures.

Counter-measure	Area affected km^2	Averted dose manSv	Monetary costs Euro	Cost-effectiveness Euro/manSv	Country
A1	560	2650	2,785,000	1,000	FI
A1	30	125	1,500,000	12,000	SE
A5	1000	1000	2,700,000	2,700	DK
A5	30	125	2,000,000	16,000	SE
A6	30	125	2,700,000	22,000	SE
A8	370	1850	5,575,000	3,000	FI
A8	30	125	3,200,000	26,000	SE
A10	1000	1300	1,300,000	1,000	DK
B4, oxen	28	13	1,091,000	84,000	NO
B4, sheep	56	2	308,000	150,000	NO
B4, lamb	56	10	1,123,000	110,000	NO
B5, milk (additive)	28	60	145,000	2,400	NO
B5, beef (boli)	1000	16	93,000	5,800	DK
B5, beef (salt-lick)	28	13	12,200	960	NO
B5, lamb (boli)	56	16	628,000	40,000	NO
C5	1000	21	(41,000,000)	(1,900,000)	DK

Report from the Danish Group

Kasper G. Andersson
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Report from the Danish Group

1 Introduction

This report describes in detail how four of the data sheets developed within BOK-1.4 may be applied for cost-benefit analysis in connection with the 'Huginn' exercise scenario. This description relates to the affected Danish areas (as indicated in the exercise 'fallout map'). The choice of data sheets was made so as to cover different types of countermeasures. Potassium fertilization is an example of the 'chemical' treatment of contaminated land areas, whereas skim-and-burial ploughing is an example of 'physical' treatment of such areas. Prussian Blue boli constitute an example of countermeasures that may be applied in the next step of the food-chain, where animals have become contaminated. This relates to both meat and dairy products. Finally, light salting of meat is an example of the processing techniques that may be applied to food products either at domestic or industrial premises.

Answers to other questions in connection with the exercise are appended after the description of cost-benefit aspects.

2 Countermeasures

2.1 Potassium fertilization

Clearly, with the isotope concentrations registered (Annex: Description of the Huginn late-phase exercise, Table 1), it is the ^{137}Cs contamination level that will govern the relevance of countermeasures with long-term impact, such as potassium fertilization and skim-and-burial ploughing, as this isotope will greatly dominate long-term doses received due to the contamination.

As deposition took place in rain, it is expected that the amount of contamination deposited on vegetation would be very little compared to that washed into the soil. Root uptake will thus be the most important pathway of dose. It is however important that control monitoring be carried out during the first season, to ensure that crop contamination levels (including contributions from direct contamination) do not exceed threshold values.

Exact demographic information on e.g. what is produced in the affected areas is probably available from the responsible ministries, but to illustrate the principles of calculation, average values based on *Statistisk Årbog 1999* are applied in the following.

From the iso-line map it is seen that the area contaminated by ^{137}Cs levels exceeding 80 kBq m^{-2} constitutes some 100,000 ha, or about 2.4 % of the total area of Denmark (a more exact measure of the area would probably in a real emergency situation be based on a GIS file). The total arable area in Denmark is about 2,700,000 ha. About 56 % of the total arable area in Denmark is grown with cereals. Areas grown with any other type of crop each represent less than one-fourth of that grown with cereals. It will therefore, for simplicity, be considered in the scenario calculations that an area, corresponding to the affected area multiplied by the fraction of Denmark that is arable land, is grown with cereals. This corresponds to ca. 62,000 ha. More than 90 % of the cereal areas in Denmark are grown with either wheat or barley. Based on the available statistical information from Statistisk Årbog 1999 for Denmark as a whole, it will be assumed in the calculations that about 60 % of the area is grown with wheat and 40 % with barley.

The most contaminated area lies in a part of Western Jutland, where the soil has low clay content. Based on the work of Eriksson (1997), the relevant transfer factor for these types of grain would be expected to be about 0.12 10^{-3} m^2 kg^{-1} (assuming that only little, if any, of the contamination is in an 'insoluble' form), and the average yield in Denmark is at the moment ca. 7.0 t ha^{-1} (0.7 kg m^{-2}) for wheat and 5.0 t ha^{-1} (0.5 kg m^{-2}) for barley. It is assumed in the calculations of potentially averted collective dose (in units of manSv) that all that is produced is also somehow consumed. As a part of the harvest will be applied for fodder in the animal food chain, where only a fraction of the contamination is transferred to humans, the estimate will be conservative. In the type of podzolic or sandy soil, we are dealing with, natural potassium reserves are likely to be small, and the dose reducing effect of supplying the soil with K would therefore be great. According to data sheet X5, a dose reduction by a factor of about 3 may in this case be expectable by application of ca. 150 kg K ha^{-1}.

If it is assumed that the ^{137}Cs level in the most severely affected area is 80 kBq m^{-2}, although it may well be higher, the benefit estimate will be conservative. The saved collective dose per ha of land, over the first growth season in contaminated soil, by potassium fertilization, can be calculated as follows:

$D = A * B * C * E * F$,

where A is the deposited activity (Bq m^{-2}), B is the fractional dose saved, C is the transfer factor (m^2 kg^{-1}), E is the average cereal production (kg m^{-2}), and F is the ICRP dose conversion factor (Sv Bq^{-1}).

$$D = 0.08 \text{ MBq m}^{-2} * 2/3 * 0.12\ 10^{-3} \text{ m}^2 \text{ kg}^{-1} * (0.6 * 0.7 \text{ kg m}^{-2} + 0.4 * 0.5 \text{ kg m}^{-2}) * 1.3\ 10^{-2} \text{ manSv MBq}^{-1} = 5.2\ 10^{-8} \text{ manSv m}^{-2} \text{ treated.}$$

If it is assumed that 62,000 ha are grain fields, potassium treatment will here save a collective dose of some 30 manSv over 1 year. Over a lifetime (70 y), it would, considering the radiological half-life of ^{137}Cs, amount to some 1000 manSv. If it is assumed (based on figures for casualties applied by the Danish ministries in statistical analyses) that an averted manSv has a value of some 300,000 DKK, the treatment would be 'worth' about 300,000,000 DKK.

The corresponding costs would be determined as follows:

Potassium fertilizer costs for treatment of 62,000 ha would, based on data sheet X5 and current K prices, be considered to be of the order of 1 DKK kg^{-1} * 150 kg K ha^{-1} * 62,000 ha = ca. 10,000,000 DKK. Over the following years, maintenance of the soil with high potassium level may well require further addition of K, but this may be regarded as a part of the routine agricultural practice in the area. In addition to this, a cost of 5 l ha^{-1} (of 5.50 DKK l^{-1}) of petrol (diesel) should be expected. This gives a total petrol consumption of ca. 2,000,000 DKK. Further, a labor cost (see data sheet

X5) of 0.4 hour ha^{-1} * 62,000 ha * 100 DKK $hour^{-1}$ = 2,500,000 DKK and an equipment discount of some 35000 EURO * 7.5 DKK $EURO^{-1}$ * 0.4 hours ha^{-1} * 62,000 ha / (37 hours $week^{-1}$ * 52 weeks y^{-1} * 5 y for total discount) = ca. 650,000 DKK should be added. This means that the total cost would be about 15,000,000 DKK, so that the operation would be considered cost-effective from a strictly differential cost-benefit point of view, with the above politically determined assumption regarding the value of an averted manSv. Further, the value of averting or reducing e.g., adverse social and psychological problems has not been included in the evaluation, and fertilizing may have a beneficial effect on the harvest yield. In some areas of the former Soviet Union, where the method was applied after the Chernobyl accident, the fertilizing effect on the production was so great, that this alone was well worth the money spent.

Potassium fertilization may, as mentioned in the data sheet, require further costs for Mg-fertilization, which would add to the total cost, and as deposition occurs during the growth season (1^{st} of July), the fertilization can, as stated in the data sheet, probably only be carried out after harvesting. The total cost of averting a manSv would thus be estimated to be of the order of 20,000 DKK. As the costs of potassium treatment are considered to be 10 times lower than the estimated (politically determined) beneficial value, it might be justifiable to expand the area to be treated, even to include all areas with a ^{137}Cs level exceeding 12 kBq m^{-2}. This area would be about 5 times as large. It should be stressed that a *full* cost-benefit analysis, including politically determined factors, may change the picture. Individual doses would even in the most contaminated areas be small compared with those received from natural background.

Harvesting of grain crops would normally take place somewhere within the period 15^{th} of July - 1^{st} of September. To minimize the dose from intake of radioiodine, it may be recommended to harvest as late as possible within this period. The isotope, which would govern the iodine dose contribution, is ^{131}I, which has a radiological half-life of about 8 days. If harvesting is delayed by e.g. 48 days, the dose contribution from iodine will thus be reduced through 6 half-lives, giving an iodine dose reduction by a factor of $2^6 = 64$. Due to the short half-life of ^{131}I, iodine doses will, however, with the reported concentrations, anyway be much smaller than caesium doses.

Green leafy vegetables (cabbage, lettuce, etc.) are not produced or consumed in nearly as large quantities as grain products. However, the root uptake of caesium to these vegetables is often 30-40 times greater than that to grain (Eriksson, 1997). A large fraction of the green leafy vegetables are produced in greenhouses, which would be expected to be practically unaffected by the contamination, which occurred in rain. However, if green leafy vegetables are grown outdoors in contaminated soil, they can contain high levels of contamination, and such areas are thus particularly important to treat. Also other crops, such as beets and carrots, take up more caesium than grain crops, but these are consumed in limited quantities and will on average be expected to contribute relatively little to the dietary caesium uptake.

2.2 Skim-and-burial ploughing

An alternative or supplementary method to the administration of chemicals, such as potassium fertilizer, is the application of mechanical measures for treatment of contaminated agricultural soil. One such method is ploughing. The ideal way to plough is to bury the thin contaminated topsoil layer deep in the vertical soil profile, with as little impact as possible on the soil fertility. This is the principle, on which the skim-and-burial plough (data sheet X10) is based. With a work rate of 0.4 man-days ha^{-1}, it would, however, require the use of several hundred of these ploughs to plough 62,000 ha before the frost sets in. Very few of these ploughs are readily available, but they could be produced over a period of time. The ploughing period may thus well reach into the 2^{nd} crop growth year. The possible loss in harvest that year would, however, easily be balanced by the higher fertility over the following years if the area is skim-and-burial ploughed and not deep-ploughed.

As stated in the data sheet, the skim-and-burial plough does not work particularly well on very sandy soils, but the affected soils are rich on organic material, and skim-and-burial ploughing should here be possible with a good result. Also, the content of stones in the soil of the affected areas is negligible. A reduction of the contamination level in the upper 20 cm soil layer by a factor of 10 would be expectable. In this type of soil, the arable vertical layer goes much deeper than the perhaps 5 cm top layer that is skimmed off and buried in the bottom of the profile. There would thus be sufficient nutrition in the upper soil layers after skim-and-burial ploughing to grow e.g. grain crops. This means that the reduction in crop radiocesium uptake could well be by a factor of 10.

Thereby, (see the calculation above for potassium fertilization; the only difference is the dose reduction factor) the dose saving over a lifetime from treatment of 62,000 ha would be about 1300 manSv. If it is assumed (based on figures for casualties applied by the Danish ministries in statistical analyses) that an averted manSv has a value of some 300,000 DKK, the treatment would be 'worth' about 400,000,000 DKK.

In addition to this, there would be a benefit from reduction of the external radiation in the fields, which would depend on the number of people spending time in the areas. This would, however, be expected to be somewhat smaller than the contribution from consumption dose. Further, the psychological and social effect of a treatment of the areas is also valuable.

As for the cost of this operation, this would partly be constituted by a labor cost (see data sheet X10) of 0.4 hour ha^{-1} * 62,000 ha * 100 DKK $hour^{-1}$ = 2,500,000 DKK and an equipment discount of some 54000 EURO * 7.5 DKK $EURO^{-1}$ * 0.4 hours ha^{-1} * 62,000 ha / (37 hours $week^{-1}$ * 52 weeks y^{-1} * 5 y for total discount) = ca. 1,000,000 DKK. In addition to this, there would be a cost of 15 l ha^{-1} (of 5.50 DKK l^{-1}) of petrol (diesel). This gives a total petrol consumption of ca. 6,000,000 DKK.

The total costs would thus be some 10,000,000 DKK (plus possibly the value of part of the following year's harvest, as ploughs are not readily available). Overall, the procedure seems somewhat more cost-effective than potassium fertilizing. The total cost of averting a manSv by skim-and-burial ploughing would be estimated to be of the order of 8,000 DKK.

How large an area that would be considered to be 'affected' and calling for treatment, would depend on political decisions, as explained above for the potassium fertilizer option.

2.3 Prussian Blue boli

A rather different problem compared to the above is the decontamination at the next step in the animal food-chain. An option is here to apply Prussian Blue boli to animals in order to reduce the contamination level in both meat and milk. This would not be considered to be an option that would be likely to be applied over many years. However, until supply of uncontaminated fodder can be established, the method can be very useful.

Calculations to be published (Andersson et al., 2000) show that generally, consumption of beef will in this type of scenarios be expected to contribute much more to dose than e.g., consumption of mutton or pork. There are, according to Statistisk Årbog 1999, about 2,000,000 cattle in Denmark. As it is estimated that the most contaminated area (see map with iso-lines) constitutes some 2.4 % of the total area of Denmark, it is in the following calculations assumed that also 2.4 % of the cattle (48,000) would be present in this area. More exact figures could undoubtedly be derived, but the above assumption can be used to illustrate the considerations.

A run of the EU FARMLAND model with standard Western European parameters, assuming that the cattle are fed with grass from the contaminated pasture, shows that the relationship between specific caesium activities of cow's meat and grass is ca. 1.6. If we assume that the soil can be characterized as a sandy loam with 10 % clay, the caesium transfer factor for uptake from soil to grass of 4.5 10^{-3} m^2 kg^{-1} has been reported by Eriksson (1997). This means that the meat contamination level, X (Bq kg^{-1}), in an area contaminated by 0.08 MBq m^{-2} would in the long run be given by:

$X = C * G * A$, where C is the transfer factor from soil to grass (m^2 kg^{-1}), G is the relationship between specific caesium activities of cow's meat and grass, and A is the deposited activity (Bq m^{-2}). This amounts to about:

$X = 4.5\ 10^{-3}\ m^2\ kg^{-1} * 1.6 * 0.08\ MBq\ m^{-2} = 0.58\ kBq\ kg^{-1}$ with respect to ^{137}Cs. That is assuming that nothing else is done to prevent the uptake of contaminants to cattle. Doses from iodine can practically be avoided, if slaughter is not carried out in the next couple of months.

In comparison, the OECD/NEA has set a guideline threshold for food moving in international trade at 1 kBq kg^{-1}, with respect to caesium.

The beneficial effect of the treatment can be described by:

$D = X * B * K * L * F$, where D is the saved dose over the first slaughtering season, X is the meat contamination level (Bq kg^{-1}), B is the fractional dose saved, K is the amount of meat produced per animal (kg $cattle^{-1}$), L is the number of cattle slaughtered each year (it is assumed in the calculation that 1 out of each 7 cattle is slaughtered each year), and F is the ICRP dose conversion factor (Sv Bq^{-1}).

This would, based on data sheet Y5, be expected to be:

D = 0.58 kBq kg^{-1} * 0.6 * 300 kg $cattle^{-1}$ * 48,000 / 7 cattle * 1.3 10^{-5} manSv kBq^{-1} = 9.3 manSv.

Here, also the ^{134}Cs should be considered, as the effect of the method is over a limited period in the early phase. The dose conversion factor for this isotope is 1.9 10^{-8} manSv kBq^{-1}, and the corresponding contamination level is 40 kBq m^{-2}. This gives an extra dose saving of about 6.7 manSv, so that the total amounts to ca. 16 manSv. It is here assumed that each of the cattle gives 300 kg of meat for human consumption.

The corresponding costs are governed by the following:

Boli material costs: 3 boli are needed for each animal for the period (ca. 3 months) prior to slaughter. This gives a cost per animal of 6 Euro (see data sheet Y5), or in total 6 * 48000 / 7 = 40,000 Euro = 300,000 DKK.

Labor costs (see data sheet Y5): these would amount to ca. 7000 / 300 * 50 * 100 DKK + 7000 / 300 * 30 * 400 DKK = ca. 400,000 DKK.

The total costs of the operation would thus be about 700,000 DKK.

This means that the cost of averting one manSv by application of boli in meat producing cattle farms would in an area contaminated by 80 kBq m^{-2} of ^{137}Cs be estimated to be some 40,000 DKK. As some of the treated cattle would also yield milk, and the contamination level in the milk would also be reduced, the benefit would be greater than the above figure.

As for the milk, this could in the earliest few months be stored, e.g., after UHT (Ultra Heat Treatment) or manufacturing of storable products such as cheese (Andersson et al., 2000), since it contains ^{131}I.

However, the application of boli would, as mentioned above, also reduce the caesium level in the milk. The effect of 3 boli in an animal would last for some 3 months, and during this period it would on average produce about 20 l of milk per day. The relationship between specific caesium activities of cow's milk and grass is estimated to about 0.32. If it is assumed that about half of the cattle are milk cattle, the dose saving by application of boli over 3 months can be described by:

$$D = C * G' * A * B * M * N * O * F,$$

where C is the transfer factor from soil to grass (m^2 kg^{-1}), G' is the relationship between specific caesium activities of cow's milk and grass, A is the deposited activity (Bq m^{-2}), B is the fractional dose saved, M is the number of milk cattle, N is the production rate of milk from each cow (kg d^{-1}), O is the effective period of 3 boli (d), and F is the ICRP dose conversion factor (Sv Bq^{-1}).

This would amount to D = 4.5 10^{-3} m^2 kg^{-1} * 0.32 * 0.08 MBq m^{-2} * 0.6 * 24,000 * 20 kg d^{-1} * 90 d * 1.3 10^{-2} manSv MBq^{-1} = 39 manSv, from the ^{137}Cs contribution, and correspondingly 28 manSv from the ^{134}Cs contribution. The total averted dose is therefore ca. 67 manSv.

If the 'value' of a manSv is set to 300,000 DKK, the averted 67 manSv would have a 'value' of ca. 20,000,000.

Few of these animals would be treated to reduce meat contamination levels. The costs would therefore be additional to the above meat treatment costs and amount to some 5,000,000 DKK (same as above, only more animals). On the basis of the differential cost-benefit analysis, it would thus be justifiable to treat a somewhat larger area than that contaminated by ^{137}Cs levels exceeding 0.08 MBq m^{-2}.

Based on the above, the cost of averting a manSv by application of boli to reduce milk contamination in cattle farms would, in an area contaminated by 80 kBq m^{-2} of ^{137}Cs, be estimated to be some 75,000 DKK. The milk contamination level would be well below the OECD/NEA guideline threshold value. For comparison, it should be mentioned that the value of the milk produced in a period of 3 months in the area would be of the order of 100,000,000 DKK.

Again, not included in the analysis are the non-radiological costs (and benefits). Although numerous researchers have concluded that Prussian Blue is harmless to the human body, skepticism may still lead to the 'political' decision not to apply the method. This would particularly be the case, if the population is not supplied with very detailed information on why and how the agent may be beneficial in the particular case.

2.4 Light salting of meat

For a later stage of the food chain, where animals have taken up the contamination and these have been slaughtered with a relatively high level of contamination in the body, methods of a different type must be applied, if doses are to be reduced. A number of options are given by Andersson et al. (2000) for processing of food products. One of these is light salting of meat to reduce the radiocesium contamination level. This method would not be expected to be the solution to the problem in the long run, but until measures can be introduced to reduce the contaminant uptake by animals, it may in some cases be useful. The method could be carried out in large factories or by the individual consumers.

This method would reduce caesium contamination in meat by 80 % (see data sheet Z5). If large pieces of meat are treated, the dose reductive effect will, however, only be by some 40-50 %. The dose, D, averted in the area over the first season by this method (assuming that it is carried out consistently on relatively small pieces of meat) can be described by:

$D = X * B * K * L * F$,

where X is the meat contamination level (Bq kg^{-1}, see calculation above for Prussian Blue Boli), B is the fractional dose saved, K is the amount of meat produced per animal (kg $cattle^{-1}$), L is the number of cattle slaughtered each year (it is assumed in

the calculation that 1 out of each 7 cattle is slaughtered each year), and F is the ICRP dose conversion factor (Sv Bq^{-1}).
This would then amount to:

0.58 kBq kg^{-1} * 0.8 * 300 kg $cattle^{-1}$ * 48,000 / 7 cattle * 1.3 10^{-5} manSv kBq^{-1} = 12.4 manSv from ^{137}Cs, and correspondingly 8.9 manSv from the ^{134}Cs contribution. This gives a total of 21.3 manSv, which, with the above assumptions on the value of an averted manSv, would give a 'value' of 6,400,000.

Costs would be difficult to give a generally valid estimate of, as these would depend on whether the method is carried out by single households or by the industry. The costs for the dilute NaCl brine would be negligible in comparison with the total cost of the meal, and the 'extra' working time could be considered as an inherent part of the routine cooking time.

The working time would be expected to dominate the costs.

If it is assumed that the procedure takes 5 minutes to apply domestically on 500 g of meat, and that 5 minutes are 'worth' some 10 DKK, the costs to treat the meat produced within the area contaminated by ^{137}Cs levels exceeding 0.08 MBq m^{-2} could be:

(48000 / 7) * 600 * 10 DKK = 41,000,000 DKK.

