Datasheet based countermeasure evaluation for radioactively contaminated Nordic food-producing areas

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Abstract

A Nordic expert group has identified and critically evaluated the countermeasures that may potentially be implemented in connection with major nuclear accident situations contaminating Nordic food-producing areas. This paper demonstrates how the derived technical information can be applied by decision-makers to identify practicable and cost-effective means for mitigation of the impact of a contamination.

Introduction

In the event of a major nuclear accident leading to airborne contamination of large Nordic food-producing areas it is imperative in advance to have identified and described potentially applicable countermeasures in terms of benefits and constraints, so that an optimised strategy for handling the situation can be developed as early as possible. The important factors forming the basis for the evaluation of strategical options for remediation of a contaminated food-producing area include the potentially averted dose, local method practicability, availability of equipment and workers with required skills, monetary costs, possible waste problems and other technical limitations. In a handbook recently published by NKS (Andersson et al., 2000), these technical factors have been evaluated for a total of 37 countermeasures, which are considered to be relevant to the Nordic context. It is these technical factors and their application in differential cost benefit analysis as a basis for countermeasure strategy formation, which are highlighted in this paper.

Methods/background

All important technical data in relation to each of the 37 countermeasures that are considered potentially feasible and practicable in radioactively contaminated Nordic food-producing areas (including food processing industry and domestic households) have been presented in a single data sheet, facilitating intercomparison of method features. Only methods influencing ingestion doses are considered. Methods for reduction of external doses are described elsewhere (e.g., Andersson & Roed, 1999). However, where methods designed for reduction of consumption doses (e.g., ploughing procedures) also affect external doses this is mentioned in the data sheets. The data sheets are systematised in the handbook according to the time stage following an accident and the food chain for which they are relevant, and guidance/ recommendations concerning their application has been provided. An extended internet-based version of the handbook is currently under development.

An example of a data sheet is given in Table 1: removal of contaminated vegetation shortly after *contaminant deposition.*

Table 1. Example of technical descriptions in a countermeasure data sheet (from Andersson et al., 2000).

Method	**Early removal of vegetation**
Description	Removal of growing crops from contaminated fields reduces ground contamination; on grass land also contamination of stubble and grass sward.
Target surface / product	Fields with rather dense vegetation, where the radionuclides are mainly retained in growing crops (dry deposited).
Time of application (number of days after deposition, season, etc.)	Removal of crops as soon as possible after fallout. Removal before the 1st rain shower after fallout is the optimal situation. Transfer of radionuclides from vegetation to soil has a half-life of about 15 days. Rainfall increases this transfer.
Expected effect: DF (decontamination factor), DRF (dose reduction factor) - internal DRF depends on diet	Reduction of external dose on contaminated fields and reduction of uptake of radionuclides in subsequently grown crops may be substantial (reduction by a factor of up to 20).
Personnel requirements and costs (method time consumption)	Typically: 1 operator, ca. 0.2-0.3 man-days ha^{-1} for crop removal. Additionally: Loading, transport and waste disposal.
Equipment and other remedies - costs	Normally harvest equipment is available on the farms. For arable crops: anything from forage and swath harvesters (ca. 10,000 to 20,000 EURO) to combines (ca. 200,000 EURO). For grass crops: tractors (ca. 50,000 EURO) with mowers (ca. 4,000 EURO). Petrol of the order of ca. 10 l ha^{-1}.
Practicability	Achievable in a large scale. The limit is the number of workers and equipment locally available over a short period of time. The possibility to remove fallout from fields is usually best on grassland.
Waste	Removed crop material may, depending on contamination level, be used (after storage and/or preparation) or disposed of in repository. Costs of transportation/storage of waste within 20 km : ca. 20 EURO m^{-3}.
Benefits	Reduction of external dose on treated fields may be substantial. Lower root uptake of nuclides due to less contamination of soils in following years.
Constraints	Sites for waste disposal and safe storage.
Remarks	Respiratory protection of workers may in some cases be radiologically necessitated.
References	CEC report EUR 12554 EN, ISBN 92-826-3272-5, 1991. NKS report NKS(97)18, BER6, ISBN 87-7893-017-0, 1997.

Method evaluation example/results

In the following a simplified example is given to illustrate how the data sheet shown in Table 1 could be used in an emergency situation. Consider a situation where airborne dry contamination occurs to a potato field in the month of July, and the contamination level of the main contaminant, ^{137}Cs, has been measured to be 10 MBq m^{-2}.

