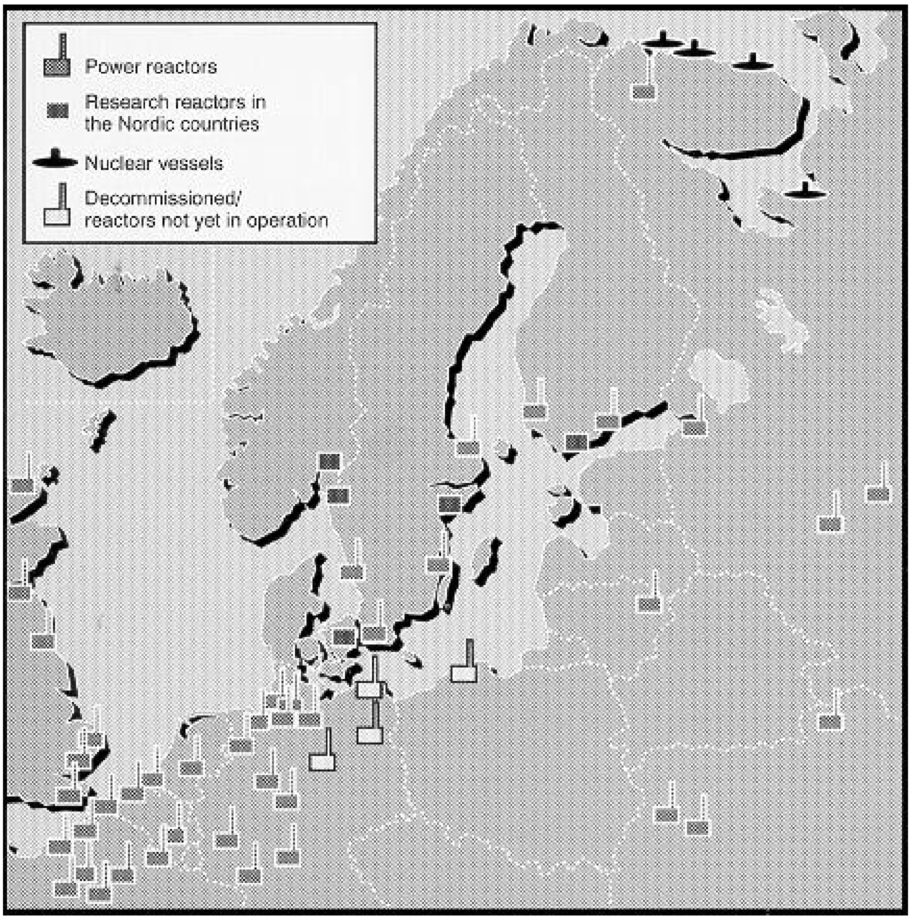
Early Phase Clean-Up Actions after Nuclear Accidents



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organizes joint four-year research programs involving some 300 Nordic scientists and dozens of central authorities, nuclear facilities and other concerned organizations in five countries. The aim is to produce practical, easy-to-use background material for decision makers and help achieve a better understanding of nuclear issues.

To that end, the results of the fifth four-year NKS program (1994 – 1997) are herewith presented in a series of final reports comprising reactor safety, waste management, radioecology, nuclear emergency preparedness and information issues. Each report summarizes one of the ten projects carried out during that period, including the administrative support and coordination project. A special Summary Report, with a brief résumé of all ten projects, is also published. Additional copies of the reports on the individual projects can be ordered free of charge from the NKS Secretariat.

The final reports – together with some technical reports and other material produced during the 1994 – 1997 period – have been collected on a CD-ROM, also available free of charge from the NKS Secretariat.

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Early Phase Clean-Up Actions after Nuclear Accidents

Guidelines for the planner

Final Report of the Nordic Nuclear Safety Research Project EKO-5

Thomas Ulvsand

June 1997

This is NKS

NKS (Nordic Nuclear Safety Research) is a scientific cooperation program in nuclear safety, radiation protection and emergency preparedness. Its purpose is to carry out cost-effective Nordic projects, thus producing research results, exercises, information, manuals, recommendations, and other types of background material. This material is to serve decision-makers and other concerned staff members at authorities, research establishments and enterprises in the nuclear field.

The following major fields of research are presently dealt with: reactor safety, radioactive waste, radioecology, emergency preparedness and information issues. A total of nine projects have been carried out in the years 1994 - 1997.

Only projects that are of interest to end-users and financing organizations have been considered, and the results are intended to be practical, useful and directly applicable. The main financing organizations are:

- The Danish Emergency Management Agency
- The Finnish Ministry for Trade and Industry
- The Icelandic Radiation Protection Institute
- The Norwegian Radiation Protection Authority
- The Swedish Nuclear Power Inspectorate and
  the Swedish Radiation Protection Institute

Additional financial support has been given by the following organizations:

In Finland: Ministry of the Interior; Imatran Voima Oy (IVO); Teollisuuden Voima Oy (TVO)
In Norway: Ministry of the Environment
In Sweden: Swedish Rescue Services Board; Sydkraft AB; Vattenfall AB; Swedish Nuclear Fuel and Waste Management Co. (SKB); Nuclear Training and Safety Center (KSU)

To this should be added contributions in kind by several participating organizations.

NKS expresses its sincere thanks to all financing and participation organizations, the project managers and all participants for their support and dedicated work, without which the NKS program and this report would not have been possible.

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Abstract

The work reported has been performed with the purpose of working out a guide for planners of early clean-up actions in nuclear fallout situations and for decision makers in the Nordic countries. The actions considered are hosing of roofs, walls and paved areas, lawn mowing, removal of snow, pruning of trees and bushes and vacuum cleaning of streets. The expected effects, mainly as life time dose reduction, and consequenses regarding practicability, waste produced, staffing and protection are presented for urban, suburban and rural living environments.

The work has been performed within the framework of the Nordic Nuclear Safety Research Programme 1994 -97 with full financial support from the Swedish Rescue Services Agency (Statens Räddningsverk).

Key words

gamma radiation, dose, dose rate, radioactivity, clean-up, decontamination, radioactive waste, residential areas

Summary

If there is a nuclear plant accident within or outside the Nordic countries, releasing radioactive matter causing a nuclear fallout situation in some of our Nordic co-untries, clean-up actions will probably be considered. When and if such actions are to be taken and performed, the outcome will be dependent on how well they are prepared. This is especially important when considering the *early* actions, because there will be limited time available for preparations, which in addition are to be carried out under severe stress.

The purpose of the work in EKO-5 has been to work out guidelines to be used in the planning of *early* clean-up actions, i.e. actions which have to be taken during the first three weeks in order to be meaningful. The work is only considering actions reducing doses from external radiation in inhabited areas.

The target group of this document is mainly those persons who are in charge of making plans for the actions taken in the case of a radioactive release, persons found on different levels in the preparedness organisations in each country.

Within the project a base report has been prepared, NKS/EKO-5 (96) 18, which is useful to experts in their work to support decision makers.

The work has extracted seven actions which can be regarded as early: hosing of roofs, walls and paved areas, lawn mowing, pruning of trees and bushes, removal of snow and vacuum cleaning of streets. For a reference deposition of 1 MBq/m² of ^{137}Cs, calculations have been performed in five urban or suburban environments such as detached wooden or brick houses, semi-detached houses, terrace houses and city center multi-storey houses. In the case of dry or wet deposition, the document describes the expected effects of the various actions and the practical, economical and protective-relevant consequenses generated by them. Even if it is hard to find a good motive for initiating clean-up actions removing short-lived nuclides, as for example ^{131}I, they still have to be considered in a work like this. In the early phase, when the relevant actions are to be performed, these nuclides will contribute with an external gamma dose to the persons involved in the clean-up. Those doses can be considerable, up to ten times the dose coming from the long-lived ^{137}Cs, which is the main target of the actions.