This means that at this scale of application, the differential cost-benefit analysis shows that the method would not strictly be worth the money. The cost of averting one manSv would be about 1,900,000 DKK. However, if the method were carried out at an industrial scale, it would undoubtedly be possible to do it in a way that was much more cost-effective.

The meat contamination level is prior to decontamination below the OECD/NEA threshold value, but the psychological effect/value of the knowledge that the meat has been treated, and 80 % of the contamination removed, may be great.

The method is very straightforward and requires only little extra work in the cooking process. However, a problem is that the procedure requires a processing period of two days. The question is whether individuals buying the meat would have the patience to correctly carry out the procedure. According to data sheet Z5, vitamin and mineral losses may be foreseen, but can be compensated for by other dietary components and additives. Further, the method may somewhat affect the flavor of the meat.

3 Conclusions

All methods were evaluated in relation to relevance, practicability and applicability (schedule 1), as well as general considerations (schedule 2).

Most methods were considered to be applicable in principle in relation to these points. However, some methods would not be considered in reality, since contamination levels are not very high (e.g., change animal production to non-consumption, change land use to forestry, growth of industrial crops).

The acceptability to farmers of countermeasures involving changes in production would not be high. However, if there were no alternatives, they would have to live with it.

Prussian Blue filtration of milk may not sound nice to consumers. Still, it might be a necessary measure, and the problem really relates to the level of information given.

Other methods require that food of specific types (e.g., milk) can be imported in sufficient quantities into the affected area. This might depend on the contamination pattern in other countries.

The result of the exercise is more than anything a demonstration of how data sheets may be applied in strategical evaluations. However, it should be remembered that the focus is here on the differential cost benefit analysis parameters, which should be weighted against socio-economical and ethical implications - factors which are to a great extent 'politically' determined.

The applied data sheets contained the information required for the analysis (except demography and transfer factors). However, some data sheets, such as that for 'change of land use to forestry' do not mention D(R)F. This difference between types of methods is stressed in the report.

Estimates of affected area greatly depend on the applied 'value' of a saved manSv, and also in reality on non-radiological factors.

For the considered methods, the cost-effectiveness parameter ranged from ca. 1000 Euro/manSv (skim-and-burial ploughing of cereal fields) to ca. 1,900,000 Euro/manSv (for light salting of meat, assuming that it is carried out by individual consumers and cannot be considered part of the ordinary cooking procedure).

4 References

Andersson, K.G., Rantavaara, A, Rosén, K., Skipperud, L., Roed, J. and Salbu, B.: A guide to countermeasures for implementation in the event of a nuclear accident affecting Nordic food-producing areas, NKS report in press, 2000.

Eriksson, Å.: The cultivated agricultural environment, Part 2 of the NKS report 'Reclamation of contaminated urban and rural environments following a severe nuclear accident' (eds. P. Strand, L. Skuterud and J. Melin), NKS (97) 18, 97-10-10, ISBN 87-7893-017-0, 1997.

Statistisk Årbog 1999, Danmarks Statistik, Sejrøgade 11, DK-2100 København Ø, 103. årgang, ISBN 87-501-1070-5, 1999.

Table 1. Data sheet numbers.

Data sheet	Countermeasure
A1	Early removal of vegetation
A2	Early removal of snow
A3	Storage of crops / grass
A4	Liming of soil
A5	Potassium fertilization
A6	Ploughing
A7	Deep-ploughing
A8	Ploughing and K-fertilization
A9	Repeated ploughing
A10	Skim-and-burial ploughing
A11	Phosphorus fertilization
A12	Turf harvesting
A13	Cultivating crops with low uptake
A14	Cultivating crops that can be processed
A15	Change production from crops to animals
A16	Use plants as fertilizer
A17	Growth of industrial crops
A18	Change land use to forestry
B1	Supply animals with stable iodine
B2	Change slaughter time
B3	Reduce animal intake of contaminated soil
B4	Clean fodder to animals before slaughter
B5	Prussian Blue salt licks/boli
B6	Supplement fodder with micas or zeolites
B7	Addition of calcium to fodder
B8	Prussian Blue filters for milk decontamination
B9	Replace sheep/goats with cattle
B10	Change from milk to meat production
B11	Change animal production to non-consumption
C1	Manufacturing of food products to be stored for months
C2	Mechanical decontamination of fresh vegetables, fruit and cereals
C3	Making cheese by Rennet method and replacing milk in diet with cheese
C4	Change milling yield and use of least contaminated grain fractions
C5	Light salting of meat
C6	Light salting of fish
C7	Parboiling mushrooms
C8	Soaking dried mushrooms in water

Schedule 1. Applicability of countermeasures.

Country: Denmark								
Counter-measure	Relevance				Practicability			Applicability
	season	nuclides	production type	production conditions	waste	supplies	manpower	yes, if yes to all questions to the left, otherwise no
A1	y	y	y	y	y	y	y	y
A2	n	y	y	y	y	y	y	n
A3	y	(n)	y	y	y	y	y	(n)
A4	y	n	y	y	y	y	y	n
A5	y	y	y	y	y	y	y	y
A6	y	y	y	y	y	y	y	y
A7	y	y	y	y	y	y	y	y
A8	y	y	y	y	y	y	y	y
A9	y	y	y	y	y	y	y	y
A10	y	y	y	y	y	y	y	y
A11	y	n	y	y	y	y	y	n
A12	y	y	y	y	y	y	y	y
A13	y	y	y	y	y	y	y	y
A14	y	y	y	y	y	y	y	y
A15	y	y	y	y	y	y	y	y
A16	y	y	y	y	y	y	y	y
A17	y	y	y	y	y	y	y	y
A18	y	y	y	y	y	y	y	y
B1	y	(y)	y	y	y	y	y	(y)
B2	y	y	y	y	y	y	y	y
B3	y	y	y	y	y	y	y	y
B4	y	y	y	y	y	y	y	y
B5	y	y	y	y	y	y	y	y
B6	y	y	y	y	y	y	y	y
B7	y	n	y	y	y	y	y	n
B8	y	y	y	y	y	y	y	y
B9	y	y	y	y	y	y	y	y
B10	y	y	y	y	y	y	y	y
B11	y	y	y	y	y	y	y	y
C1	y	y	y	y	y	y	y	y
C2	y	y	y	y	y	y	y	y
C3	y	y	y	y	y	y	y	y
C4	y	y	y	y	y	y	y	y
C5	y	y	y	y	y	y	y	y
C6	y	y	y	y	y	y	y	y
C7	y	y	y	y	y	y	y	y
C8	y	y	y	y	y	y	y	y

Schedule 2. General considerations for countermeasures that are applicable according to Schedule 1.

Country: Denmark							
Counter-measure	Legality	Acceptance				Implications for other countermeasures	Comments
		farmers	industry	consumers	public	(specify numbers)	
A1	y	y	y	y	y	A3	
A2							
A3							
A4							
A5	y	y	y	y	y		
A6	y	y	y	y	y	A10,12	
A7	y	(y)	y	y	y	A6, 8, 9, 10, 12	Affects fertility
A8	y	y	y	y	y	A10,12	
A9	y	y	y	y	y	A10,12	
A10	y	y	y	y	y		
A11							
A12	y	y	y	y	y	A10,12	
A13	y	y	y	y	y		
A14	y	y	y	y	y		
A15	y	(y)	y	y	y		Probably not popular
A16	(n)	(n)	y	y	n		Spreading removed contamination
A17	y	(y)	y	y	y		Probably not popular
A18	y	(y)	(y)	y	y		Probably not popular
B1	y	y	y	y	y		
B2	y	y	y	y	y		
B3	y	y	y	y	y		
B4	y	y	y	y	y		
B5	y	y	y	(y)	(y)		Sounds nasty
B6	y	y	y	y	y		
B7							
B8	y	y	y	(y)	(y)		Sounds nasty
B9	y	(y)	y	y	y		Probably not popular
B10	y	(y)	y	y	y		Probably not popular
B11	y	(y)	y	y	y		Probably not popular
C1	y	y	y	(y)	y		Probably not popular
C2	y	y	y	y	y		
C3	y	y	y	(y)	y		Problems with diet
C4	y	y	y	y	y		
C5	y	y	y	y	y		
C6	y	y	y	y	y		
C7	y	y	y	y	y		
C8	y	y	y	y	y		

Schedule 3. Cost benefit analysis for selected countermeasures.

Country: Denmark					
Counter-measure	Area affected km^2	Averted dose manSv	Monetary costs Euro	Cost-effectiveness Euro/manSv	Comments
A5	ca. 1000*	ca. 1000	ca. 2,700,000	ca. 2700	
A10	ca. 1000*	ca. 1300	ca. 1,300,000	ca. 1000	Additional averted external dose
B5	ca. 1000*	ca. 16	ca. 93,000	ca. 5,800	Applied over only 3 months
C5	ca. 1000*	ca. 21	ca.41,000,000#	ca. 1,900,000	Applied over in first season

* This is the area, on which the analysis is based. The area deemed 'affected' may be smaller or larger, depending on various factors, as explained in the accompanying text.

Cost estimate if all work is carried out by individual consumers. May be considered part of cooking procedures. Not much effort for the individual (see accompanying text).

Report from the Finnish Group

Riitta Hänninen, Eila Kostiainen and Ritva Saxén
STUK

Report from the Finnish Group

1 Description of the work

Checking the agricultural data of the area contaminated by the deposition started the work. Production types, the most important crops cultivated in the area as well as soil types affecting the transfer of radionuclides, were clarified. Based on this information and on the data of the deposition given, a general view about the prevailing situation in the contaminated area was formed. Contamination of various agricultural products was considered and at the same time the possibility to implement various countermeasures to decrease the contamination was assessed. The purpose was to find the most prominent problems in the contaminated area.

Several authorities on the fields of agriculture and forestry, foodstuffs of both animal and vegetarian origin and of foodstuff industry, were asked to come to a meeting to discuss and give their comments and standpoints on the agricultural and productional issues at the given season and radiation situation. The participants of the meeting were

Senior Officer, Agricultural Kari Liskola, Ministry of Agriculture and Forestry, Department of Agriculture

Senior Inspector Kyösti Siponen, National Veterinary and Food Research Institute

Senior Food Control Officer Harriet Wallin, National Food Administration

Deputy Chief of Operations Esa Latvio, Finnish Food and Drink Industries' Federation, Food Pool

Manager, Communication Irmeli Mustonen, Finnish Food and Drink Industries' Federation, Food Pool

Head of Laboratory Riitta Hänninen, STUK

Senior Scientist Ritva Saxén, STUK

Assistant researcher Eila Kostiainen, STUK

The exercise group went over the data sheets and assessed one by one the possibilities for implementation of the countermeasures. Based on this discussion the group formed a common conception on the issues asked in the Schedule 1 and filled in the Schedule. Then the group went another time over the countermeasure data sheets and filled in the Schedule 2. Finally, the group chose the main countermeasures, most useful and sensible taking into consideration the biggest problems in the area in the situation concerned, based on the consensus of the group, in other words: the strategy was chosen. The main points were to decrease the contamination as much as possible and to enable the continuation of the activities in the farms to buffer their source of livelihood.

From the data sheets we selected the main countermeasures for the strategy to reduce the contamination of the most important products in the area. The goal was to reduce the level of the contamination at least below the levels applied within the European Union after an nuclear accident (87/3954/Euratom, 89/2218/EEC), but also to reduce the contamination with feasible countermeasures to facilitate the marketing of the products originating from the contaminated area. Because the deposition area was rather small and according to the consensus of the group the same main strategy for the whole contaminated area should be applied.

The chosen countermeasures were then studied in more detail and averted doses and costs (when possible) were estimated.

2 Description of the fallout area

The total fallout area is 25 600 km^2, which is about 7.6 % of the area of Finland. The population in the area is 310 000, which is 6.2 % of the population in Finland. The area of highest fallout is 7885 km^2, and population there is 133 766. 380 000 ha in the fallout area (138 700 ha in the highest fallout area) of the land is used for agriculture and gardening. The prevailing soil types in the fallout area are peat soils (>50%) and sandy soils. The most important crops are barley, oats, silage, hay grass and potatoes. The potato production in the area covers over 30 % of the potato production in Finland. The milk and meat production in the fallout area is close to 20 % of that in Finland. Greenhouse vegetables (lettuce, tomato) are produced as large quantities (about 30% of the production in Finland) in the fallout area.

The farms produce fodder grain, silage and hay grass for animals in their own fields.

In the fallout area 40% of milk is normally consumed as fresh milk and the rest is processed to butter and dry milk.

The scenario fallout on the 1st July was at the time after the first harvest period for silage and hay in Finland. The pasture grass and other grass crops will be heavily contaminated in the area with the highest fallout. The contamination of grain is expected to reach contamination level of some kilobecquerels of ^{137}Cs in autumn.

The biggest problem in the scenario area is milk production. The first harvest of silage has been done before the fallout. It is possible to keep the cows inside and feed them with uncontaminated fodder harvested before the fallout. The farms have fodder in stock for months, because the first silage harvest covers half of the whole year's silage production. The new hay grass will be heavily contaminated in the fallout year and in the next years in peat soils, and if it is used as fodder for the cows, the milk can contain high levels of ^{137}Cs.

The concentrations of $^{137+134}Cs$ in potato grown in peat soils in the scenario fallout area will be 100-300 Bq/kg in the first year after the fallout year. The use of potato as seed instead for human consumption or for manufacturing starch should be considered.

3 Assessment of activity levels and radiation doses

The two areas with isocurves 250 and 500 in the scenario description are summed together in calculations, and deposition data for isocurve 500 is used for the summed area. The sum of depositions of ^{134}Cs and ^{137}Cs is used in calculations, and the faster decay of ^{134}Cs has not been taken into consideration, because the doses have been calculated only for the fallout year and the first year after the fallout.

Table 1. Hay grass and milk production in the fallout area

Area	$^{134+137}$Cs deposition	Hay grass fields	Hay grass yield/year (5500-6000 kg d.w./ha)	Milk production*
1	120 kBq/m^2	41890 ha	248*10^6 kg d.w.	149*10^6 l
2	60 kBq/m^2	69470 ha	411*10^6 kg d.w.	247*10^6 l

*The milk production is calculated assuming that a cow eats 70 kg (fresh weight)/day hay grass produced in the area and produces 17 l milk/day (dry weight concentration of grass is 20 %). It is assumed that half of the hay grass is used for milk cows.

^{131}I contamination in milk

The ^{131}I deposition in the area *1* is 400 kBq/m^2 and 200 kBq/m^2 in the area *2*. The maximum concentrations in milk will be 28 kBq/l in the area *1* and 14 kBq/l in the area *2* (Ref. NRPB, Vol. 5, No 1, 1994). The ^{131}I will in six weeks decay to an insignificant level in milk. The milk production in the area *1* is 438 100 l/d and in the *2* area 690 680 l/d. The level of the total dose due to the milk produced in the areas *1* and *2* will be about 5600 Sv (dose factor 2.2*10^{-8} Sv/Bq) assuming that all the milk is used as fresh milk.

$^{137+134}$Cs contamination of hay grass and milk in the fallout year

The maximum concentration of $^{134+137}$Cs in milk in the fallout year is approximated to be 5600 Bq/l, and it is assumed to decrease to the level of 100 Bq/l during two months due to weathering and growth of pasture grass (Ref. NRPB, Vol. 5, No 1, 1994). The dose received in the fallout year via $^{134+137}$Cs in milk is assumed to be of the order 2500 Sv during pasture season, if the cows are fed with pasture.

The dose via milk in the fallout year without countermeasures will be 5600 Sv (^{131}I) plus 2500 Sv ($^{134+137}$Cs), totally 8100 Sv assuming that the cows are fed after pasture season with last year's uncontaminated feed grain and hay silage harvested before the fallout and in autumn. All the milk is assumed to be used for human consumption as fresh milk.

Table 2. $^{137+134}$Cs contamination of hay grass and milk in the first year after the fallout year

Area	$^{137+134}$Cs in grass[1] (Bq/kg fresh weight)		$^{134+137}$Cs in milk[2] (Bq/l)		$^{134+137}$Cs in milk[3] (kBq)	
	peat	sand	peat	sand	peat	sand
1	2400	240	1344	134	132*10^6	6.8*10^6
2	1200	120	672	67	91*10^6	7.5*10^6

[1] TF for hay grass 0.1 m^2 kg^{-1} d.w. for peat soils and 0.01 m^2 kg^{-1} d.w. for sandy soils, dry weight concentration of grass 20 %. (Report Eriksson Åke, SLU-REK-76, Uppsala 1994).

[2] The concentration in milk during the first year after the fallout year is calculated assuming that a cow eats hay grass 70 kg (fresh weight)/day, and transfer coefficient feed-milk used is 0.008 days/l milk (IAEA, 1987).

[3] The total amount of $^{134+137}$Cs in milk (kBq) produced with the contaminated hay grass.

The amount of $^{134+137}Cs$ ($238*10^6$ kBq) in milk produced with the contaminated hay grass during the first year after the fallout year gives a dose of 3085 Sv (dose factor $1.3*10^{-8}$ Sv/Bq) if all the milk is used as fresh milk.

4 Selection of countermeasures

From the data sheets the main practicable and effective countermeasures that would reduce the contamination were selected. The general principle was that only main countermeasures applicable to main production of food (milk, potato) were considered in more detail.

The main target of the countermeasures A1 (Early removal of vegetation) and A8 (Ploughing and K -fertilization) was to decrease high radionuclide concentration of hay grass and to ensure the continuation of the work on farms. The countermeasure of ploughing without fertilization is not considered, because a standard procedure is to combine these two activities even in normal times. The group found out that after ploughing and fertilization it is possible to grow barley to produce silage in the autumn of the fallout year. For grain or hay production the growing season left after ploughing in July is too short.

Cultivating cereal crops instead of grass crops in peat soils in the first year after the fallout year (A13, Cultivating crops with low uptake) would reduce the dose received via milk.

By the implementation of the countermeasure C1 (Manufacturing of food products to be stored for several months) disposal problems are partly avoided, and time is gained for developing practical disposal methods. The use of some products may also be changed so that instead of human consumption some products may be used as fodder for fur animals.

Potato production is important in the deposition area for two reasons: high percentage of production in Finland and high consumption of potatoes. Contaminated potatoes can be used in industry for making starch or as seed potatoes (C14, Cultivating crops that can be processed).

5 Countermeasures concerning milk production

5.1 Early removal of vegetation (A1)

Fallout year

The countermeasure A1 (Early removal of vegetation) reduces the ^{131}I contamination to an insignificant level. The reduction factor is 7 (assuming the rain was not heavy), and in addition after cutting it takes two weeks before the hay grass is ready to be eaten, so ^{131}I has decayed still remarkably. For $^{134+137}Cs$ contamination using the reduction factor 7 the averted dose will be 2200 Sv. The total averted dose (^{131}I and $^{134+137}Cs$) of the countermeasure during the fallout year will be 7700 Sv, if all the milk were used as fresh milk. The averted dose would be less, the level of 3100 Sv, because only 40% of the milk is used as fresh milk in the area.

The first year after the fallout year
For $^{134+137}Cs$ the averted dose in the first year after the fallout year is 2650 Sv using a reduction factor 7 (not heavy rain). Assuming that 40 % of the milk is used as fresh milk, the averted dose would be of the order of 1060Sv.

Costs of the countermeasure
The costs of early removal of vegetation consist of the work for crop removal and waste disposal. The loss of hay grass is minor, because the new grass has not had time to grow significantly between the first harvest and the fallout. The costs of cutting and removing the grass is based on data sheet A1 personnel requirements (0.2-0.3 mandays ha^{-1}) and the assumed labor and machinery cost of the order of 25 Euro h^{-1}.

5.2 Ploughing and K-fertilization (A8)

Normally hay and grass fields are ploughed in three-year intervals, and fertilized with potassium once or twice a year. The amount of K-fertilization depends on the soil type. If the countermeasure A8 (Ploughing and K-fertilization) is done in autumn in all the hay grass fields instead, the averted dose using a reduction factor 10 for extra fields is 1850 Sv in the first year after the fallout year.

This countermeasure could be done in some peat fields immediately after the fallout in summer. After ploughing and fertilizing barley could be grown and harvested in late summer as silage. The contamination of this feed would be significantly less than that of the hay grass grown after cutting (countermeasure A1) without ploughing and K-fertilization.

Costs of the countermeasure A8
The extra cost of this countermeasure is the ploughing work done in the fields, which were not otherwise ploughed that year and the extra seeds needed. The K-fertilization is done normally in all the fields every year, and the need of extra K-fertilization depends on the soil type and its potassium status, peat soils are often deficient in potassium. The calculations are based on the assumption that extra K-fertilizing needed is 100 kg/ha and the price of K-fertilizer is 0.3 Euro/kg. The cost of the grass seed is assumed to be 40 Euro/ha.. Personnel requirements and method time consumption are based on the data given in data sheet A8. The price of labor and machinery is assumed to be of the order of 50 Euro ha^{-1} for ploughing and 30 Euro ha^{-1} for fertilizing and seeding. If the ploughing is done in July in peat fields, there will be extra costs of buying the barley seeds (100 Euro/ha).