The predominant soil type in the area is known to be sandy loam (ca. 10 % clay), and at this time of the year the potato plants cover the ground well, so it is estimated that more than 90 % of the contamination in the field occurs to the rough plant surface. The weather forecast says dry weather followed by heavy rain in 2-3 days. This means that a removal of the plants within few days would be expected to reduce the contamination level in the field by a factor of ca. 10. According to Eriksson (1997) the soil-to-potato transfer factor for this type of soil is about 1.4 10^{-3} m^2 kg^{-1} (dw). Assume that an average Nordic person consumes ca. 0.3 kg d^{-1} of potatoes with a dry matter content of 20 %. According to IAEA (1994) ordinary peeling and boiling will reduce the contamination level to ca. 60 %.

According to ICRP (1995), each Bq of ^{137}Cs consumed by an adult will result in a dose of 1.3 10^{-8} Sv (slightly less for children). This means that the averted dose to one consumer over the 1st season after deposition (assuming that a very large area has been contaminated and alternative food can not be imported in sufficient amounts) can be approximated as follows:

$D = 10\ MBq\ m^{-2} * 90\ \%\ (\text{early harvest}) * 1.4\ 10^{-3}\ m^2\ kg^{-1} * 20\ \% * 60\ \% * 0.3\ kg\ d^{-1} * 365\ d\ y^{-1} * 1.3\ 10^{-2}\ Sv\ MBq^{-1} = 2.2\ mSv\ y^{-1}$.

Taking into account the radiological half-life of ^{137}Cs and assuming that the transfer factor will decrease somewhat with time (if deposited particles are more or less readily soluble), a rough estimate of the individual averted life-time dose could be of the order of 50 mSv. The average annual yield from a potato field is in Denmark currently ca. 36 t ha^{-1}. Assuming a moderate waste fraction of the potatoes, it can be deduced that probably some 200 people can have their supply covered from a 1ha potato field. This means that early harvesting in 1 ha of potato field can result in an averted collective life-time dose of some 10 man-Sv.

A value of an averted man-Sv may, e.g., be derived from figures currently applied by Danish Ministries in connection with cost analyses of other types of accidents, for instance casualties in traffic. If such a monetary 'casualty' figure were multiplied by 0.05 Sv^{-1} (the current ICRP estimate of the probability of developing fatal, radiation-induced cancer), the result would be an estimated value of an averted man-Sv of about 40,000 EURO. This would make the dose averted by treatment of a ha worth some 400,000 EURO over a life-time.

From Table 1 it follows that the harvesting of leafy material from 1 ha can be accomplished in less than 3 hours by one operator with a harvester. With current salaries, the operator costs, including expenditures to have the equipment brought to the site and mounted, would on this background be estimated to about 150 EURO ha^{-1}.

Further, the petrol requirements would according to Table 1 be ca. 15 EURO, whereas the equipment discount corresponding to 3 hours use would amount to ca. 70 EURO. As indicated in Table 1, waste transport and storage costs would be estimated to some 20 EURO m^{-3}, if a simple repository can be constructed within 20 km distance (this may however not be feasible or legal in the particular area). From one ha, there may be some 100 m^3 of waste, corresponding to a cost of ca. 2,000 EURO. The total direct method costs are thus of the order of 2,300 EURO ha^{-1}. As mentioned in the NKS report, contaminated bio-mass may e.g. alternatively be applied as fuel for power plants, substantially reducing the amount of waste for disposal.

This means that on this background, the technique would be considered very cost-effective for the particular scenario, even without considering the reduction in external dose. However, it should be stressed that a number of other, often politically determined, factors should be considered by decision-makers prior to implementation of countermeasures. These include psychology, public acceptability, social implications, communication routes and ethical considerations.

Conclusion

A series of countermeasures for handling emergency situations involving nuclear contamination of Nordic food-producing areas have been investigated and described in a standardised datasheet format. An example is given of how the information from a datasheet may be applied by decision-makers to identify practicable and cost-effective countermeasure strategies. The example highlights how technical aspects may be considered, particularly in relation to direct method cost-effectiveness evaluation, and stresses the need for incorporation in strategy formation of other, often politically governed considerations.

References

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