In NKS/EKO-5 (96) 18 the expected effects ‘ Immediate averaged total dose rate reduction in the area’ and ‘Averaged total accumulated life time dose reduction over 70 years’ have been calculated. It also gives the ‘Averaged total accumulated life time dose to the people’ which would be the result if no actions whatever were

taken. In the guidelines resulting from this work, the reduction of life time dose has been considered as the relevant parameter.

The actions giving the largest effects, measured as reduction in life time dose reduction, are lawn mowing, removal of snow and pruning of trees and bushes. The averted life time dose can for example be estimated to about 100 mSv in a single family wooden house area, for the chosen reference deposition of 1 MBq/m², if the lawns are mowed and the grass cut is removed. With the exception of hosing, the clean-up actions will generate amounts of waste which has to be handled and deposited in a acceptable way.

The document finally discusses clean-up actions and their effects on the rural living environments. The relevant actions will be the same as those taken in the urban areas, but there is a difference in the performance. In urban areas, the actions will to a great extent be managed and performed by efforts of the society. In rural areas, on the contrary, there are the equipment and experience needed on the single farms, resulting in the inhabitants' ability and will to perform the recommended early clean-up actions themselves. These actions can be expected to give about a half of the accumulated three weeks dose, compared to the situation where no actions whatever are taken.

The document ends with the guidelines, describing the 44 considered cases which are directed to the planners. The guidelines are presented as tables, with headings as follows:

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures

Sammanfattning

Om en kärnkraftsolycka inträffar inom eller utanför Norden, med utsläpp av radioaktiva ämnen som ger en beläggningssituation i något av våra länder kommer säkert saneringsåtgärder att övervägas. När och om sådana beslutas och genomförs kommer resultatet att vara beroende på hur väl de är förberedda. Detta är extra viktigt för de *tidiga* åtgärderna, eftersom begränsad tid kommer att finnas till förberedelser, som dessutom skall göras under mycket pressade förhållanden.

Arbetet inom EKO-5 har syftat till att utarbeta riktlinjer att användas vid planläggning av *tidiga* saneringsåtgärder. Med tidiga menas i detta arbete åtgärder som måste vidtagas under de tre första veckorna för att vara meningsfulla. Arbetet berör endast åtgärder som syftar till att reducera doser från extern strålning i bebyggda områden.

Målgruppen för rapporten är främst de personer med ansvar för planläggning av åtgärder i samband med radioaktiva utsläpp som finns på olika organisationsnivåer i de nationella beredskapsorganisationerna.

Inom EKO-5 har en underlagsrapport tagits fram, NKS/EKO-5 (96) 18, som är användbar för experter i deras arbete att stödja beslutsfattare.

Arbetet har utkristalliserat sju åtgärder som kan betraktas som tidiga. De är: spolning av tak, väggar och asfaltytor, att klippa gräsmattor, att klippa träd och buskar, att avlägsna snö samt att använda gatudammsugare. För en referensbeläggning av 1 MBq/m² ^{137}Cs har beräkningar gjorts för fem boendemiljöer av stads- eller förortskaraktär. De är enfamiljshus i trä och tegel, parhus, hyreshus och mångvåningshus i stadskärnor. För deposition under torra och våta förhållanden beskriver rapporten de förväntade effekter som olika åtgärder kan ge och vilka praktiska, ekonomiska och skyddsmässiga konsekvenser de ger upphov till. Även om det inte kan anses motiverat att sätta in saneringsåtgärder för att avlägsna kortlivade nuklider, som ^{131}I, måste de beröras i ett arbete som detta. I den tidiga fasen, då de aktuella åtgärderna skall sättas in, kommer de att bidra med en externdos till de personer som engageras i olika moment i saneringen. Denna dos kan vara avsevärd, upp till 10 gånger större än dosen från den långlivade ^{137}Cs som åtgärderna syftar till att avlägsna.

I den tidigare nämnda rapporten NKS/EKO-5 (96) 18 beskrivs de förväntade effekterna som ‘omedelbar dosratsreduktion i området’ och ‘medelreduktion av livstidsdosen över 70 år’. En uppgift om vilken medellivstidsdos som skulle bli resultatet om inga åtgärder vidtages anges också. För de riktlinjer som detta arbete har resulterat i har reduktion i livstidsdos använts som den relevanta parametern.

De åtgärder som ger störst effekt i form av reduktion av livstidsdos är gräsklippning, att avlägsna snö samt klippning av träd och buskar. Exempelvis kan den avstyrda livstidsdosen vid referensnivån 1 MBq/m² uppskattas till ungefär 100 mSv i en boendemiljö av enfamiljs trähus om gräsytorna klipps och gräsklippet transporteras iväg. Med undantag för vattenspolning kommer saneringsåtgärderna att ge upphov till en avfallsmängd som måste hanteras och deponeras på ett acceptabelt sätt.

Rapporten diskuterar slutligen saneringsåtgärder och -effekter i jordbrukslandskapet. Åtgärderna som är aktuella är desamma som i de urbana miljöerna, men en skillnad finns i genomförandet. I stadsmiljö kommer åtgärder att till stor del samordnas och genomföras av samhälleliga insatser. I jordbruksmiljön däremot finns utrustning och erfarenhet på de enskilda gårdarna, vilket innebär att befolkningen själv kan genomföra de rekommenderade tidiga saneringsåtgärderna. Dessa kan förväntas ge ungefär en halvering av dosen ackumulerad under tre veckor, jämfört med om inga åtgärder vidtages.

Rapporten avslutas med att för 44 behandlade fall ge en vägledning för planeraren. Denna vägledning ges i tabellform, med tabellhuvuden enligt följande:

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures

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Purpose and constraint

The preparedness against nuclear power plant accidents is differently organised in the Nordic countries. In all countries except Sweden, the responsibility for and decisions on countermeasures lie on a national level. In Sweden this responsibility is found on the regional level, by way of the county government boards, the national authorities merely giving advice and recommendations.

In the case of a nuclear power plant accident causing release and deposition of radioactivity over large areas, there is reason to believe that early clean-up is one thing that will to be considered. For the persons in charge, there will be a lot of questions to be answered, decisions to be made and arrangements to be initiated. The questions will be put, both by a worried population and by different involved society functions as well as by the mass media and by persons and groups of people who are to effectuate the decided actions. The decisions will for example deal with questions like which actions are to be initiated, and of equal importance, which ones that are not relevant to perform. The practical arrangements will cover required man power and machinery and deposition sites among other things. All this has to be done in a limited and hectic time and under severe pressure.

Whatever the organisation looks like, knowledge about relevance, costs, benefits and practical consequenses of different clean-up actions, is of great importance in order to make the outcome of the efforts as good as possible. Likewise, the outcome will for some of the actions very strongly depend on how well they are prepared. The main purpose of this document is to serve as a guide in those preparations. Small or local accidents with radioactive sources are not treated in this document.

There are many combinations of housing conditions, deposition conditions and early clean-up actions and the purpose of the work in EKO-5 has been to describe the cases which in one way or another can be considered relevant *early* clean-up actions when making plans, guidelines and checklists for these actions. To be categorised as early, the action must be carried out early to have the expected effect or to be successful.

The work is aimed only at reducing *external doses* and do not consider actions to reduce uptake in agricultural products and food from farms and privat gardens.

Target groups

The main target groups of this document are *persons in charge of planning* and *decision makers* on the appropriate level of organisation in each country. The main document is principally aimed at persons without professional competence in the field of radiology.