5.3 Cultivating crops with low uptake (A13)

Cultivating cereal crops instead of grass crops in peat soils would reduce dose during the first year after fallout. The peat soils used for hay grass cultivation cover 27 650 ha in the area *1* and 38 210 ha in the area *2*. If these areas were used as grass feed cultivation for cows, the dose via milk would be 5800 Sv in the first year after the fallout year. If the grass crops were cultivated on sandy soils instead, the dose would be ten times smaller, 580 Sv/year. If cereal crops were cultivated on the peat fields instead of grass crops, the level of $^{134+137}Cs$ concentrations in fodder grain would be 100-200 Bq/kg. These cereal crops can be used as feed, and the cow's consumption of grain feed is a tenth of hay grass consumption, so the dose received by feeding cows with this grain is much less than if the fields were used for growing hay grass.

5.4 Manufacturing of food products to be stored for several months (C1)

If the milk produced during six weeks after the fallout in the fallout area is processed to butter and dry milk, the dose 2240 Sv (40% of 5600 Sv) of ^{131}I contamination will be averted. The concentration of $^{134+137}$Cs will be high in the dry milk, and it should not be used for human consumption. The dose due to $^{134+137}$Cs contamination in butter will be 16 % of the dose (about 600 Sv) received if this milk (six weeks) is consumed as fresh milk. The countermeasure would affect milk that would be otherwise consumed as fresh milk, 40 % of milk production. The averted dose will be 2440 Sv (40 % of 6100 Sv). The costs of this countermeasure have not been calculated.

6 Countermeasures concerning potato production

The area used for potato production is 4763 ha in the area *1* and 5422 ha in the area *2*. The ^{137}Cs concentrations in potato cultivated in peat soils in the first year after the fallout year are (transfer factor 0.012 m^2/kg d.w., dry weight concentration 20%):

Area *1*: 288 Bq/kg (fresh weight)
Area *2*: 144 Bq/kg (fresh weight)

The potato yield in the area *1* is 98 750 000 kg/y and 108 650 000 kg/y in the area *2*.

6.1 Cultivating crops that can be processed (A14)

Assuming that half of the potato yield is cultivated in peat soils the ingested dose via this potato yield is 173 Sv in the first year after the fallout (reduction factor 0.6 is used for cooking and peeling). This corresponds to a dose of 0.2 mSv per person in the year after the fallout, for the lifetime a dose of the order of 5-8 mSv per person. This dose is averted, if the potato is used as seed. The costs of this countermeasure to the producer are the difference in the price of the potato used for human consumption or as seed or starch. If the potato is used as starch, the price the producer gets is 0.2 Euro/kg less (without production subsidies) than the price of the potato produced for human consumption. The costs of the countermeasure have not been calculated.

7 Conclusions

The data sheets are a good compilation of countermeasures that are useful in planning systematically appropriate countermeasures in a radioactive deposition situation. The data sheets give information needed for assessing the radiological and economical consequences of the agricultural countermeasures in a concise form. The data sheets are useful for considering the relevance and practicability of countermeasures, and for the choice of the countermeasures that may apply in the situation.

The estimation of monetary costs of the countermeasures is difficult, especially if the production type is changed. Accordingly, systematic comparison of the costs of several countermeasures may be difficult. The future land use and enabling the continuation of activities in the farms of the contaminated area should be considered together with the monetary costs. The size of the fallout area is of importance when choosing the countermeasures. Furthermore, other factors such as the need to address the problems of major production types, acceptability of products, ratio of working and monetary costs etc. may affect handling of the situation. Generally, when using the data sheets additional radiological and agricultural production information is needed for any detailed assessment of the suitability and radiological and economic effects of countermeasures.

The data sheets are useful for experts, and they form a good basis that can be used in educating people in the areas of food-produce, food industry and information. The data sheets can be adapted for use as national guidebooks to be used in fallout situations.

Schedule 1. Applicability of countermeasures.

Country: Finland								
Counter-measure	Relevance				Practicability			Applicability
	season	nuclides	production type	production conditions	waste	supplies	manpower	yes, if yes to all questions to the left, otherwise no
A1	y	y	y	y	y	y	y	y
A2	n							n
A3	y	y	y	y	y	y	y	y
A4		n						n
A5	y	y	y	y	y	y	y	y
A6	y	y	y	y	y	y	y	y
A7				n		n		n
A8	y	y	y	y	y	y	y	y
A9	y	y	y	y	y	y	y	y
A10								n
A11		n						n
A12				n		n		n
A13	y	y	y	y	y	y	y	y
A14	y	y	y	y	y	y	y	y
A15			n	n				n
A16			n (y)					(y)
A17	n							n, y next year
A18		n						n
B1						n		n
B2	(y)	(y)	(y) n	(y)	(y)	(y)	(y)	(y) n
B3	y	y	y	y	y	y	y	y
B4	y	y	y	y	y	y	y	y
B5	y	y	y	y	y	y	y	y
B6	y	y	y	y	y	y	y	y
B7		n						n
B8						n		n
B9			n					n
B10						n		n
B11			n					n
C1								y
C2	y	y	y	y	y	y	y	y
C3	y	y	y	y	y	y	y	y
C4	y	y	y	y	y	y	y	y
C5								
C6			n					n
C7								
C8								

Schedule 2. General considerations for countermeasures that are applicable according to Schedule 1.

Country: Finland							
Counter-measure	Legality	Acceptance				Implications for other countermeasures	Comments
		farmers	industry	consumers	public	(specify numbers)	
A1	y	y	y	y	y	-	1)
A2	-						
A3	y	y	y	?	?		2)
A4	-						
A5	y	y	y	y	y	-	3)
A6	y	y	y	y	y	A10, A12	4)
A7	y	?	y	y	y		5)
A8	y	y	y	y	y	A10, A12	6)
A9	y	y	y	y	y	A10, A12	7)
A10							5)
A11	-						
A12							5)
A13	y	y	y	y	y		8)
A14	y	y	y	y	y		9)
A15		n					10)
A16	y	y	y	y	y		11)
A17	y	y	y	y	y		12)
A18		n?	n?		y		
B1	?			n	n		13)
B2	y	y	y	y	y		14)
B3	y	y	y	y	y		15)
B4	y	y	y	n	n		16)
B5	n			n	n		
B6	?			?	?		
B7							
B8	?		n	n	n		
B9	-						
B10		?					
B11	-						
C1	y		n				17)
C2	y	y	y	y	y		
C3	y	y	n	n	n		18)
C4							
C5							
C6							
C7							
C8							

Schedule 1, comments

A 16: Applicable to certain situations.

A 17: Applicable in the following year.

B 2: Applicable for cows (they are missing from the sheet).

C 1: Applicable for iodine.

C 4: Not sufficient.

Schedule 2, comments

1) The first silage has been harvested, new vegetation can be cut off. The crops of potatoes is lost, if the stems are cut off. The stems are collected for waste.

2) For iodine only. Distribution of the contamination will be prevented. General opinion and acceptance by consumers suspicious.

3) A positive idea to the public.

4) Costs should preferably be given as a rough estimate on labor and machinery costs in euro/ha or euro/h (is missing). The rough estimates on the time used for work h/ha are useful in costs calculations. New machinery is not bought.

5) Not applicable in Finland.

6) For fallows and old grassland, in summer.

7) Additional work and costs, effect is not known, positive idea, is that worth while?

8) Vegetation is removed, soil is ploughed, an extra K-fertilization is given (countermeasures A1 and A8), barley will be grown and used as animal fodder. Cereal crops are lost.

9) Can be applied in the following year. Sugar beet, potato (for seed and to be processed to starch) and seed grain, can be grown, as well as oil plants.

10) Not a quick countermeasure, preferably the species of farm animals may be changed.

11) Only on a small area, old grass lands.

12) Oil plants, sunflower, linen, a good idea, but is it worth while? Growing time is too short in the year of deposition. New machinery is not needed.

13) Possibly not acceptable by the consumers. Legislation and availability may cause problems.

14) Also for cows, problems may be caused by sufficient amount of cold storerooms.

15) Grass is cut at greater height. Extra labor costs of feeding cows with cut grass, not on pasture. Irrigation first?

16) Availability of clean fodder? Must be implemented also for milk production. Information is needed, possibly problems in exporting.

17) Production of butter is possible. Milk powder can be used for instance as feed for fur animals. Suitable for iodine, not for Cs.

18) Marketing may be problematic, rennet to fur animals, not to foodstuff industry.

Schedule 3. Cost benefit analysis for selected countermeasures.

Country: Finland					
Counter-measure	Area affected km^2	Averted dose manSv	Monetary costs Euro	Cost-effectiveness Euro/manSv	Comments
A1	557	2650	2785000	1050	1)
A8	371	1850	5575000	3010	2)
A13	660	5220			3)
A14	50	173 4800-7600			2) 4)
C1	1114	2440			5)

1) In fallout year and in the first year after the fallout year

2) In the first year after the fallout year

3) In the first year after the fallout year, sandy soils taken for hay grass production instead of peat soils

4) Averted collective dose lifetime

5) In fallout year

Schedule 4. References to general information or specific information for your country.

Country: Finland
Agricultural data 1. Yearbook of Farm Statistics 1999. SVT, Agriculture, forestry and fishery 1999:12, Information Centre of the Ministry of Agriculture and Forestry, Helsinki, 1999.
Radioecological data 1. International Atomic Energy Agency (1994a): Handbook of Transfer Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments. Technical Reports Series No.364. IAEA, Vienna 2. BER 6, Part 3, Animals. Lavrans Skuterud, Per Strand, Brenda J. Howard 3. Eriksson Å., Lönsjö H, Karlström F., Beräknade effekter av radioaktivt nedfall på jordbruksproduktionen i Sverige. II. Jordbruksgrödornas förorening. Rapport SLU-REK-73, Institutionen för radioekologi, Uppsala, 1994 4. Eriksson Å., Andersson I., Beräknade effekter av radioaktivt nedfall på jordbruksproduktionen i Sverige. III. Jordbruksgrödornas förorening. Rapport SLU-REK-75, Institutionen för radioekologi, Uppsala, 1994 5. Documents of the NRPB. Guidance on Restrictions on Food and Water Following a Radiological Accident. Volume 5 No 1 1994. National Radiological Protection Board, 1994
Regulations 1. Council Regulation (Euratom) No 3954/87 of 22/12/1987 laying down maximum permitted levels of radioactive contamination of foodstuffs and of feedingstuffs following a nuclear accident or any other case of radiological emergency, Official Journal of the European Communities, L146 of 30/12/1987, Luxembourg. 2. Council Regulation (Euratom) No 2218/89 of 18/7/1989 amending Regulation (Euratom) No 3954/87 laying down maximum permitted levels of radioactive contamination of foodstuffs and of feedingstuffs following a nuclear accident or any other case of radiological emergency, Official Journal of the European Communities L211 of 22/7/1989.

Report from the Norwegian Group

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Report from the Norwegian Group

1 Introduction

The report describes appropriate countermeasures to be taken within Norwegian agricultural systems if deposition of radionuclides takes place in accordance with the Huginn scenario. According to the Huginn deposition map for Norway the affected areas comprises of about 85 % of the Østfold county, 50 % of Vestfold and Akershus counties and about 10 % of Hedmark county. In total about 9495 km^2 should be affected, i.e. about 50 % within the isozone 150, 20 % within the isozone 500, 20 % within the isozone 1000, and 10 % within the isozone 2000. According to national statistics, the agricultural production related to plant production and husbandry has been differentiated within each isozone (Tables 1and 2). The key production affected by the radioactive contamination would be milk and meat production from cow and sheep grazing cultivated semi-natural and natural pastures. Thus, appropriate countermeasures such as the administration of

- clean fodder prior to slaughter (B4)
- Prussian Blue boli of salt-lick for animals grazing contaminated pasture (B5), or
- Prussian Blue salt added to contaminated fodder (no chart available),

should reduce the activity levels in milk and meat and thereby reduce the dose to man from dietary intake. By applying Prussian Blue additives, the transport of clean fodder from non-contaminated areas is not needed.

2 Scenario description

According to the scenario description, the deposition of radioactive caesium (^{134}Cs + ^{137}Cs) and radioactive iodine (^{131}I), within the 4 isozones is summarized in Table 2.. In a real situation, several other radionuclides of radiological relevance, especially ^{90}Sr, should be expected to be present in the deposition. Furthermore, the presence of radioactive particles should also be taken into account, as several of the suggested countermeasures should be of limited value if particles and not ionic forms of the radionuclides are predominant.

The affected area is estimated to comprise about 85 % of Østfold, 50 % of Vestfold og Akershus og 10 % of Hedmark counties. Of the total affected area, about 50 % are within the isozone 150, 20 % within isozone 500, 20 % within isozone 1000, and 10 % within isozone 2000. In 1999, the population in Norway was 4,45 mill. The population in the different counties was 246 000 (Østfold), 461000 (Akershus), (Oslo: 503000), 186000 (Hedmark) and 211000 (Vestfold), respectively. Thus, the population within the affected area was ca. 564000 (Oslo excluded). The population within the different isozones was 282000 (isozone 150), 113000 (isozone 500), 113000 (isozone 1000) and 56000 (isozone 2000), respectively.

In the calculations it is assumed that the affected areas, production types, produce volumes and population are evenly distributed within the isozones.

Table 1a. Areas and agricultural production affected by the described radioactive deposition – National agricultural statistics, 1999(FU=fodder unit).

	County agricultural statistics				Weighted sum, based on area affected
	Østfold	Akershus	Vestfold	Hedmark	
Total area (km^2)	3889	5014	2140	26120	9495
Total arable area (ha)	79000	84360	44960	110090	142819
Fully cultivated soil (ha)	76760	81530	44050	105400	138576
Grain and olive plants (ha)	64960	67630	32430	60460	111292
Potatoes (ha)	1290	690	1800	5640	2955
Green fodder and silo plants (ha)	980	1160	720	3460	2119
Vegetables on free-land (ha)	490	220	1370	670	1278
Meadow for haymaking and pasture (ha)	10020	13160	6120	38540	22011
Plant production					
Grain (mill FU)	255	244,9	137,7	283,3	436
Green fodder and silo plants (mill FU)	24,2	22,1	13,8	58,9	44
Hay (mill FU)	50,5	52,2	32,7	178,8	103
Potatoes (mill FU)	34,8	19,9	153,3	54,1	122
Vegetables on free-land (tonne)	16476	5133	26564	14055	31259
Fruits (tonne)	0	61	1532	143	811
Berries (tonne)	721	436	1148	782	1483
Animal production					
Cows milk (1000 liter)	36883	36353	17939	95373	68034
Cattle meet (tonne)	2203	2338	1224	5135	4167
Poultry (tonne)	8749	2041	2642	6407	10419
Mutton (tonne)	108	214	102	1424	392
Pork (tonne)	9282	7294	8060	12127	16779
Number of animals					
Number of cattle	26900	28500	1600	6460	38561
- lactating cow	9000	9200	520	2260	12736
- feeding animals (oxen)*	8950	9650	540	2100	12913
- calf*	8950	9650	540	2100	12913
Number of sheep	10400	25480	1040	13728	23473
- lamb**	6400	15680	640	8448	14445
- winter feeding	4000	9800	400	5280	9028

*Assuming that the total number of cattle (except lactating cow) comprise 50 % feeding animals and 50 % calves.

** Based on the average number of lambs per ewe: 1,6.

Table 1b. Areas and agricultural production affected by the described radioactive deposition – isozone distribution (FU = fodder unit).

	Isozones				**Sum**
	150	**500**	**1000**	**2000**	
Total area (km^2)	4747	1899	1899	949	9495
Total arable area (ha)	71409	28564	28564	14282	142819
Fully cultivated soil (ha)	69288	27715	27715	13858	138576
Grain and olive plants (ha)	55646	22258	22258	11129	111292
Potatoes (ha)	1453	581	581	291	2906
Green fodder and silo plants (ha)	1059	424	424	212	2119
Vegetables on free-land (ha)	639	256	256	1278	1279
Meadow for haymaking and pasture (ha)	11006	4402	4402	2201	22011
Plant production					
Grain (mill FU)	218	87	87	44	436
Green fodder and silage (mill FU)	22	9	9	4	44
Hay (mill FU)	52	21	21	10	103
Potatoes (mill FU)	61	24	24	12	122
Vegetables on free-land (tonne)	15629	6252	6252	3126	31259
Fruits (tonne)	405	162	162	81	811
Berries (tonne)	742	297	297	148	1483
Animal production					
Cows milk (1000 litre)	34017	13607	13607	6803	68034
Cattle meet (tonne)	2084	833	833	417	4167
Poultry (tonne)	5209	2084	2084	1042	10419
Mutton (tonne)	196	78	78	39	392
Pork (tonne)	8390	3356	3356	1678	16779
Number of animals					
Number of cattle	19281	7712	7712	3856	38561
- lactating cow	6368	2547	2547	1274	12736
- feeding animals (oxen)*	6457	2583	2583	1291	12913
- calf*	6457	2583	2583	1291	12913
Number of sheep	11736	4695	4695	2347	23473
- lamb**	7222	2889	2889	1444	14445
- winter feeding	4514	1806	1806	903	9028

* Assuming that the total number of cattle (except lactating cow) are 50 % feeding animals and 50 % calves

** Based on the average number of lambs per ewe; 1,6 (K. Hove. pers. comm.)

Table 2. Deposition of radioactive Cs-isotopes and ^{131}I within the isozones.

	Isozone			
	150	**500**	**1000**	**2000**
$^{134}Cs + ^{137}Cs$ (kBq/m^2)	18	60	120	240
^{131}I (kBq/m^2)	60	200	400	800

By summing the Cs-isotopes, the activity concentrations in produce can be compared with the national action levels (600 Bq/kg, 370 Bq/l milk). However, the dose calculations will be overestimated as the ICRP dose conversion factor is 1.3 10^{-5} Sv/kBq for ^{137}Cs and 1.9 10^{-8} Sv/ kBq for ^{134}Cs.

3 Activity concentration levels in vegetation

Although the deposition occurred as precipitation, the production areas are fully covered by vegetation in July. Thus, the radionuclides will be present as surface contamination on vegetation and soils. During the first few months root uptake from soil will be of minor significance, and transfer coefficients from soil to vegetation are of little relevance during this early phase. Thus, the activity concentration of radiocaesium in vegetation is estimated from the deposition density (Bq/m^2), interception coefficients (m^2/kg) and density (d.m. kg/m^2). In addition, the transport from plant to soils with a rate of 4,5 % per day (half-life ca. 15 days, NKS) should be taken into account.

The interception coefficient for pasture is assumed to be 0,3 m^2/kg (IAEA, 1994). On cultivated grass land the density may vary within 200 - 2000 g dry matter (d.m.)/m^2, (T. Garmo pers. comm.), depending on the use (grazing or fodder) and the production system (e.g., grazing strategy). In the present work 400 g d.m./m^2 is chosen as an appropriate value for pastures and 1000 g d.m./m^2 for fodder producing areas.

Most of the cultivated meadow will be utilized for fodder; ca. 77 - 87 % of the meadow area in the 4 counties will be affected. About 75 % of the meadow will be harvested and utilized for fodder during the winter, while 25 % will be utilized for grazing animals. This is in accordance with the meadow area needed for grazing animals, taking into account the grass production. Thus, grazing animals will utilize 5500 ha meadow with contaminated vegetation. Table 3 gives information on meadow area and activity concentrations of radionuclides in vegetation within the different isozones at the time of deposition, 1 month after deposition (2 half-lives, plant-to soil transfer with half-life ca. 15 days, NKS) and 2 months after deposition (4 half-lives). The dose estimates are based on maximum activity concentrations of radiocesium in vegetation.

In the affected areas, the cultivated areas are harvested 3 times a year; first time in June. Thus ca. 40 % of the fodder needed for winter is harvested prior to the assumed deposition of radioactivity (T. Garmo, pers. comm.). The second harvest should normally take place at the time of deposition. Thus, ca. 30 % of the harvest would have been surface contaminated. The last harvest (ca. 30 %) will take place in August - September and the harvest will be surface contaminated, also due to soil erosion, and contaminated due to increasing root uptake from the soil.

Table 3. Meadow area and activity concentrations of radionuclides in vegetation within the different isozones.

	Isozone			
	150	**500**	**1000**	**2000**
Meadow area (ha)	2750	1100	1100	550
Radiocesium				
Deposited activity (kBq/m^2)	18	60	120	240
Activity concentration (kBq/kg d.m.)				
- time of deposition	14	45	90	180
- 1 month after	3,5	11	22	45
- 2 months after	0.8	2.7	5.5	11
^{131}I				
Deposition (kBq/m^2)	60	200	400	800
Activity concentration (kBq/kg d.m.)	45	150	300	600

For winter fodder (hay and silage) about ca 36 *10^6 FU (fodder units) corresponding to ca 51*10^6 kg d.m. harvested from the meadow will be surface contaminated (Table 1). For meadows the interception coefficient is 0,4 m^2/kg for Cs-isotopes, while ^{131}I has decayed when the fodder is used. Table 4 gives the activity concentration of radiocesium in vegetation short time after deposition and the amount of contaminated harvest within the different isozones. Assuming a plant to soil transfer with a rate of 4,5 % per day (half-life ca 15 days, NKS), the activity concentrations are reduced with a factor of 4 after 30 days and a factor of 16 after 60 days.

Table 4. Activity concentration of radiocesium in vegetation from meadow and the amount of contaminated harvest within the different isozones.