Part of the work consists of calculations, resulting in a set of data sheets for various combinations of deposition conditions, clean-up actions and living environments. The result is presented in the report, NKS/EKO-5 (96) 18 (ref 1), which will be useful to *experts* and *professionals* in their work to support decision makers.

Ionising radiation

Radioactivity (in some sections of this report referred to as 'activity') is the property of spontaneous disintegration possessed by certain unstable types of atomic nuclei. Such disintegrations are accompanied by the emission of different types of radiation: either α (alpha) or β (beta) particles and/or γ (gamma) photons. Ionising radiation is radiation that is capable of causing ionisation, which for instance could have a devastating effect on human tissue.

Although β particles may in some cases give doses to the human skin, when the contamination is located on or very close to the skin, only the γ-radiation is considered in this report, which solely deals with the external radiation (as opposed to internal radiation from ingestion or inhalation of contaminants) from an accidental contamination of surfaces in the living environment. This follows from the very short range of β particles, but in particular α particles which do not even have the power to penetrate the superficial dead cell layer of human skin.

The level of contamination on a surface is given in the report in units of MBq/m^2. The Bq term, which is short for 'Becquerel', is defined simply as the number of radioactive disintegrations per second, and the prefix 'M' means 'mega' which stands for 1 Million. Likewise, contamination per unit of volume is given in units of MBq/m^3.

The energy imparted by ionising radiation per mass unit of e.g. human tissue is termed the absorbed dose. In this report, which deals exclusively with the impact of γ-radiation, doses are expressed in units of Sievert (Sv), and correspondingly, dose rates are defined as the dose increment per unit of time. Common prefixes for Sv are 'm' (10^{-3}) and 'μ' (10^{-6}).

The natural environment in which we live constitutes various radioactive sources from naturally occurring radioactivity. The total natural dose contribution (usually termed the natural background dose) amounts to about 1 mSv/year in the Nordic countries. This comprises contributions from cosmic radiation, internal radiation from the body and terrestrial radiation from the ground, etc. In addition to this, there is a contribution from radon progeny which varies according to the type and texture of the ground, the dwelling constructions, etc. This contribution is on an average estimated to 2-3 mSv/year in the Nordic countries.

Generally, the likelihood of a received dose of less than 1 Sv (1000 mSv) having a short-termed (often referred to as non-stochastic) fatal effect is extremely small. However, smaller doses add to a cancer risk (normally referred to as stochastic).

According to ICRP (International Committee on Radiation Protection) publication 60 (1990), the dose-specific risk of developing fatal cancer is 5,0 10^{-2} Sv^{-1}.

In this work we have focused on doses caused by the gamma-radiation emitted from ^{137}Cs (caesium-137), which is likely to be released in comparatively large quantities from a major nuclear power plant accident. The long half-life, high solubility and mobility in certain environments, together with the metabolic similarity with potassium (one of the most commonly occurring elements in nature) are some of the key factors that make ^{137}Cs the principal radiation emitter in this context.

Introduction

A prestudy ”Preplanning of early clean-up after fallout of radioactive material” made by Studsvik EcoSafe, pointed out the need and request for preplanning of actions. The prestudy suggested, that a main study should be initiated, a study proposing test methods, elaborating scenarios, describing relevant clean-up strategies in different environments and the preparing of a checklist. Based on that prestudy, this project was started and because of the common interest shared by the Nordic countries, it has been carried out within the framework of the Nordic Nuclear Safety (NKS) Research Programme 1994 -97.

This document deals with *early clean-up actions*, performed not later than three weeks after the accident causing the release. Regardless of if the decision to take actions is taken on a local, regional or national level, the success of the decided actions is strongly dependent on preparations made. This is especially important if the actions are to be taken shortly after the accident.

To be able to make a document like this, it is necessary to limit the work to some generalised cases. Therefore, the only radionuclide considered in the work is the long-lived ^{137}Cs. One reason is that if such powerful and demanding efforts as clean-up actions are considered, the purpose must be to reduce the effects, for example life time dose, caused by long-lived nuclides.

Another reason for using only caesium is that it sticks very hard to various surfaces. So if you are successful in decontaminating caesium, you have often removed other contaminants as well.

Five generalised urban environments have been used in the calculations. They are:

- detached wooden house environment
- detached brick house environment
- semi-detached house environment
- terrace house environment
- multi-storey house environment

They are described in more detail in the chapter "Methodologies applied for the estimates of doses and related factors in urban areas".

Ten clean-up actions have been considered initially. They are:

- fire hosing of roofs
- fire hosing of walls
- fire hosing of paved areas
- top soil removal
- pruning of trees and bushes and felling trees
- ploughing

- lawn mowing (grass cutting)
- snow removal
- vacuum sweeping of roads and pavements
- triple digging

Details and explanations about environments and actions are given in NKS/EKO-5 (96) 18, ref (1).
Lawn mowing, pruning of trees and bushes and snow removal can give large effects, but the actions have to be carried out very shortly after the deposition in order to be meaningful and are therefore put on the list of relevant actions. Fire hosing and vacuum sweeping should be done early before the deposition is fixed to the surface and these actions are therefore also put on the list of relevant early cleanup actions.

Not on the list of relevant *early* clean-up actions are ploughing, soil removal and tripple digging, as these do not critically require early implementation. They should, however, be considered when the clean-up strategies are made in the early phase, as other methods may not suffice to reduce the long-term dose significantly.

The clean-up procedures selected for the study were chosen because they were believed to be the most appropriate ones for the particular task in the specific types of Nordic environments. The procedures are thought to have the widest potential applicability due to the general availability of equipment, availability of experienced operators, straightforwardness, etc. The cost element and public acceptability of the implications of an effectuation of the considered operations were of course also evaluated carefully. Naturally, all types of surfaces in the residential area had to be represented.

Even though we can only look at a limited selection of methods in this work, there are of course a rather large number of other methods which might in special cases be applied successfully.

A relatively new technique in this connection has been suggested for removal of for instance surface soil: the turf harvester. The advantage of this procedure - particularly in the early phase - is that soil layers as thin as a few centimetres could be removed. However, the method can not be applied to stony soils, and as it requires a very mature turf mat, it can not be considered as a generally applicable method.

Experimentation has indicated the potential use of rotation-broom sweepers with steel bristles for removal of top soil. The drawbacks of this method are that it is necessary to ensure that the removed contamination is not suspended in the air, thus giving rise to an inhalation risk as well as a redistribution of the radioactive matter. Therefore, it must be carried out in wet media, under shielded conditions and possibly with some sort of vacuuming device. The availability of the equipment as well as the costs and manoeuvrability of the device in the often small open urban or suburban areas limit the applicability.

Skim and burial ploughing would be more advantageous to carry out than ordinary ploughing, because the thin contaminated surface soil layer is buried in the bottom of the ploughing trench, while the layer which is initially immediately under this top layer will be placed at the very top without inversion. This will ensure the optimal dose-reductive effect as well as the minimum impact on the soil fertility. However, skim and burial ploughs are currently not available in large numbers.

Application of ammonium solutions for ion exchange with caesium has been found to have a (not very large) beneficial effect compared to that obtained by treatment with ordinary tap water, and sand-blasting can for instance also give a large dose-reduction on construction materials, but these methods are rarely cost-effective.

An exhaustive list of all clean-up procedures that have been considered over the years for residential areas would be extremely long, so this is just to inform the reader that other methods, often with a more narrow applicability, also exist. The effect of many of these alternative techniques could be roughly evaluated from the data sheets in this report. For instance, there are many ways to remove a top soil layer, which would have similar beneficial effects. The final report of an earlier Nordic project, KAN2, (ref 9) contains information of a variety of alternative methods in Chapters 2 and 7 as well as in Appendix 1.