	Total	Isozone			
		150	**500**	**1000**	**2000**
Number of fodder units affected (mill FU)	36	18	7	7	4
Radiocesium concentration (kBq/kg d.m.)		7	24	48	96

About 80 % of the cultivated areas affected are areas grown with cereals. The vegetation density will be ca 1000 kg d.m./m^2 at the time of deposition (J. Diseth, pers. comm.). The activity concentration (Bq/kg d.m.) in the crop will be about the same as for contaminated grass (Table 3). The growth and filling of the grains will occur after the plants have been surface contaminated. As the root uptake is believed to be of minor importance during the first 2 months, the contamination of the cereal products will be minor the first year. However, countermeasures involving the removal of the vegetation from the field after harvesting and ploughing are of relevance for the harvest next year. A similar concept can be utilized for root fruits like potatoes. Fruit and vegetables such as lettuce grown on land while exposed to air will be severely surface contaminated. Assuming a production of ca. 0,5 kg d.m./m^2

and interception coefficient of 0,3 m^2/kg, the activity concentrations are estimated in Table 5.

Table 5. Activity concentration (Bq kg^{-1} d.m.) of radiocesium in air-exposed vegetables and fruit within the different isozones.

	Isozone			
	150	**500**	**1000**	**2000**
kBq/kg d.m. radiocesium	10.8	36	72	144

Assuming a plant to soil transfer with a rate of 4,5 % per day (half-life ca 15 days, NKS), the activity concentrations should be reduced with a factor of 4 after 30 days and a factor of 16 after 60 days i. e. at the time of harvesting. Still, the produce will be too contaminated for allow commercial sale (action limit of 600 Bq/kg).

4 Activity concentration in animal produce

The contamination will be highly relevant for the meat and milk production from cattle and meat production from sheep and lamb. As the production of poultry and pig is based on concentrates mainly, no measures are needed the first year.

The activity concentration of radiocesium in vegetation, calculated from deposition (kBq/m^2), interception coefficient for pasture (0,3 m^2/kg) and the density of the vegetation (400 g d.m./m^2) as given in Table 3, forms the basis of estimating the contamination of animal produce. The activity concentration of radionuclides in milk for cattle is calculated from vegetation to animal transfer coefficients (day/l or day/kg), while the activity concentration for meat is based on aggregated transfer coefficients (soil to meat transfer).

Transfer coefficients

Transfer coefficients from vegetation to animal products used for radiocesium are based on IAEA Technical report series No. 364, (1994):

- Cows milk (day/l): $7{,}9 \cdot 10^{-3}$
- Sheep milk (day/l): $5{,}8 \cdot 10^{-2}$
- Cattle meat (day/l): $5{,}0 \cdot 10^{-2}$
- Meat from sheep (day/kg) $1{,}7 \cdot 10^{-1}$
- Meat from lamb (day/kg) $4{,}9 \cdot 10^{-1}$
- Transfer coefficients from vegetation to cows milk (day/l) for iodine: $1{,}0 \cdot 10^{-2}$

The aggregated transfer coefficient from deposition on soil to sheep grazing meadow (T_{ag}) is 0,04 m^2/kg meat (Howard et al., 1998). For lamb the transfer is assumed to be a factor of 3 higher; 0,12 m^2/kg (the ratio between T_{ag} for lamb and sheep is equal to the ratio observed based on daily intake). T_{ag} for cattle is 0,017 m^2/kg (the ratio between T_{ag} for sheep and ox is ca. 3.4, based on daily intake).

Activity concentration of radionuclides
Based on the activity concentrations in vegetation, transfer coefficients from vegetation to milk (day/l or day/kg), Table 6 and 7 give the activity concentrations for radiocesium and ^{131}I in milk. Based on the deposition (Bq/m^2) and the aggregated transfer coefficients, Table 6 gives the maximum activity concentration in meat within the different isozones. It should be mentioned that the activity concentration of Cs-isotopes in the products also have been calculated from daily intake of contaminated fodder. These estimates are somewhat higher than estimates based on transfer factors.

The milk production will be mostly affected during July and August (caesium and iodine) the first year (1/6 of the production), while the meat production will only be affected by radiocesium in animals to be slaughtered in the autumn. As the activity concentration in vegetation is expected to decrease with time after deposition (plant to soil transfer with a rate of 4,5 % per day, half-life ca 15 days, NKS), the activity concentrations in animal produce should be reduced with a factor of 4 after 30 days (early August) and a factor of 16 after 60 days (early September). Although the root uptake will be of increasing importance with time after deposition, the activity concentration in meat at the time of slaughtering (September – October) should be substantially lower than estimated from the total deposition (Table 6, 60 days after deposition).

Table 6. Maximum activity concentrations of radiocesium in milk and meat within the different isozones.

	Isozone			
	150	**500**	**1000**	**2000**
Activity concentration of radiocesium in milk (kBq/l)	1.3	4.7	8.9	17
Maximum activity concentration of radiocesium in meat				
Cattle (Bq/kg)	306	1020	2040	4080
- 60 days after deposition (Bq/kg)	19	64	127	255
Mutton (Bq/kg)	720	2400	4800	9600
- 60 days after deposition (Bq/kg)	45	150	300	600
Lamb meat (Bq/kg) *	2160	7200	14400	28800
- 60 days after deposition (Bq/kg)	125	450	900	1800

* Lamb can in addition to vegetation intake have a contribution of radiocesium from mother's milk. The intake of milk is ca. 3 l/day.

Table 7. Daily intake for cows and activity concentration of ^{131}I in milk within the different isozones.

	Isozone			
	150	**500**	**1000**	**2000**
Intake of ^{131}I (kBq/day)	563	1875	3750	7500
Concentration of ^{131}I in milk (kBq/l)	5.6	18	37	75

5 Selection of suitable countermeasures

Among the countermeasures suggested in the NKS/BOK-1.4 datasheets, A8 (ploughing and K-fertilization), A9 (repeated ploughing), B2 (changing slaughter time), B4 (clean fodder to animals before slaughter), B5 (Prussian Blue salt licks and boli), C3 (make cheese by rennet method and replacing milk in diet with cheese) and C5 (light salting of meat) could be applied. However, the ploughing techniques are considered to be rather expensive, as the area affected is large. Furthermore, the food treatment procedures will probably not be accepted by Norwegian consumers. Thus, the application of B2, B4 and B5 should be most suitable for reducing the radiocaesium contamination in animal products. If B4 or B5 is applied, the change in slaughter time (B2) is also avoided. If Prussian Blue is applied, the animals can eat contaminated fodder and no clean-fodder administration is needed.

When B4 is applied, the cost-benefit analysis is based on purchase of clean fodder from non-contaminated regions and additional labor costs associated with the administration of the fodder to the stock. B5 is, however, a good alternative as Prussian Blue is an efficient low-cost Cs-binder. Prussian Blue can be given as boli and salt lick for animals grazing semi-natural pastures or can be added to concentrates together with contaminated fodder for animals staying at the farm. Based on several years of experience, the favorable administration of Prussian Blue for milk production, should be the addition of the salt to concentrate given to lactating cows. For meat production (ox, sheep), Prussian Blue salt lick is most feasible, while for lamb meat production, the use of two Prussian Blue boli simultaneously should be preferred. Thus, cost-benefit analysis has been performed for B5 using Prussian Blue as countermeasures for radiocesium administered in different ways to different animals, depending on the produce.

The calculations are based on the information on the animal production and number of animals within each isozone (Table 1b), the activity concentrations in milk based on transfer coefficients and meat based on T_{ag} as illustrated for cattle in Table 8. When Prussian Blue is applied, the amount given to each animal in each treatment is optimized to reduce the activity levels efficiently. The number of treatments depends on how many treatments are needed before the activity levels have reached the presently applied action levels for radiocesium of 370 Bq/l in milk and 600 Bq/kg in meat.

6 Cost-benefit calculations

The cost-benefit analysis is carried out for B4 and B5. The analysis is based on dose saved by implementing specific countermeasures (reduction of the activity concentrations in produce due to the countermeasures applied, number of animals treated and number of treatments, converted to dose saved by the ICRP dose conversion factor) and costs associated with the specific countermeasure within the different isozones and finally the costs per unit of dose saved, Euro per manSv. To illustrate the results for B5, administration of Prussian Blue differently to cows, oxen and lamb are detailed.

Table 8. Animal production, number of cattle and activity concentrations in milk, based on transfer coefficients and meat, based on T_{ag}, within each isozone.

	Total	Isozone			
		150	500	1000	2000
Animal production info					
Cow milk (1000 l)	68034	34017	13607	13607	6803
Cattle meat (1000 kg)	4167	2084	833	833	417
Number of animals					
Total	38561	19281	7712	7712	3856
- Cow	12736	6368	2547	2547	1274
- Ox	12913	6457	2583	2583	1291
- Calf	12913	6457	2583	2583	1291
Milk production per day (1000 l)	186	93	37	37	19
Milk production per 2 month (1000 l)	11339	5670	2268	2268	1134
Activity intake (kBq/day)					
- Cow		169	563	1125	2250
- Ox		98	315	630	1260
- Calf		35	113	226	452
Activity concentration in milk (Bq/l)		1383	4447	8895	17790
Activity concentration in meat (Bq/kg)		306	1020	2040	4080

Costs

The costs include the expenses of Prussian Blue as salt, as salt lick stones or as boli. The costs associated with labor vary according to the measure taken and are estimated from the hours needed for treating a livestock, to costs associated with treatment of each animal. As the number of animals and the number of treatments needed vary between the isozones, the costs are differentiated and are given for each isozone.

Averted dose and cost effectiveness

The dose saved (Sv) is calculated from

D=A x P x F

where A is the reduction in the activity concentration (Bq/l or Bq/kg) for a specific produce (milk or meat) when measures have been introduced (activity concentrations in contaminated products multiplied with a dose reduction factor). P is the total production (liter of milk produced within 60 days from all animals treated, or kg meat obtained from animals slaughtered) within each isozone. F is the ICRP dose conversion factor (1.3 x10^{-5} Sv/kBq for ^{137}Cs and 1.9 10^{-8} Sv/kBq for ^{134}Cs).

Detailed calculations for the implementation of B5 are given below. As maximum activity concentrations for the sum of Cs-isotopes in milk and meat are used in the estimates, the costs- benefit analyses given are also maximum estimates.

Prussian Blue in concentrate to lactating cows

The activity concentration in milk, number of cows and milk production data (Tab. 8), the activity concentration in milk after the use of PB concentrates, and the costs for adding PB salt to concentrates are given in Table 9. About 1 g Prussian Blue salt is added per kg concentrate. About 3 kg per day of this fodder should reduce the activity in milk to about 90 % within 1 week. The cost per kg concentrate is about 0.6 Euro. The additional cost for adding PB to concentrates is 1/8 Euro per kg, thus the total cost is 0.38 Euro per animal per day (3 kg per animal per day), amounting to 22.8 Euro/animal for the 2 month period. It is assumed that the cows are eating contaminated fodder during the following 60 days.

Table 9. Cost-benefit analysis for Prussian Blue salt added to concentrate (cows milk).

	Isozone			
	150	**500**	**1000**	**2000**
Activity concentration in milk (Bq/l)	1383	4447	8895	17790
Number of animals	6368	2547	2547	1274
Activity in milk after treatment	138	445	890	1779
Activity concentration acceptable (limit 370 Bq/l)	yes	no	no	no
Activity reduction (kBq/kg)	1.2			
Costs 60 days (Euro)	145190			
Cost per cow in 60 days (Euro)	22.8			
Milk production per day (1000 l)	93,2			
Milk production in 60 days (1000 l)	5592			
Dose saved in 60 days (manSv)	60			
Cost-effectiveness (Euro/manSv)	2408			

The averted dose from milk obtained by administration of PB salt to cows during 60 days is given by:

D (manSv) = A x P x F

where A= reduction in activity concentration in milk, P= total milk production and F= dose conversion factor. As the ratio of ^{137}Cs to ^{134}Cs is 2:1, then

D for ^{137}Cs = 1.2 x 2/3 kBq/l x 5592 000 l x 1.3 10^{-5} manSv/kBq = 60 manSv,
D for ^{134}Cs = 1.2 x 1/3 kBq/l x 5592 000 l x 1.9 10^{-8} manSv/kBq = 0.04 manSv,

insignificant compared to ^{137}Cs.

Costs = 0.38 Euro/animal per day x 60 days x 6368 animals = 145,190 Euro.
The cost-effectiveness is about 2,400 Euro/manSv,

Shortly after the deposition (first 2 month), all milk within isozone 150 will be saved by using PB added to concentrates. Similarly, the costs of wasting 2-month produce of milk have been calculated (0.4 Euro x production) to 2,2367,000 Euro, which is substantially more expensive than applying the above-mentioned countermeasure for isozone 150. The activity levels in milk in isozones 500 –2000 will be too high compared to action levels during the first months after deposition. With time, however, the activity concentration in vegetation and thereby in milk should be reduced (factor of 4-16). Then, milk produced within the isozone 500 and 1000 can probably be saved using this measure.

Cost-benefit analysis for Prussian Blue salt lick to oxen

The activity concentration in meat based on T_{ag} and the number of animals (half the stock) within each isozones (Table 8), and the activity in milk after treatment are given in Table 9. The costs when Prussian Blue salt lick is provided to oxen grazing contaminated vegetation is based on an estimated need for salt of 25 g per day per ox. Costs per salt lick stone (10 kg) are 25 Euro, i.e. 0.063 Euro per day per animal. The grazing period is 60 days, the radiocesium reduction is 67 % (2/3, NKS database refers to 50-75 % reduction) and the half-life is 20 days (1 treatment period). The average weight of oxen is assumed to be 300 kg corresponding to the annual intake of 50 kg for 6 persons.

The averted dose from meat obtained by administration of PB salt lick to oxen is given by

D (manSv) = A x P x F

where A= reduction in activity concentration in meat, P= total meat production and F= dose conversion factor. The activity concentration in meat in isozone 150 is below the action limit (600 Bq/kg and no treatment is needed

As the ratio of ^{137}Cs to ^{134}Cs is 2:1, then the adverted dose

D for ^{137}Cs in isozone 500 is 0.5 x 2/3 kBq/kg x 300 kg/animal x 1291 animals x 1.3 10^{-5} manSv/kBq = 1.7 manSv,

D for ^{134}Cs = 0.5 x 1/3 kBq/kg x 300 x 1291 x 1.9 10^{-8} manSv/kBq = 1.2 10^{-3} manSv, i.e., insignificant compared to ^{137}Cs.

Costs = 0.063 Euro/animal per day x 60 days x 1291 animals = 4,881 Euro

The cost-effectiveness is about 2,900 Euro/manSv, which is an overestimate as it is assumed that the treatment period is 60 days, although the activity concentration in the vegetation will decrease during the 60 days period.

Administering PB salt lick to oxen, all meat is saved. Assuming that the activity concentration in vegetation in September (time of slaughter) is reduced with a factor 4-16, due to the plant to soil transfer and minor root uptake, the PB salt lick treatment should only be needed in the isozones 100o and 2000 during the autumn.

Table 10. Cost-benefit analysis for Prussian Blue salt lick to oxen.

	Isozone			
Cattle	**150**	**500**	**1000**	**2000**
Maximum activity concentration in meat (Bq/kg)	306	1020	2040	4080
Number of animals	3228	1291	1291	645
Number of treatment until limit is reached	0	1	2	3
Activity reduction (kBq/kg)		0.5	1.5	3.6
Costs (Euro) per treatment (20 days)		1627	1627	813
Total cost (Euro) –60 days		4881	4881	2440
Dose saved per animal (manSv)-^{137}Cs		1.7	5.0	6.0
Cost-effectiveness (Euro/manSv) – 60 days		2937	969	400

Boli administered to lamb

The number of animals (half the stock to be slaughtered, Tab. 1b), the activity concentration in meat (Tab. 6) and the activity concentration reduced due to PR boli treatment are given in Table 11.Two boli per lamb are needed in each treatment. Price per boli is 2 Euro, total 4 Euro per animal. Labor is about 1/6 hrs per animal, corresponding to 3 Euro. Total costs per animal are 7 Euro per treatment. In each treatment the activity level of radiocesium is reduced with ca. 2/3. The average weight is assumed to be 20 kg, corresponding to an annual intake of 5 kg for 4 persons.

The averted dose from meat obtained by administration of PB boli to lamb is given by:

D (manSv) = A x P x F

where A= reduction in activity concentration in meat, P= total meat production and F= dose conversion factor. As the ratio of ^{137}Cs to ^{134}Cs is 2:1, then

D for ^{137}Cs in isozone 150 = 1.7 x 2/3 kBq/l x 20 kg/animal x 7222 animals x 1.3 10^{-5} manSv/kBq = 2.1 manSv,

D for ^{134}Cs = 1.7 x 1/3 kBq/l x 20 x 7222 x 1.9 10^{-8} manSv/kBq = 1.6 10^{-3} manSv, insignificant compared to ^{137}Cs.

Costs = 7 Euro/animal per treatment x number of treatments x animals
= 7 x 2 x 7222 Euro =101,108 Euro.

The price of the saved meat is about 10 Euro/kg x 20 kg/animal x 7222 animals = 1,444,000 Euro.

The cost-effectiveness is about 48,000 Euro/manSv for isozone 150, about 65,000 Euro/manSv for isozone 500, about 32,000 Euro/manSv for isozone 1000 and about 29,000 Euro/manSv for isozone 2000.

Administering PB boli to lamb, all meat is saved. Assuming that the activity concentration in vegetation in September is reduced with a factor 4 - 16, due to the plant to soil transfer and minor root uptake, the PB boli treatment should only be needed within the isozones 1000 and 2000 in the autumn.

Table 11. Cost-benefit analysis of Boli administered to lamb.

	Isozone			
Lamb	**150**	**500**	**1000**	**2000**
Maximum activity concentration in meat (Bq/kg)	2160	7200	14400	28800
Number of animals	7222	2889	2889	1444
Number of treatments to reach limit	2	3	3	4
Activity reduction (kBq/kg)	1.7	5.6	11.2	22.4
Costs per treatment (Euro)	50554	60669	60669	40432
Total costs (Euro)	101108	182007	182007	161728
Dose saved for the total production (manSv) - ^{137}Cs	2.1	2.8	5.6	5.6
Cost-effectiveness (Euro/manSv)	48077	64904	32452	28847

Administration of clean fodder (B4)
The high costs of this countermeasure (schedule 3) is based on the assumption that the cost of clean fodder is 0.4-0.6 per kg dry matter and 7 kg dm fodder/day is needed for cattle and 1 kg dm fodder/day is needed for lamb. Clean fodder is given to the animals to be slaughtered for a different number of days depending on the contamination levels in the isozones. Furthermore, the work load associated with clean fodder administration is 1 man per stock in 20 (lamb) or 30 (cattle), amounting to 90 Euro/cattle and 46 Euro/lamb. The workload (number of days with clean fodder administration) depends also on the number of stocks within each isozone. The costs (Schedule 3) is extremely high, and if fodder has to be purchased and workers have to be hired, alternative countermeasures should be significantly more cost-effective.

7 Conclusions

For milk producing animals (cows) eating contaminated fodder, Prussian Blue salt added to concentrate is the most feasible countermeasure, as the additional labor costs for animals staying at the farm are small. For isozone 150 all milk can be saved, while at higher deposition levels, the activity level in milk will exceed the action levels. The use of salt lick for grazing meat-producing animals is by far the most cost-efficient countermeasure to reduce the radiocaesium activity concentration in meat (65 Euro/manSv), as costs associated with labor are insignificant. For lamb grazing semi-natural pastures where ploughing is not applicable, however, salt lick may not be functioning well and boli seems to be the only countermeasure feasible, even though the costs are substantially higher. However, the administration of clean fodder is extremely expensive if clean fodder has to be bought and additional manpower has to be hired, and alternative countermeasures should be applied.

The estimates are based on maximum concentration levels in soils (Bq/m^2) and vegetation (Bq/kg) at the time of deposition. Although deposition took place as precipitation, it is assumed that the vegetation is heavily surface contaminated as the production areas were fully covered by vegetation at the time of deposition. Thus, it is assumed that the activity concentration in vegetation is mainly attributed to surface contamination rather than soil to plant transfer (root uptake) during the first 2 months. As the activity concentration in vegetation decreases with time after deposition due to the plant to soil transfer (half-life of 15 days) and that root uptake probably is of minor importance 1-2 months after deposition, the activity levels in milk and meat will gradually decrease. For meat the activity concentrations in September-October (time of slaughtering) could be reduced with a factor up to 20. Then, the need for countermeasures will be limited to the most contaminated isozones, and the costs will be significantly reduced compared to the estimates given in this report.

Table 12. Agricultural countermeasures.

Data sheet	Countermeasure
A1	Early removal of vegetation
A2	Early removal of snow
A3	Storage of crops / grass
A4	Liming of soil
A5	Potassium fertilization
A6	Ploughing
A7	Deep-ploughing
A8	Ploughing and K-fertilization
A9	Repeated ploughing
A10	Skim-and-burial ploughing
A11	Phosphorus fertilization
A12	Turf harvesting
A13	Cultivating crops with low uptake
A14	Cultivating crops that can be processed
A15	Change production from crops to animals
A16	Use plants as fertilizer
A17	Growth of industrial crops
A18	Change land use to forestry
B1	Supply animals with stable iodine
B2	Change slaughter time
B3	Reduce animal intake of contaminated soil
B4	Clean fodder to animals before slaughter
B5	Prussian Blue salt licks/boli
B6	Supplement fodder with micas or zeolites
B7	Addition of calcium to fodder
B8	Prussian Blue filters for milk decontamination
B9	Replace sheep/goats with cattle
B10	Change from milk to meat production
B11	Change animal production to non-consumption
C1	Manufacturing of food products to be stored for months
C2	Mechanical decontamination of fresh vegetables, fruit and cereals
C3	Making cheese by Rennet method and replacing milk in diet with cheese
C4	Change milling yield and use of least contaminated grain fractions
C5	Light salting of meat
C6	Light salting of fish
C7	Parboiling mushrooms
C8	Soaking dried mushrooms in water

Schedule 1. Applicability of countermeasures.