Calculations have been made for dry and wet deposition.

The resulting guidelines are relatively neutral to scenarios, as they mainly are dealing with practical consequenses of different actions. How to perform fire hosing of roofs for example is independent of the scenario causing the release of activity. But the deposition level and resulting dose rate and accumulated dose will of course influence on the decision to do or not to do a specific action. For that reason a reference deposition of 1 MBq/m² of ^{137}Cs on grassed areas has been used in the calculations.

To give some idea of the relevance of this level it can be mentioned that in large areas in Ukraine, Russia and Belarus, the depositions caused by the Chernobyl accident were 1 - 2 MBq/m² and in the most contaminated areas in Sweden the deposition was about 0,2 MBq/m². Another example is the scenario used in the Nordic Decision Conference (ref 16), where areas with a deposition of 1 MBq/m² of ^{137}Cs could be found up to 200 km from the source, the Loviisa Nuclear Plant in Finland.

The rural living environment is treated with much less emphasis compared to what has been done regarding the urban and suburban environments. This is due to the fact that one must consider rural areas as a smaller problem, as long as one talks about preplanning of early clean-up actions. The inhabitants can act on their own responsibility in accordance with recommendations because they normally have most of the equipment needed and the experience to use it.

It must be stressed that all values given in the report (guidelines inclusive) are estimations coming from calculations based on generalised and simplified assumptions. They can not be considered as true values, but show the order of magnitude for that specific effect and are useful in comparisons between different actions and effects.

The most important effect to be considered in analysing the benefit of various early clean-up actions, is what *reduction in life time doses* to people in the area you can gain. If the accident, releasing radioactive matter, takes place in or in the vicinity of the Nordic countries, there can be effects caused by short-lived nuclides, for example doses to the thyroidea from inhaled radioactive iodine.These effects must be avoided by other means than clean-up actions. But doses from short-lived nuclides still have to be considered in one respect, because they can constitute a radiation hazard to the clean-up teams, thus making it necessary to plan for radiation protection.

The most relevant short-lived nuclide is ^{131}I. It has a half-life of 8 days and can be released in a gaseous or a particulate form. In this report, dealing with early clean-up actions, only the particulate iodine is relevant. The gaseous form will be "gone with the wind" when the clean-up starts. For the same activity per squaremeter of ^{137}Cs and ^{131}I, the dose rate free in air for iodine will be 0,68 of the dose rate from caesium (ref 4). The activity relation ^{131}I to ^{137}Cs can be estimated to 1 - 5 (ref 5,6,7,8). Other short-lived nuclides as well can contribute to the dose rate in the early phase, for example ^{134}Cs and ^{140}La. All in all, this roughly indicates that the dose rates in the early phase can be up to ten times higher than the calculated dose rates from ^{137}Cs given in the data sheets.

The accident in Windscale 1957 gave troublesome contamination of the ground mainly with ^{131}I, but ^{137}Cs and ^{134}Cs also contributed. About 1000 TBq of ^{131}I and 40 TBq of the two Cs nuclides were released.
At the accident on Three Mile Islands, only radioactive noble gases and small amounts of iodine were released.
At the Chernobyl accident, the release consisted of noble gases, iodine and caesium, but there were also some low volatility nuclides from the fuel elements. Some strontium and ruthenium was also released. The clean-up actions in the three most affected countries Belarus, Ukraine and Russia are, and have been caused by contamination with caesium, strontium and fuel fragments.

On greater distances, for example in the Nordic countries, the radiation doses, when the short-lived ^{131}I has declined, are almost totally caused by the caesium isotopes (ref 2).

Probably the most important radiation protection problem to handle is that of the doses from collected radioactive waste given to personnel in the clean-up teams. Two of the considered early phase actions will give this type of waste: vacuum sweeping and lawn mowing. In the collection tank of the vacuum sweeper there will be highly concentrated waste. For the chosen reference level of 1 MBq/m^2, the specific activity in the tank can be calculated to 5000 MBq/m^3, giving a dose rate to the driver of 50 - 100 μSv/hour. This can be compared to the 12 μSv/day coming from the deposited caesium in the environment.

Methodologies applied for the estimates of doses and related factors in urban areas

First of all, it must be stated that only *external* doses are considered in the following, so wherever the term 'dose' is mentioned, it only refers to external dose.

The formation of the data sheets on cost-effective details for application of different clean-up methods under different circumstances demanded that some dose and dose rate modelling had to be made. In the early phase, doses received by the public from untreated contaminated areas can be estimated on the basis of the initial dose rate which, at least for a ^{137}Cs contamination, is not likely to change considerably over a period from the first few days to the first couple of months. In order to estimate the doses potentially averted by the introduction of a countermeasure, it is however necessary to integrate over life-long periods of time.

To accomplish these tasks, the URGENT model, described in detail in ref (1), was applied to obtain both integrated doses and initial dose rates.

Four different urban and suburban environments have been chosen according to R. Meckbach, P. Jacob and H.G. Paretzke (ref. 3). These are shown in Figures 1a-1d. By using relative figures for initial contamination levels, estimates of initial dose rates and integrated doses were made for these environments, which have been found to adequately cover the construction practice in the Nordic countries.

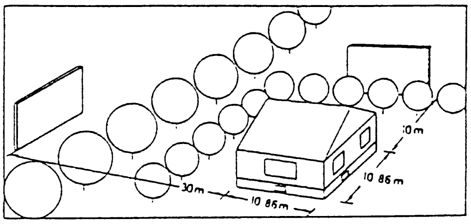


Figure 1a Detached single-family house area

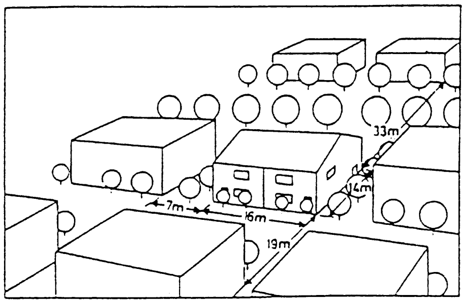


Figure 1b Semi-detached house area

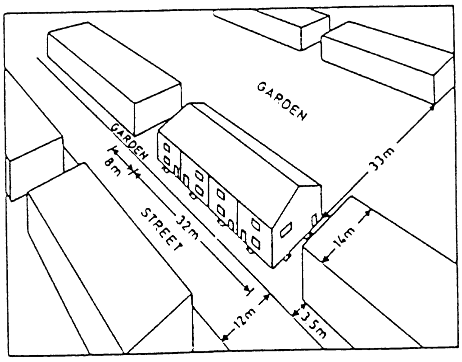


Figure 1c Terrace (row) house area

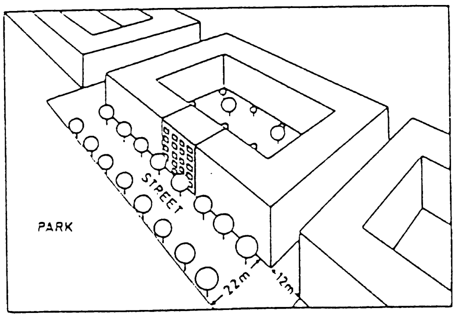


Figure 1d Multistorey building area

Figures 1a-1d. Four different housing environments, for which data sheets for decontamination have been worked out (illustrations published by Meckbach, Jacob and Paretzke, 1988).

However, a need was recognised for data on small detached houses both with bricked and with wooden outer walls, wherefore construction data modifications were made, and the dose rate data for the detached house (Fig 1a) therefore exist both for 3.8 cm wooden outer walls supported with gypsum and glass wool and for 11 cm brick walls supported with 11 cm thick breeze block layers.

The semi-detached house in two stories has a similar construction to the detached brick house, but has a slightly higher window fraction. However, the garden areas are much smaller here, as can be seen from Figures 1a and 1b.

The terrace house area is in many ways similar to the semi-detached house area. The house walls and window fractions are practically identical. The differences between the two environments in terms of average dose-conversion factors mainly illustrate that people living in the middle of the long terrace house are better shielded through internal walls. Further, the influence of road contamination was assumed to be negligible in the semi-detached housing environment, but becomes important in the terrace house environment, where relatively wide roads have been modelled close to the buildings.

The five-storey urban centre block of flats has very thick outer walls (30 cm brick). Further, the grassed areas are smaller, the road areas are increasingly important and some of the inhabitants are living high above the ground and are most of the time receiving a comparatively small dose rate contribution from the many contaminated ground level surfaces.

In all calculations it was assumed that the average person spends 85 % of the time indoors, that time equally spent on the different residential floors, and 15 % outdoors in gardens and on streets.

The input parameters in URGENT are, where possible, based on experimental results, mainly obtained after the Chernobyl accident.

The following dose-related information can be found in the data sheets presented in NKS/EKO-5 (96) 18, ref (1), for each method that has been considered for each contamination scenario. An example of such a data sheet (for vacuum sweeping of roads) is given later in this report.

All doses and dose rate contributions in these data sheets are given per 1 MBq/m^2 ^{137}Cs initially deposited on a grassed surface, so as to facilitate a scaling to the actual contamination levels.

The 'Immediate averaged total dose rate reduction in the area' is the percentage reduction of the total averaged dose rate level (to which there are contributions from different types of surface) which can be achieved immediately by implementing a countermeasure shortly after the contaminant deposition. The averaging is done with respect to the location of the people in the area.

The 'Averaged total accumulated lifetime dose reduction over 70 years' is an estimate of the percentage reduction achievable by a countermeasure of the total accumulated dose (total of dose contributions from different surfaces) to a person who stays in the area for 70 years. This is also averaged with respect to the location of the people in the area.

The 'Averaged total accumulated lifetime doses to people living in the area' are estimates of the location averaged total doses received by a person staying in the area for 70 years if no countermeasures were implemented to reduce the dose.

Other parameters given in the data sheets are almost exclusively based on knowledge obtained through experimental investigations. For each data sheet, references are given to relevant literature.

Based on the data sheets in NKS/EKO-5 (96) 18, ref (1), a compilation of information on countermeasures was generated, containing data and guidelines which are considered relevant when developing a check-list for the local planners. This list only includes those countermeasures which *must* be carried out in the early phase. They are:

- fire hosing of roads and pavements
- fire hosing of walls
- fire hosing of roofs
- lawn mowing
- pruning of trees and bushes
- snow removal
- vacuum sweeping of roads

However, it might in some cases be beneficial to apply methods which need not necessarily be initiated in the early phase. Such methods are included in the data sheets (ploughing, soil removal and triple digging).

In this context, the *early* countermeasures are thus considered to be the ones which would have significantly smaller or in some cases no effect if they were not carried out immediately.

Clean-up strategies

As indicated in the guidelines for the local planners, numerous aspects have to be considered. Clearly, it is important not only to consider the traditional cost-effective aspects of such an operation, but also to evaluate the local relevance, psychological impact and general acceptability of each suggested countermeasure.

It is also important to consider the order in which different strategical decontamination procedures in an area are carried out. Due to the risk of resuspension or translocation of contaminants, the most heavily contaminated surfaces should generally be treated first. However, also the orientation of the surfaces should be taken into account. A procedure such as water hosing of walls should for instance be carried out before treatment of the soil surfaces or pavements directly under below wall (although these may well have a much higher level of initial contamination), as such surfaces would inevitably receive some of the radioactive material which was removed from the wall.

When prioritising, the strategy planner should take into account that the doses stated in the data sheets are estimates for adults, and that doses received by children from contamination on horizontal surfaces are higher (by a factor of approximately 1,2 on a large field and more than that in areas of limited dimensions) as the target person comes closer to the source. According to the ICRP (ICRP 60), the probability of a fatal radiation induced cancer is higher for children (averaged over ages <10 years) than the average for adults (over 30 years of age) by a factor of about 2. Therefore, special efforts should be made to clean for instance schools, kindergartens, children's playgrounds and sandboxes particularly well.

Other special considerations need also to be made in the specific case. Although the data sheets are grouped in sections of methodologies which are thought to be particularly suitable for a special situation, such as a radiocaesium contamination by rain over an urban centre, there is still often a choice to be made between different methods to clean a surface, which all of them have their advantages depending on for instance different seasons (e.g., snow removal and pruning of trees) or the amount of time which passes before remedial action is initiated (e.g., lawn mowing and pruning of trees).

These five different environments could not only be regarded as five distinct options. Interpolations between the data for two or more of these environments could be made to evaluate for instance the situation in areas with buildings resembling one of the standard house types, but perhaps with slightly larger gardens, as modelled in another of the five standard environments. The main features and differences between the five standard environments are outlined in the section with the illustrations. Similar considerations can be made when reflecting upon other differences between the five different standard environments and the reality (NKS/EKO-5 (96) 18, Chap 3, ref (1)).

Indoor contamination

In the planners' guidelines, as well as in the data sheets in NKS/EKO-5 (96) 18, ref (1), only the dose contributions from contamination on outdoor surfaces have been considered. However, calculations have shown that, in some *dry* deposition scenarios, the contribution to doses from contamination on indoor surfaces may be highly significant, even when integrated over longer periods of time. If the ventilation rate and the deposition rate are high, the accumulated doses from indoor and outdoor contamination over the first year may in well-shielded houses be almost equal in magnitude. Further information on the influence of indoor contamination can be found in ref (1).

Waste produced by clean-up actions

Another important aspect of an implementation of decontamination methods is the generation of (mostly low level) radioactive waste, which must be treated and disposed of.

In connection to this, two things must be taken into consideration. The radioactive waste must be handled and transported to a final disposal site. This will in some cases give additional doses to the workers, possibly also by inhalation and redistribution of radioactive matter to skin or clothings. The other consideration which must be made is the location and design of the disposal site and in some cases preprocessing of the waste.

The solid radioactive waste generated from operations such as the removal of contaminated top soil and vegetation could be very large in quantity, since large areas would often require treatment. Reduction of the waste volume would clearly be advantageous, but the methods which have been suggested so far are too expensive and do not have a large scale potential (e.g., electrokinetic migration and soil washing, as described in ref (9).

The disposal of solid waste could take place in large, specially constructed centralised trenches, but it would often be an advantage to choose a disposal site in the vicinity of the decontaminated area to avoid labour-intensive, extensive and costly large scale waste transportations.

Such a disposal site could be constructed by landfilling, where the radioactive waste is buried in a shallow ground repository. The current legislative directives issued by the CEC regarding landfill procedures are stated in ref (10). An alternative (where practicable) to this is landraising, where the waste is not placed in an excavation, but above the ground, for instance between two natural hills. In both cases, one is trying to find the ideal situation where the radioactive waste can be retained permanently (which is impracticable in reality), or as long as possible, within the disposal trench, and slow down any further dispersion to the environment so as to allow the waste to decay radioactively and keep any ground water leaching on an acceptable level.