Country: Norway								
Counter-measure	Relevance				Practicability			Applicability
	Season	nuclides	production type	production conditions	Waste	supplies	manpower	yes, if yes to all questions to the left, otherwise no
A1	Y	Y	Y	Y	Y	Y	Y	Less relevant for wet deposition
A2	N	Y	Y	Y	Y	Y	N	N
A3	Y	Y	N	Y	Y	Y	Y	N
A4	Y	N	Y	Y	Y	Y	Y	N, relevant for Sr
A5	N	Y	Y	Y	Y	Y	Y	N, but of interest when ploughing (A8)
A6	Y	Y	Y	Y	Y	Y	Y	Y, favorable when combined with K-fertilization (A8)
A7	Y	Y	Y	Y	Y	N	Y	N
A8	Y	Y	Y	Y	Y	Y	Y	Y
A9	Y	Y	Y	Y	Y	Y	Y	Y
A10	N	Y	Y	Y	N	N	Y	N
A11	Y	N	Y	Y	Y	Y	Y	N, relevant for Sr
A12	Y	Y	Y	Y	N	N	N	N
A13	N	Y	N	Y	Y	N	N	N
A14	N	Y	N	Y	Y	N	N	N
A15	N	Y	N	Y	Y	N	Y	N
A16	N	Y	N	Y	Y	N	N	N
A17	N	Y	N	Y	Y	N	N	N
A18	N	Y	N	Y	Y	Y	Y	N
B1	Y	Y	Y	Y	Y	N	Y	N
B2	Y	Y	Y	Y	Y	Y	Y	Y
B3	Y	Y	Y	N	Y	Y	N	N
B4	Y	Y	Y	Y	Y	Y	Y	Y
B5	Y	Y	Y	Y	Y	Y	Y	Y
B6	Y	Y	Y	Y	Y	N	Y	N
B7	Y	N	Y	Y	Y	Y	Y	N, relevant for Sr
B8	Y	Y	Y	Y	Y	N	Y	N
B9	N	Y	N	N	Y	Y	Y	N
B10	Y	Y	N	Y	Y	N	Y	N
B11	N	Y	N	Y	Y	N	Y	N
C1	Y	Y	Y	Y	Y	Y	Y	Y
C2	Y	Y	Y	Y	Y	N	N	N
C3	Y	Y	N	Y	Y	Y	Y	Y
C4	N	Y	Y	Y	Y	Y	Y	N
C5	N	Y	Y	Y	Y	Y	Y	N
C6	Y	Y	Y	Y	Y	Y	Y	Y
C7	Y	Y	Y	Y	Y	Y	Y	Y
C8	Y	Y	Y	Y	Y	Y	Y	Y

Schedule 2. General considerations for countermeasures that are applicable according to Schedule 1.

Country: Norway							
Counter-measure	Legality	Acceptance				Implications for other countermeasures	Comments
		farmers	Industry	consumers	Public	(specify numbers)	
A1	y	y	y	y	y	A6, A8	simplifies ploughing, low effect after wet deposition
A6	y	y	y	y	y	A8	
A8	y	y	y	y	y	A1, A5, A6	substitutes A5 and A6 before next season
A9	y	y	y	y	y		low effect when A6 is applied
B2	y	y	y	y	y	B4, B5	no change due to provision of clean fodder
B3						A1,A6	low effect compared to B2, B4 and B5
B4	y	y	y	y	y	B2, B5	slaughter time not changed
B5	y	y	y	y	y	B4	missing: Prussian Blue added to feed concentrates
C1	y	y	y	n	n		
C3	y	y	y	n	n		
C6	y	y	y	n	n		
C7	y	y	y	n	n		
C8	y	y	y	n	n		

Schedule 3. Cost benefit analysis for selected countermeasures.

Country: Norway					
Counter-measure	Area affected km^2	Averted dose manSv	Monetary costs Euro	Cost-effectiveness Euro/manSv	Comments
B4, clean fodder to oxen	11	1.7	242000	140 000	Clean fodder for 20 days, 1/5 of the stock*
	11	5.1	485000	95 000	Clean fodder for 40 days, costs 50% labour*
	5.5	6.0	364344	60 000	Clean fodder for 60 days, costs 60 % labour*
B4, sheep clean fodder	28	0.2	81100	500 000	All meat saved. Costs 78 % labour*
	11	0.3	64900	200 000	
	11	0.7	97300	130 000	
	5.5	0.8	65000	80 000	
B4, lamb clean fodder	28	1.2	303300	250 000	All meat saved*
	11	1.7	242700	140 000	
	11	3.5	364000	100 000	
	5.5	3.6	213000	68 000	
B5, Prussian blue in con-centrate to lactating cows	28	60	145200	2 400	All milk saved in isozone 150 during 60 days*.
B5, Prussian blue salt lick to oxen and sheep	11	1.7	4880	2 900	All meat saved*
	11	5.0	4 880	970	
	5.5	6.0	2 440	400	
B5, Prussian blue boli to lamb	28	2.1	102200	48 000	All meat saved*
	11	2.8	182000	65 000	
	11	5.6	182000	32 000	
	5.5	5.6	161700	29 000	

*At the time of slaughtering, in September-October, the activity concentration in vegetation and thereby in meat should be significantly reduced (by a factor up to 20) compared to short time after deposition.

Schedule 4. References to general information and specific information.

Country: Norway
Agricultural data 1. National production statistics. Statistisk Sentralbyrå Årbok 2000, Norway
Radioecological data 1. IAEA technical report No.364
Regulations 1.

Report from the Swedish Group

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Report from the Swedish Group

1 Important food chains

In the first year after a fallout the development phase of crops is crucial for the uptake of radionuclides in different food chains. The most important food chains for intake of radionuclides are via milk, via meat, via cereal products, via vegetables, via reindeer meat, via fungi, via berries and via game and via fish. The cultivated soil is an open system where the biomass grows and decomposes and nutrient flows circulate in various ways. Radioactive materials brought by fallout follow the natural cycles within agriculture.

- The food chain, **fodder – cows– milk – humans,** is special due to the very fast transport.
- The food chain, **fodder** – **animals – meat – humans,** is a relatively fast transport.
- The food chain, **grain – bread – humans,** is normally a longer cycle.
- The food chain, **vegetables – humans,** is a very short and fast cycle.
- The transport, **drinking water – humans,** via soil to groundwater takes a very long time.

2 Description of the situation and fallout area

The imaginary area of fallout covers most of Svealand in Central Sweden, which is divided into two geographical regions: the flat country (Ss) and the forested region (Ssk). Fallout figures are shown in Table 1 and fallout map in the annex, “Description of the Late Phase Exercise Huginn”, page A19-A25.

Table 1. Dose rate and deposition of radioactive iodine and radioactive caesium deposited in districts 1-4 after Huginn fallout in Central Sweden, 1 July, 2000, see Annex.

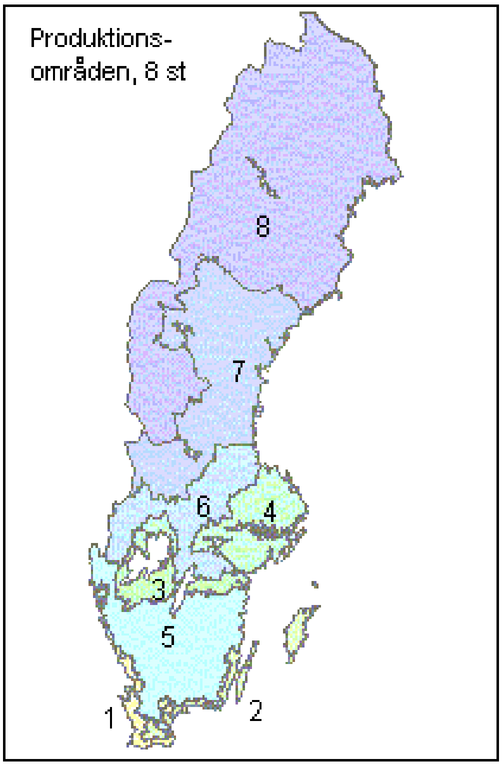
DISTRICT	Isocurve nSv/h	I-131 kBq/m^2	Cs-134 kBq/m^2	Cs-137 kBq/m^2
1	150	60	6	12
2	200	80	8	16
3	500	200	20	40
4	1000	400	40	80

The situation on 1 July is described as one where most farmers have taken their first grass harvest. Grass is either harvested as silage or hay. A few farmers in Svealand’s flat country (4, Ss) and more in Svealand’s forested region (6, Ssk) have not yet taken their first harvest, Figure 1. It can also be assumed that some farmers in Ssk are drying their hay on racks, particularly in county of Dalarna. Dairy and beef cattle as well as sheep and goats are assumed to be out grazing at the time of the fallout. Growth rates for agricultural products including grass and cereals are high in the fallout area. The leaf surface area of many plants is such that they have a large capacity to intercept and take up radioactivity: grassland regrowth has not reached its peak but the capacity to intercept and take up radioactivity is high.

The amount of fallout measured on 7 July for the radionuclides ^{131}I, ^{134}Cs and ^{137}Cs for the different fallout districts is shown in Table 1. After 6 - 7 weeks ^{131}I has halved 6 times and only a couple of per cent of iodine remain, see Table 2.

Table 2. Break down of ^{131}I over 6 half-lives for districts 1-4 after Huginn fallout in Central Sweden on 7, 14, 21, 28 July and 4, 8 and 18 August 2000, see Annex.

Region	2000-07-07	2000-07-14	2000-07-21	2000-07-28	2000-08-04	2000-08-11	2000-08-18
1	60	33.0	18.1	9.9	5.5	3.0	1.6
2	80	43.9	24.1	13.3	7.3	4.0	2.2
3	200	109.9	60.4	33.2	18.2	10.0	5.5
4	400	219.7	120.7	66.3	36.4	20.0	11.0



1 = Gss, Götalands södra slättbygder
2 = Gmb, Götalands mellanbygder
3 = Gns, Götalands norra slättbygder
4 = Ss, Svealands slättbygder
5 = Gsk, Götalands skogsbygder
6 = Ssk, Svealands skogsbygder
7 = Nn, Norrland nedre
8 = Nö, Norrland övre

Figure 1. Sweden, the division in 8 production areas.

3 Production data from the fallout regions

Administratively the fallout area comprises nearly all of the counties of Uppsala, Västmanland and Värmland as well as bordering areas of the counties of Gävleborg, Dalarna and Örebro. The counties cover a larger area than that of the fallout area described. Distribution of agricultural land and production from the six counties and 4 fallout districts are shown in Tables 3-6. The more fertile soils are found mainly in Ss, which has a higher content proportion of clay soils and better climatic conditions than Ssk, where productivity is lower and soils poorer.

Table 3 shows the hectarage of agricultural land, the number of farms and livestock density in the areas that received radioactive fallout. These data are compared with the production regions Ss and Ssk as well as agricultural data for the country as a whole. The table is based on Statistics Sweden (SCB) figures from 1998 for the Huginn districts 1-4.

Table 3. Crop and animal husbandry data in 1998 for the six counties, Ss, Ssk and the total for Sweden. (Code letters are official county designations in Sweden). (SCB, 1999)

County		Hectarage	No. of	No. of Animals					
		(10^3 ha)	Farms	Dairy cows	Dairy herds	Cattle	Sheep	Pigs	Hens
Dalarna	W	63.0	2 593	11 947	340	41 190	12 022	7 866	90 696
Gävleborg	X	74.2	3 196	13 221	469	36 741	15 901	18 052	32 371
Västmanland	U	125.8	2 480	8 845	188	30 593	-	51 272	-
Uppsala	C	153.8	2 933	15 509	372	56 667	17 937	88 813	-
Värmland	S	115.5	4 728	8 845	331	46 411	18 275	69 863	-
Örebro	T	109.4	2 763	12 432	291	49 642	10 102	40 220	184 523
Total for Sweden		**2 783.8**	**85 307**	**449 130**	**11 012**	**1 738 496**	**421 189**	**2 286 030**	**7 516 430**
Ss*		634 390	12 567	51 054	-	219 549	28 000	321 354	745 458
Ssk*		203 699	8 320	32 684	-	124 283	14 522	47 044	528 605
Total for Ss & Ssk		**838 089**	**20 887**	**83 738**		**343 832**	**42 522**	**368 398**	**1 274 063**

* Svealand's flat country (Ss) and Svealand's forested region (Ssk)

The distribution of agricultural land in the fallout districts 3 and 4 of the Huginn scenarios and the crops there have been studied in more detail. Data from the districts are based on statistics of EU subsidies applied for by farmers in the regions. This means that approximately 95-98 % of the hectarage is accounted for since not all farmers apply for EU subsidies.

The area of interest was selected as a square on the map in a GIS system. It had to lie in an east-west or north-south direction. The corner coordinates of the square were calculated. Then from the corner coordinates, details about those agricultural blocks that had their "center" within the square were compiled, together with the farmers' figures about hectarage and crops. Because districts 3 and 4 in Exercise Huginn are not square, a larger area was selected, see fallout map and Table 4.

Table 5 shows an estimate of the size of production in districts 3 and 4.

Table 4. The coordinates for districts 3 and 4 (500+1000) are (ABCD). The coordinates for district 4W are (EFGH) and the coordinates for district 4E are (KLMN), see page A24-25 in Appendix A.*

	North-south	East-west direction on the map		North-south	East-west direction on the map		North-south	East-west direction on the map
A	6706	380	E	6670	390	K	6705	445
B	6706	497	F	6670	420	L	6705	480
C	6622	497	G	6635	420	M	6660	480
D	6622	380	H	6635	390	N	6660	445

* A number 1 should be added before the east-west figure for an international comparison of the coordinates.

Table 5. Estimate of the number of animal products in fallout districts 3 and 4 and the total for Sweden.

Animal	**No. of animals in districts 3 and 4**	**Total for Sweden**	**Comments**
Dairy cows	3 700	435 000	
Cows with calves	850	160 700	Not slaughtered in autumn
Young beef cattle	4 300	587 400	about 1000 beef expected to go to slaughter autumn 2000
Ewes	2 500	193 300	
Lambs	4 370	-	ca. 1.75 lamb per ewe slaughtered in autumn
Hogs	2 500	1 927 000	
Laying hens	20 000	6 000 000	
Broilers	-	5 000 000	

The larger part of districts 3 and 4 is situated in Ssk where conditions are less favorable for production than the more productive conditions and soils of Ss. Table 6 shows that the hectarage devoted to pasture, grassland and cereals for animal feed is the most extensive and important in these districts. Oil-yielding plants, potatoes, legumes and market gardening only take up a small hectarage in districts 3 and 4. Consequently milk and meat production predominate.

The average consumption of agricultural products in Sweden is shown in Table 7. The products were chosen with consideration to what is produced in districts 3 and 4.

Table 6. Background values for Exercise Huginn in districts 3 and 4. Hectarage of different crops, 1999 year statistics (0 indicates that the information is missing).

Calculated hectarage	**District 3**		**District 4**		**Districts 3 and 4**	
Crop	**500**	**Total**	**1000**	**Total**	**500+1000**	**Total**
Pasture etc. (not arable)						
Pasture for grazing	2 249.7		112.8		2 362.5	
Meadows for hay	53.6		0.3		53.9	
Forest grazing	41.2	2 344.5	7.3	120.4	48.5	***2 464.9***
Grass & Fodder crops						
Vetch	0.4		0.0		0.4	
Fodder beet	2.5		0.0		2.5	
Hay & grazing on arable	7 686.1		2 228.9		9 915.0	
Seed grass	13.1		0.8		13.9	
Green fodder	35.6	7 737.7	3.9	2 233.6	39.5	***9 971.3***
Cereals						
Barley (winter)	33.0		5.3		38.3	
Barley (spring)	4 036.9		991.0		5 027.9	
Oats	1 179.9		159.0		1 338.9	
Wheat (winter)	154.0		23.0		177.0	
Wheat (spring)	20.4		0.0		20.4	
Mixed cereals	208.5		5.4		213.9	
Rye	46.2		0.0		46.2	
Canary seed	1.6	5 680.5	0.0	1 183.7	1.6	***6 864.2***
Oil crops						
Rape (spring)	18.0		0.0		18.0	
Sunflower	0.0		4.6		4.6	
Oil crop experiment	1.9		0.0		1.9	
Flax Oljelin	32.5	52.4	0.0	4.6	32.5	***57.0***
Potatoes						
Potatoes (human consumption)	177.3	177.3	11.0	11.0	188.3	***188.3***
Legumes						
Peas (not for processing)	63.6		2.7		66.3	
Field beans	14.6	78.2	0.0	2.7	14.6	***80.9***
Fallow						
Fallow	1 049.4	1 049.4	300.0	300.0	1 349.4	***1 349.4***
Market gardening						
Strawberries	4.7		5.8		10.5	
Other berries	0.3		33.2		33.5	
Fruit (apples etc.)	0.4		0.0		0.4	
Vegetables	10.9	16.3	0.9	39.9	11.8	***56.2***
Others						
Grazing for wild animals	3.3		1.9		5.2	
Salix	83.6		0.0		83.6	
Protection zones	10.3		1.4		11.7	
Gröngödsling	9.7		4.3		14.0	
Wet land	1.6		0.0		1.6	
Christmas trees	0.1		0.0		0.1	
Other land use	96.3	204.9	22.0	29.6	118.3	***234.5***
Subtotal	17 341.2		3 925.5		21 266.7	
Unidentified crops	258.0	258.0	5.6	5.6	263.6	***263.6***
Total	**17 599.2**	**17 599.2**	**3 931.1**	**3 931.1**	**21 530.3**	**21 530.3**

Table 7. Average consumption of agricultural products per person and year in Sweden 1999.

Product	(l/y or kg/y)	**Product**	kg/y
Milk	142.0	Pork products	37.7
Yoghurt	16.2	Beef	20.7
Cheese	12.6	Poultry	9.7
Butter	1.5	Lamb	0.8
Margarine	13.7		
Cooking Oil	1.1		

4 Basis for assessing countermeasures for the fallout year

General measures 1 July, 2000: Announcement of the imaginary nuclear accident ”NABO” should lead to the 1st countermeasure being taken, housing of dairy cows and animals destined for slaughter in the region Norra Götaland (south central Sweden) and the whole of Svealand.

Measures taken for dairy herds can be lifted on 7-8 July in areas outside of the fallout districts 1, 2, 3 and 4, with the exception of a border-transition zone of approximately 5-10 km around district 1. Sampling of grass and pasture should begin as soon as possible: the border-transition zone around district 1 and the whole of districts 3 and 4 being of immediate importance. Sampling should concentrate on grassland, pasture and cereals on individual farms.

It is impossible to make a uniform assessment of the four fallout districts. The districts are divided up partly according to the production regions, Svealand's flat country (Ss) and Svealand's forested region (Ssk) and partly according to how the fallout is dispersed. Agricultural production differs according to soil type and crop production, and animal density. See production statistics above.

As regards the *unperceived fallout*, the consequences of not taking any countermeasures will be discussed below. Assessments or estimates are based on facts found in the literature. In certain cases districts 1 and 2 can be assessed in the same way, as districts 3 and 4. However, in most cases a separate assessment must be made for each of the districts 1-4 and for the production regions Ss and Ssk.

4.1 Limits as a basis for assessment

The current limit for how much ^{137}Cs most foods on sale in Sweden may contain is 300 Bq/kg. For certain products such as meat from game, reindeer meat, berries and fungi, the limit has been set higher at 1 500 Bq/kg. In Exercise Huginn the limit is taken as 300 Bq/kg in Sweden. If the limit were set at 600 Bq/kg, the values in Tables 7-11 would be approximately doubled.

The assessment of how large a ^{137}Cs fallout, kBq m^{-2}, would cause a caesium level of 300 Bq per kg in a product is based on the transfer of caesium to crops and the size of the local fallout. The development stage of the crop at the time of fallout is of great importance in regard to how large an amount is intercepted and taken up by the vegetative parts of the plant. The size of the leaf surface determines how much can be intercepted and taken up: large leaves, of for example lettuce and spinach, are able to intercept much more than blades of grass. Conditions at the time of the fallout are also of importance in determining how much caesium a plant retains. Is it a wet or dry deposition? How heavily is it raining at the time of fallout? Heavy rain at the time of deposition can wash away a large part of the radioactivity intercepted by plants. I assume in the case of Huginn that it rained ca. 15 mm, with a variation of 7-20 mm, on the night of 1-2 July. Only a wet deposition is recorded in the case of Huginn and not how much rain fell or how intensively it rained, which is of significance for the crops' capacity to intercept and take up caesium. We are assuming that the capacity to intercept and take up radioactivity is about 50 % (which is usual in literature reviews). However, this is an estimate, which in reality can vary between 10-70 %. The amount remaining at harvest would, therefore, be ca. 15-25 %.