Probably the most problematic gamma emitting isotopes from a nuclear facility accident are the radiocaesium isotopes, as they emit both gamma and beta radiation and have relatively long half-lives, which in the case of ^{137}Cs is comparable to the duration of a human life. Luckily, the migration rate of caesium in practically all soils is exceedingly slow. This is due to the strong, selective fixation of caesium ions, at so-called frayed edges, by the interlayer spacing in the most common 3-layer soil micas. This fixation mechanism retains the caesium ions, even in the presence of excessive amounts of similar, competitive cations, such as potassium and ammonium.

For containment of other, more easily migrating ions in the radioactive waste, stabilisation and cement solidification processes for the radioactive soil have been envisaged, ref (11).

Clearly, a landfilling for permanent storage of radioactive waste requires careful consideration in the construction phase. A detailed practical example of how it might be carried out is given in ref (9), where radioactive soil waste from a removal of a contaminated layer of top soil was buried in a specially constructed disposal trench with ditches on the sides so as to collect run-off water from the arched trench-top and avoid groundwater contamination.

Examples of landfilling and landraising operations are also illustrated in ref (12).

In some cases it is possible (though perhaps not desirable) to collect liquid radioactive waste, for example from wash-off procedures, instead of leading it to the sewers. In such cases, a rather simple filtering of the liquid would remove by far the largest part of a radiocaesium contamination from the liquid and concentrate it in a small solid fraction, as these ions will attach to practically any surface (in the liquid: for instance small grains of sand or small fragments of construction materials or algae loosened by using an abrasive method).

For instance, the 'liquid' waste from a water hosing of a roof could be collected in the roof gutter and lead through a down pipe into a large vessel, where it could be filtered so that the liquid fraction would be clean of contamination while the solid phase in the liquid would be caught in the filter. Here it is important to have a large filter surface, wherefore sand might be a possibility, although other filter designs might be considered, ref (1).

Regarding disposal of very large amounts of contaminated water in the form of snow masses, which are difficult to clean, one possibility would be to dump the snow into the ocean, where the resulting increase in radionuclide concentration will often be negligible.

An example of a data sheet

(extract from NKS/EKO-5 (96) 18, ref (1))

Region: Suburban or urban
House type: Terrace-house
Weather conditions at deposition: Wet
Surface type: Roads and pavements

***Clean-up action**:* Vacuum sweeping (Literature 1, 4)
Municipal vacuum sweepers are currently being used in most urban and suburban areas in the Nordic countries for routine street cleaning. Similar devices were used by the authorities in Kiev to clean the streets after the Chernobyl accident. The seated vacuum sweeper has a water nozzle which sprays a fine mist of water (for dust control) onto the road before 3 typical rotating brushes sweep the road. Finally, a vacuum attachment collects the loosened dust in a vessel behind the operator.

Expected effect: Immediate averaged total dose rate reduction in the area by some 14 % by application in the early phase. Averaged total accumulated lifetime dose reduction over 70 years by 1.5-2.5 %. The road paving areas in the scenario contribute about 21 % of the dose rate in the early phase - or in other terms: 1.3 µGy/d per 1 MBq/m^2 of ^{137}Cs deposited to a lawn. The averaged total accumulated lifetime dose to people living in the area would amount to ca. 37 mGy per 1MBq/m^2 initially deposited to a lawn if no action were taken. The relative dose contribution from pavings to people who spend much time on the paved areas could be up to 4 times higher.

Personnel requirements and costs: The procedure should be carried out by the local municipal road sweepers and personnel who know the equipment. The inhalation hazard to the workers would be very low due to the water application. It is estimated that the procedure could be carried out at a speed as high as ca. $4 \cdot 10^{-5}$ man-days per treated m^2. Overheads are estimated to 100 % of the manpower costs.

Equipment / other requirements and costs: The required equipment is a vacuum sweeping street cleaning machine (price: ca. 90000 ECU). The equipment would often be available and ready to use, locally within the Nordic countries. Further, about 0.1 m^3 water per hour would be used, plus 5-6 l of petrol per hour.

Practicability: The procedure could be carried out at large scale in many inhabited areas.

Waste - amounts and costs: Wastes (amount normally in the order of 100-200 g/m^2 with a concentration in the order of 5000 Bq/m^3 per Bq/m^2) are collected in the vehicle's vessel, which is later emptied into a waste transport truck. The costs for transportation and final storage of waste at a repository at a distance of less than 20 km are estimated to be in the order of 30 ECU/ha.

Further remarks: Special care should be taken to proper cleaning of road gutters, as washed-off material from the rest of the road may accumulate here. Further, if radiation levels are high, the radioactive material collected in the waste vessel of the vacuum sweeping vehicle may give a significant dose to the operator.

Rural living environments

The scope of this work is limited to early clean-up actions with the aim to reduce doses from external radiation. Actions aimed at reducing uptake in agricultural products and food will for that reason not be treated. If there is a deposition of radioactivity in an agricultural area, the production of corn and milk will probably cease for a period. It is reasonable to belive that a great part of the live-stock would be kept indoors, and fed with non-contaminated fodder. For that reason, early clean-up actions might be needed for the purpose of reducing dose rates in residential houses and in live-stock buildings, making it possible for people to stay in the area and take care of the live-stock. Relevant actions are hosing of roofs and walls, removal of the top soil or asphalt in the vicinity of the buildings, mowing and the removal of grass and snow. Like for the urban environments, it is necessary to do generalised and simplified assumptions to perform calculations.

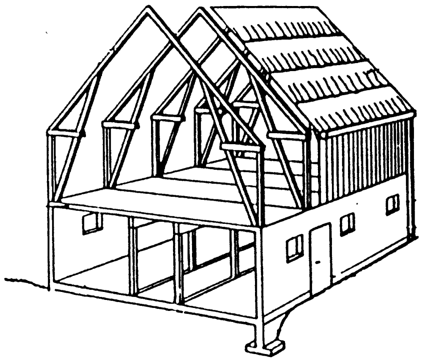
By contrast with urban environments, the recommended early clean-up actions in most cases can be performed by the inhabitants themselves, using their own equipment and machinary, normally used in the ordinary work.

Unlike urban environments, houses and buildings are situated relatively isolated and have in the calculations been treated as situated alone on a plane, infinite fallout area, with a reference deposition of 1 MBq/m² and a mean energy of 1 MeV. This is somewhat higher than the ^{137}Cs energy of 0,66 MeV, but the difference is not critical, since the ratio between indoor and outdoor dose rate varies very slowly with gamma energy at these levels.

The radiation level (measured as dose rate) inside a building comes from direct incoming gamma radiation and from gamma radiation that are scattered into the building from surrounding walls, roof and air. It is dependent on the dimensions of the building, the thickness and material of the walls and the relation between the windows and doors area compared to the total wall area.

The relation between the dose rate inside and outside a building can be expressed as a shielding factor, where a lower factor represents a better radiation shielding effect than a higher one. For livestock buildings in Sweden, calculations have been made on typical shielding factors. The calculations were performed by using KVAST, a code developed by FOA, based on an american civil preparedness code concerning shelter design and analysis. Comparisons between calculated values and measured values in dwellings in the area of Gävle after the Chernobyl accident show a good correspondence. The measurements were performed by FOA during the period June - October 1986, ref (13). Calculated values for agricultural buildings can be expected to be at least in the same good correspondance with real values, due to the fact that the geometry of these buildings is often more simple than the one of the dwelling houses.

The calculations of the live-stock buildings are made for high and low buildings, fig 2a and 2b. The low buildings and the lower part of the high buildings have been calculated with thin, moderate and thick walls respectively. More detailes about the buildings are given in the reference below. The calculations give shielding factors for different types of livestock buildings within the range of 0,18 - 0,71. An inventory shows that in the parts of Sweden where the main part of the livestock is managed, the buildings are characterized by radiation shielding factors of 0,3 - 0,4; ref (14).



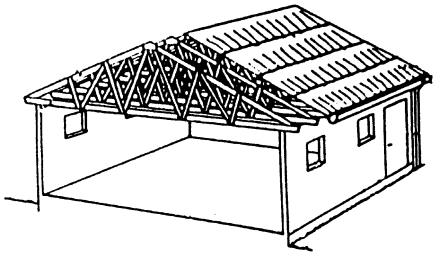


Figure 2 a High live stock building **Figure 2 b** Low live stock building

Calculations were also made on estimated effects as reduction of dose rate inside the buildings following clean-up of roofs or the surrounding ground. For roofs, the dose rate inside the buildings has been calculated for no clean-up and for clean-up taking away the washed down activity surrounding the building. For buildings with moderate wall thickness, the dose rate will decrease by about 40 % and for high buildings by about 20 %. In practice, the reduction will be less, due to the fact that in the calculations, all of the activity on the roof is taken away, which will not be possible in reality.

By taking away the top soil, cutting the grass or removing contaminated snow, one can reduce the radiation level inside the house. However, large areas have to be cleaned, generating hundreds of cubicmeters of waste requiring disposal. For most buildings the radius of the surrounding area to be cleaned has to be 15 - 30 times the width of the building to achieve a 50 % reduction in dose rate inside.

For the type of one family houses, common in rural areas, the shielding factors are typically in the range of 0,17 - 0,65; ref (13,15), and if the results of the calculations for the livestock buildings can be accepted as applicable on dwelling-houses the following rough estimation of clean-up effects can be made.

1 MBq/m² of ^{137}Cs as a plane, infinite source gives a dose rate of about 2,5 µSv/hour free in air, ref (4). Suppose that a person stays 8 hours in house, 8 hours in the livestock building and 8 hours outdoors every day and that the shielding factors are 0,4 for both buildings; that person will receive 0,75 mSv during the first three weeks. If clean-up actions are performed on day four after deposition, giving a 50% reduction in dose rate, the accumulated dose for three weeks will be 0,45 mSv and if the actions are performed on day ten, the accumulated dose will be 0,52 mSv.

If there are short-lived nuclides as ^{131}I in the fallout, and supposing that the dose rate from ^{131}I initially is three times that from ^{137}Cs, the accumulated dose for the first three weeks will be 1,8 mSv. If actions are taken on day four, the dose will be 1,1 mSv and if the actions are taken on day ten the accumulated dose will be 1,3 mSv.

Guidelines for urban environments

The main purpose of this report is to be a guide in ordinary preparedness planning. It can also serve as a guide in a real fallout situation. This intended use makes it necessary to keep the report in a very generalised form. The data, results and discussions in this report and in NKS/EKO-5 (96) 18 have been summarised in a set of guidelines for the selected urban environments and clean-up actions. These guidelines are presented as tables, one for each clean-up procedure. The various residential environments show the expected reduction in life time dose, staffing and costs, equipment and costs, practicability and waste, protection and influences on other procedures. The guidelines are given in Appendix 4.

For each specific clean-up action, the calculated reduction in life time dose is independent of other actions. This means that if more than one early clean-up action is performed, the expected reductions in life time dose can be added together.

The planner has knowledge about the regional state of things. These can for example include urban environments in the region, entrepreneurs, available equipment, important objects for clean-up actions, suitable areas for waste dumping and other things. This regional knowledge, combined with the general guidelines of this report, will hopefully constitute a base from which it is possible to make a plan for early clean-up actions.

It must be stressed that all values given in the guidelines are estimations coming from calculations with generalised and simplified assumptions. They can not be considered as true values, but show the order of magnitude for that specific effect and are therefore useful in comparisons between different actions and effects.

The tables show specific factors for the different cases to be considered and planned. Not mentioned in the tables are general things which always have to be considered or performed, such as information and the closely related psychological effects. Actions taken by the society or by the inhabitants themselves, together with relevant information, will in most cases be beneficial to people’s confidence. In a plan for clean-up actions, it is therefore very important to prepare the information about:

- why the action is performed
- how it will or must be done
- what will be the benefit of the action
- when it will or must be performed
- what can be said about restrictions

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Appendix 1

References

1) Andersson, Kasper G.1996. Evaluation of early phase nuclear accident clean-up procedures for Nordic residential areas. NKS/EKO-5 (96) 18.

2) Devell, Lennart.1996. Saneringsåtgärder i Norden - Aktuella radionuklider. Studsvik Eco & Safety AB. NKS/EKO-5 (96) 20.

3) Meckbach, R., P. Jacob and H.G. Paretzke.1988. Gamma exposures due to radionuclides deposited in urban environments. 1. Kerma rates from contaminated urban surfaces. Radiat. Prot. Dosim., 25:3, 167 - 179.

4) Svensson, Leif.1979. Dose conversion factors for external photon radiation. FOA Report C 40060-A3.

5) Finck, Robert et al.1980. Konsekvenser och åtgärder vid stora utsläpp av radioaktiva ämnen från svenska kärnkraftverk under beredskap och krig. FOA rapport A 40032-A3.

6) SSI 86-12: Chernobyl - its impact on Sweden.

7) Edvarson, Kay.1989.External Irradiation from the Chernobyl Fallout over Sweden. SSI 89-17.

8) Studsvik/ NS-91/19.

9) Clean-up of Large Radioactive-Contaminated Areas and Disposal of Generated Waste.1994. Ed. Jukka Lehto. Final report of the KAN2 project, Nordic Council of Ministers, TemaNord 1994:567.

10) CEC.1991. Proposal for a council directive on the landfill of waste. COM (91) 102 Final, SYN335, Brussels.

11) Brodersen, K.1993. Cement solidification of soil and interactions between cement and radioactive contaminated soil, Risø-I-721(EN), Risø National Laboratory, Denmark.

12) Little, R.H., C. Torres, D. Charles, H.A. Grogan, I. Simon, G.M. Smith, T.J. Summerling and B.M. Watkin.1993. Post-disposal safety assessment of toxic and radioactive waste: waste types, disposal practices, disposal criteria, assessment methods and post-disposal impacts, CEC Report EUR 14627 EN.

13) Finck, Robert.1991. Shielding factors for gamma radiation. *In* The Chernobyl Fallout in Sweden, Ed. Leif Moberg., SSI, Stockholm.

14) Andersson, Inger, Thomas Ulvsand, Johan Hansson och Carl-Magnus Dolby.1993. Byggnader för animalieproduktion. FOA rapport C 40306-A3.

15) Danielson, Göran.1984. Svenska Bostadshus. FOA rapport C 20546-A3.

16) French, S., R Finck, R.P. Hämäläinen, E. Naadland, J Roed, A .Salo, K Sinkko. Nordic Decision Conference: An Exercise on Clean-up Actions in an Urban Environment after a Nuclear Accident. STUK-A132.

Appendix 2

Documents produced

ES-96/26: Lennart Devell, Anders Appelgren, Studsvik EcoSafe: Planning of early cleanup after fallout of radioactive material - Prestudy (English and swedish version).

NKS/EKO-5 (96) 18: Kasper G Andersson: Evaluation of early phase nuclear accident clean-up procedures for Nordic residential areas.

NKS/EKO-5 (96) 19: Årsrapport 1996 för EKO-5.