4.2 Districts 1 and 4 after 1 week and 5 weeks

^{131}I

After a very short time ^{131}I will be found in milk: 1-2 days if the cows are out to graze. The period when they are housed should extend until the amount of ^{131}I has diminished and has no significance for milk production, i.e. ca. 5-6 weeks, compare Table 2. The ecological half-life of ^{131}I in milk and grass depends mainly on 3 factors:

1) ^{131}I has a half-life of 8 days in terms of its physical break down.
2) As grass or pasture grows, concentrations halve approximately every 14 days (growth doubled after 14 days).
3) Falloff of nuclides to the soil has a halftime of 14 days.

This means that the ecological half-life of ^{131}I in grass and pasture is ca. 4 days. Thus, after about 5-6 weeks, ^{131}I has little significance for milk production, see Table 2.

^{137}Cs & ^{134}Cs

After 5-6 weeks, the concentrations of ^{137}Cs and ^{134}Cs in milk will have also decreased to below levels requiring implementation of countermeasures, due to growth and dilution effects in districts 1 and 2, see Table 8.

Table 8. Estimate of the size of the ^{137}C fallout which, due to use of locally produced fodder, causes caesium concentrations of 300 Bq per kg in milk, beef, pork products and cereals at different times during the fallout year in Ss and Ssk. The average for all eight production regions in Sweden is given below.

Fallout period and product	Time after fallout (1/7), after first hay harvest week 1 kBq m^{-2}	 week 5 kBq m^{-2}	 December kBq m^{-2}
Milk	2	14	51
Beef	2	2	11
Pork products	-	-	5
Grain (bread)	-	-	3
Grain (fodder)	-	-	3

a) Beef cattle that are out to graze can not be sent for slaughter unless certain countermeasures are taken.

b) Cereals harvested in August – September will have high concentrations, which can be a problem if they are used as feed for fattening pigs. Compare Tables 7, 10 and 11.

By using measurements from grass samples, assessments can be made of the farms or districts where concentrations in milk and meat will be over the critical limit of 300 Bq/kg ^{137}Cs if no counter-measures are taken, see Table 9.

Table 9. The level of caesium concentrations in grass that will lead to a concentration of 300 Bq/kg in food products is determined by the animals' daily fodder intake. With a normal daily intake of 3000 Bq per kg consumed in roughage, concentrations can come close to the limit. By estimating the size of ^{137}Cs fallout, kBq m^{-2}, an average value can be calculated for the entire Swedish area of pasture and grass.

Fallout period	**Pasture, week 1 20% d.m.***	**Pasture, week 5 20% d.m.**	**Grass§ –regrowth 20% d.m.**
Summer, after hay harvest	2 kBq m^{-2}	20 kBq m^{-2}	21 kBq m^{-2}

* d.m.= dry matter

c) It is recommended that grass sampling on farms starts immediately after deposition has been determined in an area. This should be done to allow an effective assessment of the concentrations of caesium that can be expected in milk and meat. Cereal samples can supply information about whether it is worthwhile or not to harvest these products for animal feed.

4.3 Activity concentration of ^{131}I, ^{134}Cs and ^{137}Cs in milk in the fallout year

The values in Table 10 show that dairy cows in districts 1 and 2 can go out to graze after approximately 5 weeks. However, there is a risk that concentrations in the forested region, Ssk, are somewhat over 300 Bq/l (320 Bq/l). This is mainly due to lower growth rates.

Concentrations in milk in districts 3 and 4 are still much to high after 5 weeks to show values below 300 Bq/l.

Example: If milk is not to contain more than 300 Bq per liter of ^{137}Cs, a cow can consume at most ca. 40 000 Bq. Grassland or pasture produces ca.0.1-0.2 kg grass d.m./m^2 and a cow eats in total ca. 8-10 kg d.m. grass per day (40-50kg grass w.w.*). Consequently, a cow needs to graze on an area of ca 20 m^2 if she consumes everything; but a cow grazes unevenly between 50%-25% /m^2 to obtain her daily need of 50 kg grass w.w. Therefore the grass can not contain more than 750 Bq/kg w.w. or 3000 Bq/kg grass d.m.. Accordingly, 750 Bq/kg w.w.*50 kg grass w.w. = 37 000 and results in a concentration in milk of 0.008 (factor)*3700Bq = 300Bq/l milk.

Table 10. Estimate of concentrations of ^{131}I, ^{134}Cs and ^{137}Cs in milk after 1 and 5 weeks in districts 1 to 4. After 5 weeks, levels in milk in districts 1 and 2 have decreased to such an extent that concentrations of ^{137}C in milk are under 300 Bq/l if the cows are only eating grass.

Content in milk	**I-131**			**Cs-134**			**Cs-137**			**Cs-137+134**	
	kBq/m²	kBq/kg milk		kBq/m²	kBq/kg milk		kBq/m²	kBq/kg milk		kBq/kg milk	
Region District nSv/h	Dep	after **1 w.**	after **5 ws.**	Dep	after **1 w.**	after **5 ws.**	Dep	after **1 w.**	after **5 ws.**	after **1 w.**	after **5 ws.**
Ss 1 =150	60	6	0.06	6	0.6	0.09	12	1.2	0.18	1.8	0.27
" 2 =200	80	8	0.08	8	0.8	0.12	16	1.6	0.24	2.4	0.36
" 3 =500	200	20	0.2	20	2	0.3	40	4	0.6	6	0.9
" 4=1000	400	40	0.4	40	4	0.6	80	8	1.2	12	1.8
Ssk											
" 1=150	60	6	0.06	6	0.6	0.12	12	1.2	0.24	1.8	0.36
" 2=200	80	8	0.08	8	0.8	0.16	16	1.6	0.32	2.4	0.48
" 3=500	200	20	0.2	20	2	0.4	40	4	0.8	6	1.2
" 4=1000	400	40	0.4	40	4	0.8	80	8	1.6	12	2.4

4.4 Activity concentrations of ^{134}Cs and ^{137}Cs in meat in the fallout year

Table 11 presents an estimate of concentrations of ^{131}I, ^{134}Cs and ^{137}Cs in meat, Bq/kg, after 1 week and after 5 weeks, in districts 1-4. After 1 week concentrations of ^{137}Cs in meat are far too high. After 5 weeks, the concentrations in districts 1-4 are still so high that there is no meat available for sale with concentrations under 300 Bq/kg meat. After 20 weeks, concentrations in districts 1 and 2 have decreased to an extent that the critical limit of 300 Bq/kg is no longer exceeded. This means that no animals can go out to graze as they would in a normal year in fallout districts 1-4 during the period of vegetation, 2000. Countermeasures should be taken for animals that are due for slaughter at the end of the growing season.

Table 11. Estimate of concentrations of ^{131}I, ^{134}Cs and ^{137}Cs in Bq/kg meat after 1 week, and after 5 weeks, for districts 1-4 in Ss and Ssk in the Huginn case.

Content in meat		**^{131}I**			**^{134}Cs**			**^{137}Cs**			**$^{134+137}$Cs**		
		kBq/m²	kBq/kg meat		kBq/m²	kBq/kg meat		kBq/m²	kBq/kg meat		total kBq/m²	kBq/kg meat	
Region	District **nSv/h**	Dep	after **1 w.**	after **5 ws.**	Dep	after **1 w.**	after **5 ws.**	Dep	after **1 w.**	after **5 ws.**	Dep	after **1 w.**	after **5 ws.**
Ss	1=150	60	0.9	0.1	6	1.2	0.6	12	2.4	1.2	12	3.6	1.8
"	2=200	80	1.2	0.2	8	1.6	0.8	16	3.2	1.6	16	4.8	2.4
"	3=500	200	3.0	0.4	20	4.0	2.0	40	8.0	4.0	40	12.0	6.0
"	4=1000	400	6.0	0.8	40	8.0	4.0	80	16.0	8.0	80	24.0	12.0
Ssk													
"	1=150	60	0.9	0.1	6	1.2	0.9	12	2.4	1.8	12	3.6	2.7
"	2=200	80	1.2	0.2	8	1.6	1.2	16	3.2	2.4	16	4.8	3.6
"	3=500	200	3.0	0.4	20	4.0	3.0	40	8.0	6.0	40	12.0	9.0
"	4=1000	400	6.0	0.8	40	8.0	6.0	80	16.0	12.0	80	24.0	18.0

4.5 Activity concentrations of ^{137}Cs in cereals and grass in the fallout year

Table 12. Estimated concentrations of ^{137}Cs, kBq/kg, in grass and cereals in Svealand (Ss and Ssk), the TF (transfer factor, m^2/kg) value calculated from the Huginn fallout 1/7. Grass in districts 1 and 2 will have acceptable concentrations for milk production. Cereals grown in the fallout districts 1 and 2 will have relatively high concentrations. Grass and cereals in districts 3 and 4 will have relatively high concentrations of ^{137}Cs, and can not be used directly.

Region and district	nSv/h 6 July	Grass Cs-137 dep kBq/m^2	kBq/kg grass 2nd harvest	Cereals Cs-137 dep kBq/m^2	kBq/kg grain at harvest
			TF= 0.12		**TF= 0.1**
Ss 1	150	12	1.40	12	1.2
" 2	200	16	1.90	16	1.6
" 3	500	40	4.80	40	4
" 4	1000	80	9.60	80	8
Ssk			**TF= 0.17**		**TF= 0.1**
" 1	150	12	2.04	12	1.2
" 2	200	16	2.70	16	1.6
" 3	500	40	6.80	40	4
" 4	1000	80	13.60	80	8

Grass will have high concentrations of ^{137}Cs in districts 3 and 4 and cannot be used as fodder unless countermeasures are taken. In district 3 concentrations in milk are estimated to be about 350 Bq/l when the cows are consuming ca. 8-9 kg hay per day. In districts 1 and 2 grass consumption will most probably lead to ^{137}Cs concentrations of less than 300 Bq/l in milk, but not in meat.

Cereals in districts 1-4 have too high levels for concentrations in pork products or beef to be below the limit. They will probably be rejected as animal fodder if no counter-measures are taken.

4.6 Countermeasures in districts 1 – 4

The case of unnoticed fallout:
when no countermeasures are taken for districts 1 and 2.

^{131}I

After 5 weeks:
No dairy cows or beef cattle that are destined for slaughter should be graze during the immediate weeks/months. According to calculations in Table 9 and 10, ^{131}I concentrations in milk and meat will exceed the limit of 300 Bq/kg for districts 1-2. For districts 3-4 the concentrations of ^{131}I will be between 200-800 Bq/ l or kg.

^{137}Cs

After 5 weeks concentrations in pasture and grass will have decreased to below the limit set for milk in the regions Ss and Ssk. However, levels may be higher in the forested region. Caesium concentrations in meat will be to high for all district the first year and the meat will probably be unsuitable for consumption unless countermeasures are taken.

Sampling according to above provides a basis for a thorough assessment of the countermeasures needed to be taken. The latter are necessary to reduce or eliminate the averted dose of radioactivity to the population via contaminated milk and meat. The averted dose of radioactivity for ^{131}I, ^{137}Cs and ^{134}Cs via milk consumption is estimated in chapter 4.

5 Cost-benefit calculations

5.1 Early removal of vegetation (A1)

a) Grass vegetation

Areas 1-2. The nuclide content in the 2nd harvest of grass on leys will have 1.4-2.7 kBq per kg d.m. which indicates that countermeasure A1 is not necessary within these areas.

Areas 3-4. Removal of grass on leys as soon as possible. The ley-area in this district are 9 970 ha. The grass should be cut as close to the ground as possible. The method will decrease the contamination of the new grass, available for winter feeding, with factor up to 20 compared with the grass removed initially by application of method A1.

b) Cereal crops

Early removal is not actual in district 1-2. The crops should be removed at normal harvest time. Within district 1 and 2 it must be analyzed for ^{137}Cs to decide if it can be used as fodder.
The grain product cannot be used for winter-feeding pigs and cattle within district-areas 3 and 4. Use for energy purpose may be possible, both grain and straw in district-area 3 and 4. The cereal-area in this two district-are 6 860 ha.

Calculation for A1a: Grass vegetation

Production of contaminated fodder

Time for dep. 1/7
A = Dep. mean = 60 kBq/m^2 in region 3 and 4.
B = Area in district used for fodder for milking cows = 3 000 ha in total for region 3 and 4
C = Interception 50%
D = Harvest time for 2nd cut 15/8
E = Falloff 1/7 to 15/8 = 0.125 %
F = Growth 1/7 to 15/8 from 0.5 to 1.0 kg/m^2 f.w. = 0.5
G = Ratio between f.w. and d.w. = 5
Formula:
Cs in produced fodder = A*C*E*F*G
= 9 375 Bq / kg d.m.

Production of contaminated milk

Production 1 kg f.w. grass / m^2
Total grass production in 1 ha 2000 kg d.m.

Grass production in 3000 ha 6 000 000 kg d.m.
Milk production 20 kg/ day*cow
Number of cows = 3 700
Total milk production in the area 3&4 in 100 days 3700*20*100 = 7 400 000 kg milk
The cow eat 10 kg grass/day = 93 750 Bq / kg milk *0.008 (Fm) = 750 Bq /l milk

Cost:
Grass cost = 1.5 SEK/kg
Cost 2nd harvest of grass = 1.5 SEK * 2 000 kg d.m./ha * 3 000 ha = 9 000 000 SEK
Milk cost = 3 SEK
Cost of total milk production 3 SEK/kg milk 7 400 000 *3= 22 200 000 SEK

Dose:
ICRP dos conversion factor ^{137}Cs =1.3 10^{-8} and ^{134}Cs = 1.9 10^{-8}
Kg milk * radiocesium Cs =
(^{137}Cs) 750 Bq / l * 7 400 000 l milk = 5 550 000 000 Bq * 1.3 10^{-8} (dose conversion factor) = 72.2 manSv
(^{134}Cs) 2 780 000 000 Bq * 1.9 10^{-8} (dose conversion factor)= 52.8 manSv
Total = 125 manSv

Balance:
1 Euro= 8.5SEK
Cost of 2nd harvest of grass = 1.5 SEK/kg * 2 000 kg d.m./ha * 3 000 ha
= 9 000 000 SEK = 1 060 000 Euro
Extra cost for farmers 1000 SEK/ha * 3 000 ha = 3 000 000 SEK = 353 000 Euro
Total cost in Euro 1 413 000 Euro; about, 1 500 000 Euro
Euro/mansSv 12 000

5.2 Potassium fertilization (A5)

Limited quantities of K-fertilizer are available during the fallout year. Should mainly be reserved for application on grass after removal of grass vegetation (method A1). K-fertilization is effective on pastureland.
Direct uptake and root uptake will be the two most important pathways for the nuclides the first year. The following years will root uptake be most important pathway.
The ley-area in district 3-4, deposition with 40 and 80 kBq/m^2 has an area of 9 970 ha. The data sheet A5 gives a reduction in dose by a factor 3-(5) if application of 150 kg K ha^{-1}.

Calculation for A5:

Averted dose: See method A1a

Cost:
2nd cut for 3 700 cows = 13.5 10^6 SEK. K-fertilization 1000 SEK/ha and for 3000 ha= 3 10^6 SEK. Total cost 16.5 10^6 SEK.

5.3 Ploughing (A6)

a) Grass vegetation

Up to 50 % of the grass can be ploughed in the autumn of the fallout year in the existing crop rotations. The grass-area in the district with 40 and 80 kBq/m^2 are 9 970 ha. The grass crop on this land can alternatively be used as plant fertilizer (method A16), or used for cereal growing in the next year. Cereals can then, if necessary, be under sown with new grass.

Calculation for A6a:

Averted dose: **See method A1a**

Cost:

2nd cut for 3 700 cows = 13.5 10^6 SEK. Ploughing 1 500 SEK/ha for 3 000ha =4.5 10^6 SEK. Sowing new grass 2000 SEK/ha for 3000ha = 6 10^6 SEK. Total cost 23 10^6 SEK.

b) Cereal crops

All cereal land within areas 1-4 should be ploughed in the autumn of the fallout year. The cereal-area in district-area 3 and 4 are 6 860 ha.

5.4 Ploughing and K-fertilization (A8)

a) Grass vegetation

See methods A5 and A6.

Calculation for A8:

Averted dose: **See method A1a**

Cost:

2nd cut for 3 700 cows = 13.5 10^6 SEK. Ploughing 1 500 SEK/ha for 3 000ha =4.5 10^6 SEK. K-fertilization 1000 SEK/ha and for 3000 ha = 3 10^6 SEK. Sowing new grass 2000 SEK/ha for 3000ha = 6 10^6 SEK. Total cost 27 10^6 SEK.

6 Summary and conclusions

Radioactive fallout in Central Sweden at the levels assigned will to different extent cause disturbance in farming from 1 July 2000 in the four districts, 1-4 (Iso-curve, 1=150, 2=200, 3=500 and 4=1000 nSv/h). Immediate housing of dairy cows and animals destined for slaughter will be necessary in all districts and in a big area outside the districts. After 1 week this restriction may be cancelled in the area outside the border, prolonged 4 weeks in districts 1-2 and to next year in districts 3-4.

Housing the animals at least the five first weeks will be necessary due to ^{131}I in districts 1-4.

Method - Limits as a basis for assessment of how large a ^{137}Cs fallout, kBq m^{-2}, would cause a caesium level of 300 Bq per kg in a product is based on the transfer of caesium to crops and the size of the local fallout.

K-fertilization, 100-150 kg K/ha, the first two-three weeks after fallout is to recommend if possible on all grassland. In districts 1-2 it will be lower transfer of ^{137}Cs to grass and safely decrease the ^{137}Cs-content in milk will bee below 300 Bq/l from cows grazing 5 weeks after fallout.

In districts 3-4 removal of grass is considered as soon as possible. If the new grass in late August can be used for diary cows or for meat cattle will depend on the actual ^{137}Cs-content (in re-growth of grass considerably). If the land is not used for winter feed the leys can be ploughed and the land used for new crops in the next year. K-fertilization of pasture, in districts 3-4 after removing of vegetation is recommended.

No animals for meat production can go out to graze as they would in a normal year in fallout districts 1-4 during the period of vegetation, 2000. Countermeasures should be taken for animals that are due for slaughter at the end of the growing season. Clean fodder will be necessary for longer time in district 3-4 than in district 1-2.

At 1st of July cereals have large leaf areas and therefore they are sensitive for interception of radionuclides. No countermeasures can be taken to decrease later transfer to grain during the first season. About 10-20 % of ^{137}Cs may be present in grain at harvest in August or September 2000.

Feeding with contaminated grain will probably means too high levels of ^{137}Cs-content in pork and beef. Change of slaughter time and feeding with clean fodder are probably necessary countermeasures. Alternatively the grain will be rejected as animal fodder. It may be used for energy production or ploughed down as organic fertilizer. On mineral soils the year after fallout, farming can continue as before in district 1-2.

Housing of dairy and meat cattle for 5 weeks will be necessary in all districts, 1-4, and in district 3-4 to the next year. Effects of countermeasures are shown in Schedule 3.

Removal of grass vegetation, A1 and K-fertilization, A5, of leys in district 3 may save the 2nd cut of grass in August. Ploughing, A6, of leys in district 3-4 after removing grass the 2nd cut of grass is to be recommended.

Combination of ploughing and K-fertilization, A8 in district 3-4 after removing grass and cropping of cereals is effective to decrease contaminated crop products. If contaminated crops products after activity measurements are to be used in districts 1-4 for winter feeding of meat cattle, sheep and goats in autumn 2000, it will also be necessary to change slaughter time, B2 and / or use clean fodder before slaughter, B4. Prussian blue licks/boli, B5 may also be used for these animals.

The contaminated area in district 3-4 are relative small 10 000 ha for grass and 7 000 ha for cereals. The area for gracing cows (3 700) in the two district are only 3 000 ha. To replace all vegetation for winter fodder would be possible by clean fodder to a relative low cost. The total cost for clean grass and cereals to district 3- and 4 will be about 68 000 000 SEK. The cost for clean grass to the milking cows will only bee 10 000 000 SEK.

7 References

Andersson, K,G., Rantavara, A., Roed, J., Rosén, K., Skipperud, L. & Salbu, B. (2000). NKS/BOK-1.4, A guide to countermeasures for implementation in the event of a nuclear accident affecting Nordic food-producing areas. NKS-16. NKS/BOK-1.4. Risø. ISBN 87-7893-066-9.

Eriksson, Å., Lönsjö, H. & Karlström, F., (1994). Beräknade effekter av radioaktivt nedfall på jordbruksproduktionen i Sverige, II, Jordbruksgrödornas förorening. *Rapport SLU-REK-73, Sveriges lantbruksuniversitet, Uppsala.* (In Swedish with English summary.).

Eriksson, Å & Andersson, I (1994). Beräknade effekter av radioaktivt nedfall på jordbruksproduktionen i Sverige III. Djurprodukternas förorening Inst för Radioekologi, *Rapport SLU-REK-75* (In Swedish with English summary.).

Eriksson Å. (1994): A database model for calculations of the transfer of ^{90}Sr and ^{137}Cs in complex agricultural environments. Report SLU-Rek-76.

Eriksson, Å. (1997). The cultivated agricultural environment. Ed: Strand, P., Skuterud, L. & Melin, J. Reclamation of Contaminated Urban and Rural environments following a severe nuclear accident. BER 6, NKS (97) 18, 97-10-10. Risö, pp 18–51.

Eriksson, Å., Rosén, K. & Haak, E. (1998). Retention of simulated fallout nuclides in agricultural crops. I. Experiments on leys. Rapport SLU-REK-80, Uppsala. pp 1-32.

Eriksson, Å., Rosén, K. & Haak, E. (1998). Retention of simulated fallout nuclides in agricultural crops. II. Deposition of Cs and Sr on Grain Crops. Rapport SLU-REK-81, Uppsala. pp 1-36.

Haak, E., Eriksson, Å., Lönsjö, H. & Rosén, K. (1998). Överföring av Cesium-137 till jordbruksprodukter i Skåne och Blekinge efter en kärnenergiolycka. Rapport SLU-REK-82, Uppsala. pp 1-44. (In Swedish with English summary.)

ICRP, (1996). Annals of ICRP. Age-dependent doses to members of the public from intake of radionuclides: ICRP, publication 72. ISSN 0146-6453

IAEA, (1994). Guidelines for agricultural countermeasures following an accidental release of radionuclides. A joint undertaking by the IAEA and FAO. Technical reports series no. 363. Vienna.

Rosén, K. (1996). Field studies on the behaviour of radiocaesium in agricultural environments after the Chernobyl accident. pp 1-65. Report SLU-REK-78. Uppsala.

Rosén, K. (1997). Hotskedet. *"(The crisis period)".* Underlag för utarbetande av myndigheternas rekommendationer till lantbrukare i händelse av en kärnenergiolycka - Efter ett larm, men före nedfallet av radioaktiva ämnen. Rapport SLU-REK-79, Uppsala, pp. 1–24. (In Swedish with English summary.)

SCB, (1998). (*Statistics Sweden*) Jordbruksstatistisk årsbok 1998. Sveriges officiella statistik jordbruksverket. Statistiska centralbyrån. Halmstad.

Schedule 1. Applicability of countermeasures.

Country: Sweden								
Counter-measure	Relevance				Practicability			Applicability
	Season	nuclides	production type	production conditions	Waste	supplies	manpower	yes, if yes to all questions to the left, otherwise no
A1	Yes	Cs, I	Yes	Yes	Yes	Yes	Yes	Yes, area 1- 4
A2	No	"	No	No	No	No	No	No
A3	Yes	I	Yes	Yes	Yes	Yes	Yes	Yes, area 3 - 4
A4	Yes	Sr	Yes	Yes	Yes	Yes	Yes	No
A5	Yes	Cs	Yes	Yes	-	Yes	Yes	Yes, area 3 - 4 and Ssk2
A6	Yes	"	Yes	Yes	-	Yes	Yes	Yes, area 3 - 4
A7	Yes	"	Yes	Yes	-	No	Yes	No
A8	Yes	"	Yes	Yes	-	Yes	Yes	Yes, area 2 - 4
A9	Yes	"	No	No	-	Yes	Yes	No
A10	Yes	"	Yes	No	-	No	Yes	No
A11	Yes	Sr	Yes	Yes	-	Yes	Yes	No
A12	Yes	Cs	Yes	No	No	No	Yes	No
A13	No	"	No	Yes	-	Yes	Yes	No
A14	No	"	No	Yes	Yes	Yes	Yes	No
A15	Yes	"	No, not 1st year	No	No	Yes	Yes	No (long term)
A16	Yes	"	Yes	Yes	-	Yes	Yes	Yes, area 3-4
A17	No	"	No	Yes	No	Yes	Yes	No
A18	No	"	Yes	Yes	Yes	Yes	Yes	No (long term)
B1	Yes	I	Yes	Yes	Yes	Yes	Yes	Yes, area 3-4
B2	Yes	Cs	Yes	Yes	-	Yes	Yes	Yes, area 1-4
B3	Yes	"	Yes	Yes	No	Yes	Yes	No, yes, area 1-4, new grass stand
B4	Yes	"	Yes	Yes	Yes	Yes	Yes	Yes, area 1-4
B5	Yes	"	Yes	Yes	-	Yes	Yes	Yes, area 1-4
B6	Yes	"	Yes	No	-	Yes	Yes	No (limited quantities)
B7	Yes	Sr	Yes	Yes	-	Yes	Yes	No
B8	Yes	Cs	Yes	No	Yes	Yes	Yes	No
B9	No	"	No	No	No	No	Yes	No
B10	No	"	No	No	No	Yes	Yes	No
B11	Yes	"	No	Yes	Yes	Yes	Yes	No
C1	Yes	I	Yes	Yes	-	Yes	Yes	Yes, area 3-4
C2	Yes	Cs	No	No	No	Yes	Yes	No
C3	Yes	"	Yes	No	Yes	Yes	Yes	No
C4	Yes	"	No	No	Yes	Yes	Yes	No, (resistance)
C5	Yes	"	No	No	Yes	Yes	Yes	No, (resistance)
C6	Yes	"	No	No	Yes	Yes	Yes	No, (resistance)
C7	Yes	"	No	No	Yes	Yes	Yes	No
C8	Yes	"	No	No	Yes	Yes	Yes	No

Schedule 2. General considerations for countermeasures that are applicable according to Schedule 1.

Country: Sweden							
Counter-measure	Legality	Acceptance				Implications for other countermeasures	Comments
		farmers	industry	consumers	public	(specify numbers)	
A1	Yes	Yes	Yes	Yes	Yes		Area 1-4
A3	Yes	Yes	Yes	No	No		Resistance
A5	Yes	Yes	Yes	Yes	Yes	A6	Area 2- 4+ Ssk area 1
A6	Yes	Yes	Yes	Yes	Yes	A5, A16	"
A8	Yes	Yes	Yes	Yes	Yes		"
A16	Yes	Yes	Yes	Yes	Yes		"
B1	Yes	Yes	Yes	No	No		
B2	Yes	Yes	Yes	Yes	Yes		Area 1-4
B4	Yes	Yes	Yes	Yes	Yes		"
B5	Yes	Yes	Yes	Yes	Yes		"
C1	Yes	Yes	No	No	No		Area 3-4

Schedule 3. Cost benefit analysis for selected countermeasures.

Country: Sweden					
Counter-measure	Area affected ha	Averted dose manSv	Monetary costs Euro (1Euro=8.4 SEK)	Cost-effectiveness Euro/manSv	Comments
A1 Area	3 000 ha ley	125	1 500 000	12 000	2nd cut is only 40 % of the diet to milking cows
A5 Area 3-4	3 000 ha ley	125	2 000 000	16 000	Limited quantities of K-fertilizer available
A6 (+A1) Area 3-4	3 000 ha ley	125	2 700 000	22 000	30 % of the total ley area (10 000) are to be used to milking cows
A8 Area 3-4	3 000 ha ley	125	3 200 000	25 000	30 % of the total ley area (10 000) can be ploughed and used for the milking cows
A 16 Area 3-4	10 000 ha ley; 6860 ha cereals				
B2 Area 3-4					Actual for Cattle, sheep, goats
B4 Area 1-4					Actual for Cattle, sheep, goats
B5 Area 1-4					Actual for Cattle, sheep, goats

Annex

Description of the Huginn late-phase exercise

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Description of the Huginn late-phase exercise

1 Introduction

Within the NKS/BOK-1.4 project on agricultural countermeasure strategies for nuclear emergency preparedness it has been decided to conduct a late-phase nuclear emergency exercise. In this context, the exercise Huginn is devised. The exercise is an internal exercise of the BOK-1.4a project and serves to evaluate and progress project work. In the present document, the exercise format, scenario and instructions for the players are described. The exercise scenario describes a fallout situation (i.e., a late-phase situation), in which large areas have been contaminated with radioactive material.

In the BOK-1.4 project, background information has been compiled on the radiological and economical consequences of a number of specific countermeasures, aiming at reducing doses to man via the foodstuff pathways. The background information, organized in the form of one data sheet for each countermeasure, provides quantitative information about dose reduction and economical impact, as well as qualitative information about the applicability of the countermeasures.

Some, but not all of the countermeasures may apply in a fallout situation, where food-producing areas have been contaminated from radioactive deposition. It is the purpose of this exercise to test the ability to provide decision support by identifying possible countermeasures and estimating the positive and negative effects of the agricultural countermeasures selected.

The main objectives of the exercise are

1) to test the usefulness of the data sheets in the process of identifying possible agricultural countermeasures and calculating the radiological and economical consequences of such countermeasures;
2) to determine and describe supplementary information required for assessing the radiological and economical consequences of the agricultural countermeasures;
3) to describe useful revisions/additions to the data sheets, that will facilitate decision making on agricultural countermeasures in a radiological emergency.

2 Exercise format

The exercise is organized by NKS, and is planned for and prepared within the BOK-1.4 project group. The exercise is conducted in the Nordic countries on a national basis, and is to be carried out concurrently in the five countries. Coordinators of the exercise are as follows,

Exercise coordinator	Magnus Brink	(NKS/BOK-1.4)
National coordinators	Magnus Brink	(Denmark)
	Riitta Hänninen	(Finland)
	Sigurður Örn Hansson	(Iceland)
	Brit Salbu	(Norway)
	Jan Preuthun	(Sweden)

In each participating country, the national coordinator will be responsible for organizing a national group for carrying out the exercise. The national groups may seek outside help if needed. However, it is *not* an objective of the exercise to test communication or consultation between countries. Also, the exercise is not intended to test the emergency preparedness systems of the Nordic countries.

The national groups, provided with the exercise scenario and instructions described in the present document, will be asked to address a number of questions related to late-phase agricultural countermeasure strategies. Each national group will address the situation in its own country.

A suggested timetable for the exercise is shown below.

Date	Task	Action
March 1, 2000	exercise description distributed to national coordinators	exercise coordinator
March 15, 2000	deadline for commenting on the exercise description	national coordinator
June 1, 2000	exercise to be reported, i.e., schedules with comments returned to exercise coordinator	national coordinator
June 6, 2000	results presented at project group meeting	exercise coordinator
summer, 2000	evaluation of exercise	to be decided
fall, 2000	reporting of the exercise	to be decided

3 Exercise scenario

The exercise scenario is an adaption of the scenario described for the ODIN exercise (NKS/BER-5). The present, late-phase exercise commences on day 6 after a severe nuclear accident. Preceding events are common to the Nordic countries and the radioactive fallout is similar in all five countries. The radiological impact and decisions taken by the emergency management however, may differ because of differences, e.g., in the ecosystems of the affected areas.

The accident, classified as an INES 6 event, takes place at the nuclear power plant NABO on July 1^{st}, 2000, and radioactive fission products, including noble gases, iodine, and cesium, are released to the atmosphere. As deplorable meteorological conditions prevail during the first few days after the accident, the Nordic countries all experience radioactive fallout, contaminating large areas in each country. After 48 hours, the release is brought to an end.

On day 6, preliminary fallout maps have been produced for each country, based on meteorological forecasts, airborne gamma-ray surveys, and ground based measurements.

The following information is known at the onset of the exercise, and the players will give advice on agricultural countermeasures:

a. Prior to the accident, the weather had been nice and warm in all of the Nordic countries.
b. Iodine and cesium has been detected in the fallout; other nuclides will not be considered in the exercise.
c. Coarse maps of external gamma-dose rates, and ^{131}I, ^{134}Cs, and ^{137}Cs depositions have been produced for each country.
d. Deposition mostly took place as wet deposition. Therefore, on a local scale, a large variability should be expected in the actual amount of deposited material.
e. The BOK-1.4a group of NKS has made a first draft of a report containing data sheets on agricultural countermeasures,
f. The weather is nice again and meteorological services assert that further fallout is very unlikely.

Fallout maps are provided in Annex 1 to this document. A single map for each country shows isocurves for external dose rate above the background level and contamination levels of iodine and cesium, referring to the date of the start of the exercise (day 6 after the accident). The translation from isocurve labels to dose rate and surface activity concentrations is shown in Tables 1-5, Annex 1.

4 Exercise instructions

The agricultural countermeasures considered are listed in Annex 2. (Data sheets for the separate countermeasures are not included in this document.) The national groups are asked to answer three general questions about each of the listed countermeasures:

1) Does the countermeasure apply in the situation described?
2) Are there general considerations that are relevant for the countermeasure?
3) Can the monetary costs and the avertable dose be estimated?

Schedules for reporting results are provided in Annex 3. The first question (Schedule 1) is intended to be answered by a "yes/no", and, if affirmative, questions 2 and 3 (Schedules 2, 3) should be addressed. Finally, references to relevant information, e.g., on demographic and agricultural data, radioecological data, and regulations, should be listed in Schedule 4.

The three questions are discussed in more detail in the following.

4.1 Schedule 1. Applicability of countermeasure

A countermeasure may apply if it is both relevant and practicable to implement. The following questions are intended to be answered by a "yes/no". If one or more questions are answered by a "no", the method can be ruled out as being irrelevant or impracticable. If affirmative to all questions, the method is deemed to be applicable and should be given further consideration.

a. Relevance: Is the countermeasure relevant with respect to

- season of production vs. date of the accident
- nuclide composition of fallout
- type of production
- production conditions (soil type, water content, topography, etc.)

b. Practicability: Is it practicable to implement the countermeasure, considering that

- waste generated can be disposed of
- supply of equipment and materials, incl. protective equipment is sufficient
- manpower, incl. number of skilled or trainable people, is sufficient
- other ?

Note that in the present scenario, iodine and cesium nuclides are present in the fallout; the actual activity concentrations however, are not relevant for filling out Schedule 1.

4.2 Schedule 2. General considerations

Are there special reasons that a countermeasure may not be appropriate, although the method is deemed to be applicable? The following questions should be answered by a "yes/no". Note that answering "no" to one or more questions in this schedule will *not* be sufficient to preclude a countermeasure. Comments may be required and are welcome.

The countermeasure

- is legal (not in conflict with existing legislation) ?
- has no implication on other countermeasures (the present countermeasure does not preclude other relevant countermeasures, considering sequence and timing of countermeasures) ?
- is generally acceptable by farmers, industry, consumers, and the public ?

4.3 Schedule 3. Cost-benefit analysis

Provided a countermeasure is applicable according to Schedule 1, the scale (area affected), monetary costs and benefits in form of averted dose for the countermeasure should be assessed. Elements needed for assessing costs and benefits are the following,

a. Locate problem. Important elements for deciding on the scale of the problem are

- contamination levels
- area, demography

- production type
- production volume.

The cost-benefit assessment is greatly simplified if actual contamination levels are approximated by a single contamination level (for each nuclide) within a specified, fairly large area. The area (and the contamination level) should be chosen considering all of the elements listed above.

b. Dose reduction. Estimation of the total dose reduction is to be based on

- BOK-1.4a data sheets
- radioecological information: Transfer factors, etc. (IAEA-363, NKS/BER-6)
- Basic Safety Standards (BSS-115): Effective dose per unit intake
- other ?

Results should be given in terms of the averted collective, committed effective dose. Only internal doses, i.e., doses arising from the foodstuff pathways, need to be considered.

c. Monetary costs. Estimation of the monetary costs is based on

- BOK-1.4a data sheets
- agricultural information

Results should be given as the total monetary costs in units of Euro.

d. Cost-effectiveness. Estimation of the ratio of monetary costs to the averted collective dose. The values obtained for the different countermeasures will allow for an initial prioritization of the different countermeasures and may be compared to the intervention levels (the alpha value) recommended by the Nordic radiation protection authorities. Results should be given in units of Euro/manSv.

e. Comment on other costs and benefits. In addition to the assessment of dose reduction and monetary costs, less quantifiable effects of a countermeasure may be noted. The participants should comment on, e.g.,

- loss of market share
- gain in credibility
- other ?

5 References

NKS/BER-5. Nordic Nuclear Emergency Exercises, TemaNord 1995:606.

NKS/BER-6. Reclamation of contaminated urban and rural environments following a severe nuclear accident, BER-6, NKS(97)18, ISBN 87-7893-017-0, Eds. Per Strand, Lavrans Skuterud, and Judith Melin (1997).

IAEA-363. Guideline for Agricultural Countermeasures Following an Accidental Release of Radionuclides, IAEA Technical Reports Series No. 363, Vienna, 1994.

BSS-115. International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources, IAEA Safety Series No. 115, Vienna, 1994.

Appendix 1 Fallout maps

Tables 1-5. Left column is the isocurve numbers shown on the map. Columns 2-5 show the corresponding values for the dose rate above the background, and the surface activity of iodine and cesium.

Country: Denmark				
isocurve	external γ-dose rate nSv/h	^{131}I kBq/m^2	^{134}Cs kBq/m^2	^{137}Cs kBq/m^2
125	125	50	5	10
250	250	100	10	20
500	500	200	20	40
1000	1000	400	40	80

Table 2.

Country: Finland				
isocurve	external γ-dose rate nSv/h	^{131}I kBq/m^2	^{134}Cs kBq/m^2	^{137}Cs kBq/m^2
250	250	100	10	20
500	500	200	20	40
1000	1000	400	40	80

Table 3.

Country: Iceland				
isocurve	external γ-dose rate nSv/h	^{131}I kBq/m^2	^{134}Cs kBq/m^2	^{137}Cs kBq/m^2
120	120	48	5	10
1000	1000	400	40	80
2000	2000	800	80	160

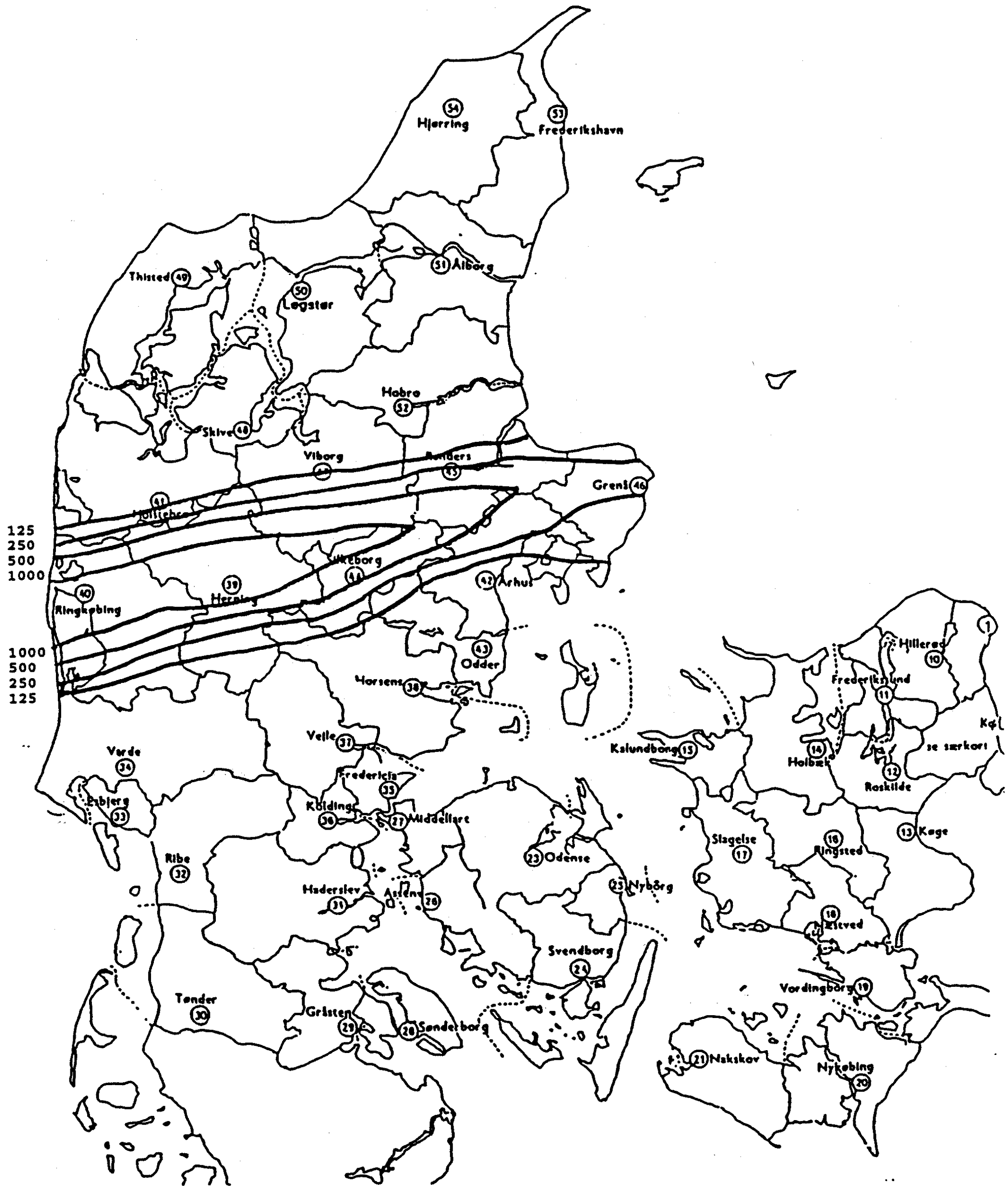
Table 4.

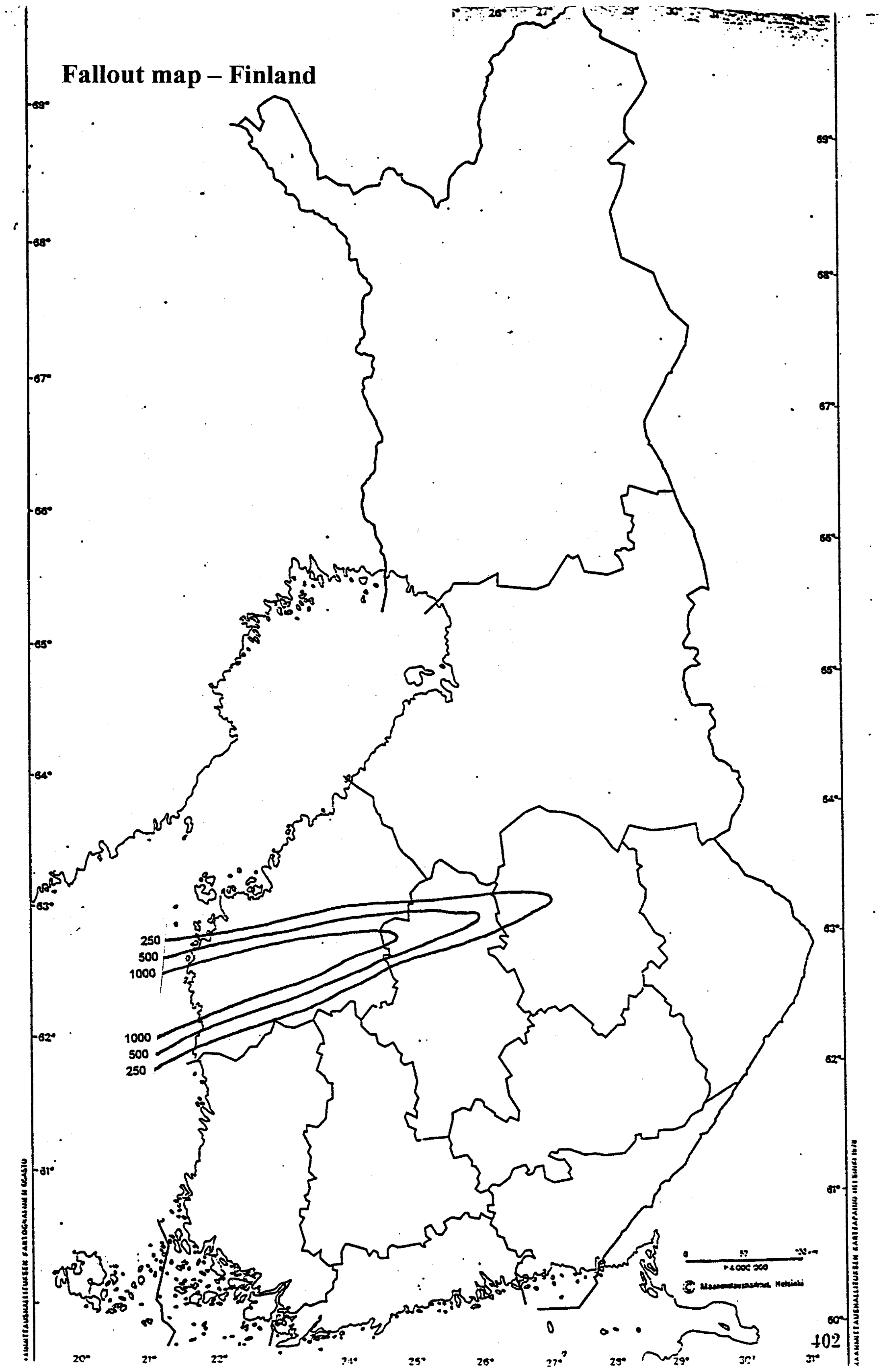
Country: Norway				
isocurve	external γ-dose rate nSv/h	^{131}I kBq/m^2	^{134}Cs kBq/m^2	^{137}Cs kBq/m^2
150	150	60	6	12
500	500	200	20	40
1000	1000	400	40	80
2000	2000	800	80	160

Table 5.

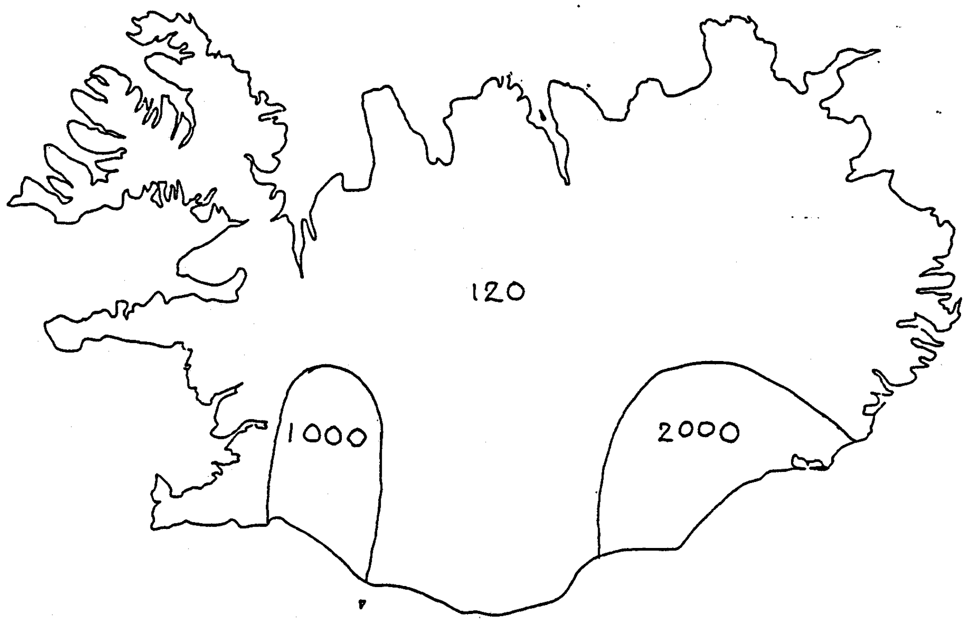
Country: Sweden				
isocurve	external γ-dose rate nSv/h	^{131}I kBq/m^2	^{134}Cs kBq/m^2	^{137}Cs kBq/m^2
150	150	60	6	12
200	200	80	8	16
500	500	200	20	40
1000	1000	400	40	80

Fallout map - Denmark

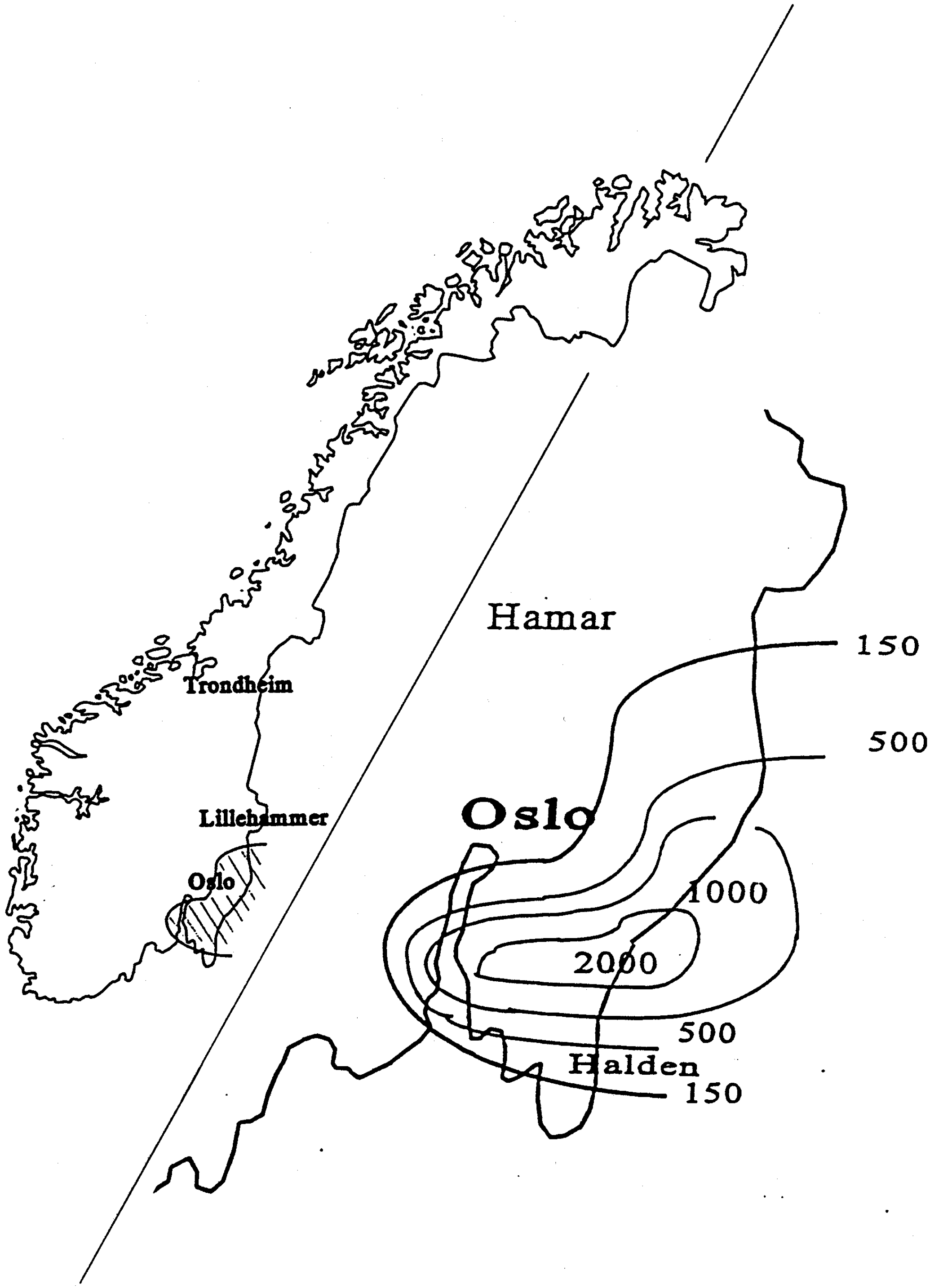



Fallout map – Finland
250
500
1000
1000
500
250
402

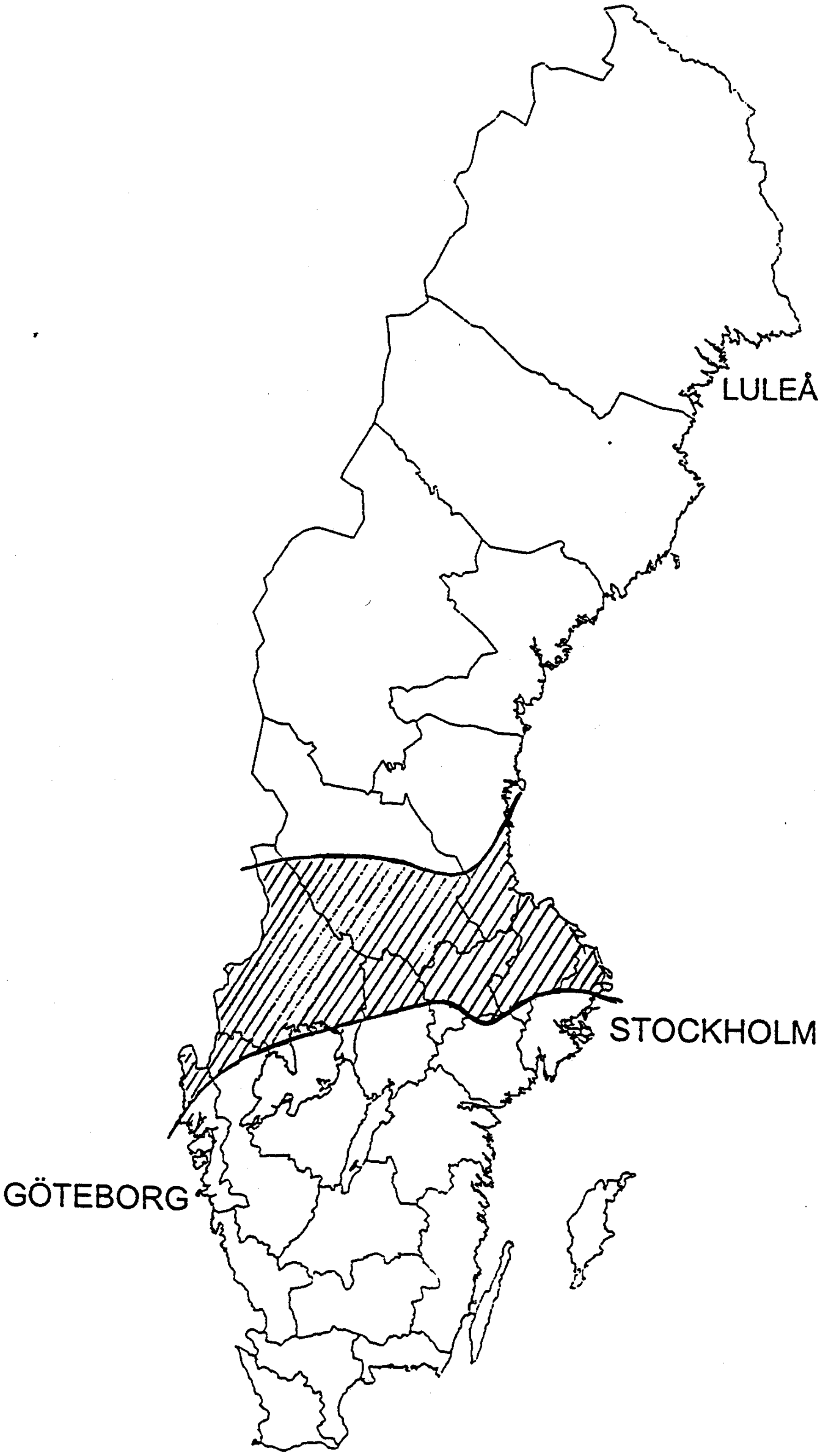
Fallout map - Iceland



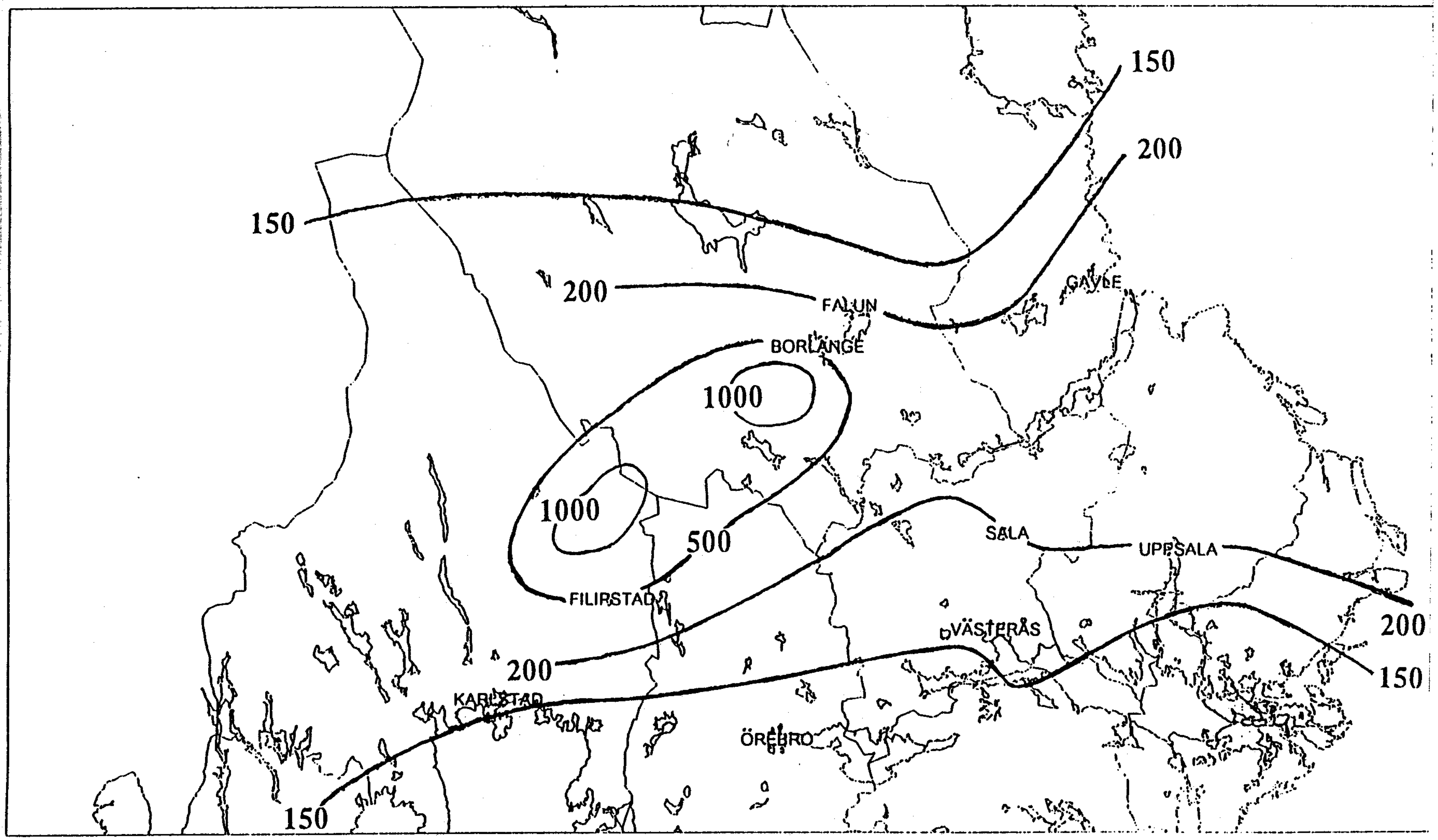
Overview and detailed fallout map - Norway



Overview - Sweden



Detailed fallout map - Sweden



Appendix 2 Agricultural countermeasures

Table 6. Data sheet numbers.

Data sheet	Countermeasure
A1	Early removal of vegetation
A2	Early removal of snow
A3	Storage of crops / grass
A4	Liming of soil
A5	Potassium fertilization
A6	Ploughing
A7	Deep-ploughing
A8	Ploughing and K-fertilization
A9	Repeated ploughing
A10	Skim-and-burial ploughing
A11	Phosphorus fertilization
A12	Turf harvesting
A13	Cultivating crops with low uptake
A14	Cultivating crops that can be processed
A15	Change production from crops to animals
A16	Use plants as fertilizer
A17	Growth of industrial crops
A18	Change land use to forestry
B1	Supply animals with stable iodine
B2	Change slaughter time
B3	Reduce animal intake of contaminated soil
B4	Clean fodder to animals before slaughter
B5	Prussian Blue salt licks/boli
B6	Supplement fodder with micas or zeolites
B7	Addition of calcium to fodder
B8	Prussian Blue filters for milk decontamination
B9	Replace sheep/goats with cattle
B10	Change from milk to meat production
B11	Change animal production to non-consumption
C1	Manufacturing of food products to be stored for months
C2	Mechanical decontamination of fresh vegetables, fruit and cereals
C3	Making cheese by Rennet method and replacing milk in diet with cheese
C4	Change milling yield and use of least contaminated grain fractions
C5	Light salting of meat
C6	Light salting of fish
C7	Parboiling mushrooms
C8	Soaking dried mushrooms in water

Appendix 3 Schedules for reporting

Schedule 1. Applicability of countermeasures; to be answered by y/n.

Country: ___________________								
Counter-measure	Relevance				Practicability			Applicability
	season	nuclides	production type	production conditions	waste	supplies	manpower	yes, if yes to all questions to the left, otherwise no
A1								
A2								
A3								
A4								
A5								
A6								
A7								
A8								
A9								
A10								
A11								
A12								
A13								
A14								
A15								
A16								
A17								
A18								
B1								
B2								
B3								
B4								
B5								
B6								
B7								
B8								
B9								
B10								
B11								
C1								
C2								
C3								
C4								
C5								
C6								
C7								
C8								

Schedule 2. General considerations; to be answered by y/n, if applicable according to Schedule 1.

Country: ________________							
Counter-measure	Legality	Acceptance				Implications for other countermeasures	Comments
		farmers	industry	consumers	public	(specify numbers)	
A1							
A2							
A3							
A4							
A5							
A6							
A7							
A8							
A9							
A10							
A11							
A12							
A13							
A14							
A15							
A16							
A17							
A18							
B1							
B2							
B3							
B4							
B5							
B6							
B7							
B8							
B9							
B10							
B11							
C1							
C2							
C3							
C4							
C5							
C6							
C7							
C8							

Schedule 3. Cost benefit analysis for countermeasures that are applicable according to Schedule 1.

Country: ________________					
Counter-measure (specify)	Area affected km^2	Averted dose manSv	Monetary costs Euro	Cost-effectiveness Euro/manSv	Comments

Schedule 4. References to general information or specific information for your country.

Country: ________________
Agricultural data 1. 2. 3.
Radioecological data 1. 2. 3.
Regulations 1. 2. 3.
Other 1. 2. 3.

Bibliographic Data Sheet **NKS-23**

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No. of illustrations	7
No. of references	34
Abstract	The Huginn late-phase exercise was carried out by the NKS/BOK-1.4 project group in the spring 2000. National teams from Denmark, Finland, Norway and Sweden took part in the exercise. The objective of the exercise was to test the ability to calculate the radiological and economical consequences of various agricultural countermeasures following a nuclear accident. This report describes the findings of the four national teams, including the approaches made by the teams, selection of countermeasures and the results of the cost-benefit analyses that they performed. The methods used and findings by the four teams have been compared and recommendations issued based on the exercise results.
Key words	Agriculture; Cost Benefit Analysis; Fallout; Radiation Doses; Radioecological Concentration; Remedial Action

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