Appendix 3

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Appendix 4

Guidelines for urban environments

Fire hosing of roads and pavements, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Terrace houses	2 - 8 % reduction in life time dose (70 year) For an estimated life time dose of 42 mSv this will give a reduction of 1 - 3 mSv. Contribution after 10 years is negli-gable	Fire brigade Civil defense units Approx. 1 man-day per 1000 m²	Hosing equipment Water supplies (250 m³/1000 m²) (Tank trucks) Fire boats	Instructions how to handle the flush water (into the drain system rather than to leave it into the road gutters)	Water resistant protective clot-hing Radiological considerations	Hosing of roofs and walls must be performed before this action
Multi-storey blocks	3 -12 % reduction in life time dose (70 year) For an estimated life time dose of 33 mSv this will give a reduction of 1 - 4 mSv Contribution after 10 years is negli-gable	Same as above	Same as above	Same as above	Same as above	Same as above

Remarks. For details see NKS/EKO-5 (96) 18, page 70 and 84.

Fire hosing of roofs, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Detached, wooden	3 - 7 % reduction in life time dose (70 year) For an estimated life time dose of 186 mSv this will give a reduction of 6 - 13 mSv.	House owner Fire brigade Civil defense units (Note the security considerations concerning working on roofs) Specialists in working on roofs 4 man-days/1000 m²	Hosing equipment Water supplies High pressure equipment Sky lifts Ladders Security equipment	Filtering must be performed if the down-pipes are not connected to the sewer. (Filters can be sand, rock wool or textiles) Special procedures for control, handling and storage of the filter materials The gutters must be hosed carefully	Water resistant protective clothing Radiological considerations	Must be performed before hosing of walls and roads If the water comes to the ground without being filtered, the top layer around the down-pipes must be removed
Detached, brick	5 - 11 % reduction in life time dose (70 year) For an estimated life time dose of 121 mSv this will give a reduction of 6 - 13 mSv.	Same as above	Same as above	Same as above	Same as above	Same as above

Fire hosing of roofs, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Semi-detached	6 - 13 % reduction in life time dose (70 year) For an estimated life time dose of 70 mSv this will give a reduction of 4 - 9 mSv.	Same as above	Same as above	Same as above	Same as above	Same as above
Terrace houses	3 - 9 % reduction in life time dose (70 year) For an estimated life time dose of 42 mSv this will give a reduction of 1 - 4 mSv.	Fire brigade Civil defense units House owners (Note the security considerations concerning working on roofs) Specialists in working on roofs 4 man-days/1000 m²	Hosing equipment Water supplies High pressure equipment Sky lifts Ladders Sequrity equipment	Same as above	Same as above	Same as above

Remarks: For details see NKS/EKO-5 (96) 18, page 32, 44, 56 and 68.

The dose reduction is shown for surfaces where the radioactivity can be hosed off effectively . For other surfaces, the life time dose reduction will be less. The hosing must be done very carefully, even if the surface of the roof appears to be smooth. Caesium contamination will be located in micro-pores rather than in visible cavities.

Fire hosing of walls, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Detached, wooden	8 % reduction in life time dose (70 year) For an estimated life time dose of 186 mSv this will give a reduction of 15 mSv.	House owner Fire brigade Civil defense units 1 man-day/1000 m^2	High pressure equipment Hosing equipment Water supplies Ladders	Hose from top to bottom of the wall Not covered soil surrounding the house must be removed and other areas must be cleaned after hosing the walls	Water resistant protective clothing Radiological considerations	Should be performed after hosing of the roof, but before treatment of the ground
Detached, brick	4 % reduction in life time dose (70 year) For an estimated life time dose of 121 mSv this will give a reduction of 5 mSv.	Same as above	Same as above	Same as above	Same as above	Same as above
Semi-detached	1 - 2 % reduction in life time dose (70 year) For an estimated life time dose of 70 mSv this will give a reduction of 1 mSv.	Same as above	Same as above	Same as above	Same as above	Same as above

Fire hosing of walls, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Terrace houses	2 % reduction in life time dose (70 year) For an estimated life time dose of 42 mSv this will give a reduction of 1 mSv.	Fire brigade Civil defense units House owner 1 man-day/1000 m²	Hosing equip-ment Water supplies High pressure equipment Sky lifts Scaffolds Ladders	Same as above	Same as above	Same as above
Multi-storey blocks	3 % reduction in life time dose (70 year) For an estimated life time dose of 33 mSv this will give a reduction of 1 mSv.	Fire brigade Civil defense units 1 man-day/1000 m²	Hosing equip-ment Water supplies High pressure equipment Sky lifts Scaffolds	Same as above	Same as above	Same as above

Remarks. For details see NKS/EKO-5 (96) 18, page 31, 43, 55, 67 and 82.

The hosing must be done very carefully, even if the surface of the walls appears to be smooth. Caesium contamination will be located in micro-pores rather than in visible cavities.

Vacuum sweeping of roads and pavements, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Terrace houses	2 - 8 % reduction in life time dose (70 year) For an estimated life time dose of 42 mSv this will give a reduction of 1 - 3 mSv.	Vacuum road sweeper personnel 4 man-days / 100 000 m²	Vacuum road sweeper	At least 7 m³ waste will be produced per 100 000 m², depending on time of the year. It can be considerably more The waste must be considered as low activity waste and must be treated and stored in accordance with relevant regulations	5000 MBq/m³ of waste in the tank. This can give a dose to the driver of about 0,5 mSv during a 8 hour working period Consider also doses to other involved personnel	After house cleaning efforts, if possible
Multi-storey blocks	2 - 12 % reduction in life time dose (70 year) For an estimated life time dose of 33 mSv this will give a reduction of 1 - 4 mSv.	Same as above	Same as above	Same as above	Same as above	Same as above

Remarks: For details see NKS/EKO-5 (96) 18, page 69 and 83.

The activity and doses given in the table are based on a ground deposition of 1 MBq/m².

Fire hosing of roads and pavements, wet deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Terrace houses	2 - 8 % reduction in life time dose (70 year) For an estimated life time dose of 37 mSv this will give a reduction of 1 - 3 mSv. Contribution after 10 years is negligable	Fire brigade Civil defense units Approx. 1 man-day per 1000 m²	Hosing equipment Water supplies (250 m³/1000 m²) (Tank trucks) Fire boats	Instructions how to handle the flush water (into the drain system rather than to leave it into the road gutters)	Water resistant protective clothing Radiological considerations	Hosing of roofs and walls must be performed before the action
Multi-storey block	5 -20 % reduction in life time dose (70 year) For an estimated life time dose of 29 mSv this will give a reduction of 2 - 6 mSv Contribution after 10 years is negligable	Same as above	Same as above	Same as above	Same as above	Same as above

Remarks. For details see NKS/EKO-5 (96) 18, page 76 and 90.

Fire hosing of roofs, wet deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Detached, wooden	3 - 7 % reduction in life time dose (70 year) For an estimated life time dose of 170 mSv this will give a reduction of 5 - 12 mSv.	House owner Fire brigade Civil defense units (Note the security considerations about working on roofs) Specialists in working on roofs 4 man-days/1000 m^2	Hosing equipment Water supplies High pressure equipment Sky lifts Ladders Sequrity equipment	Filtering must be performed if the down-pipes not are connected to the sewer. (Filters can be sand, rock wool or textiles) Special procedures for control, handling and storage of the filter materials The gutters must be hosed carefully	Water resistant protective clothing Radiological considerations	Must be perfor-med before hosing of walls and roads If the water comes to the ground without being filtered, the top layer around the down-pipes must be removed
Detached, brick	5 - 11 % reduc-tion in life time dose (70 year) For an estimated life time dose of 111 mSv this will give a reduction of 5 - 12 mSv.	Same as above	Same as above	Same as above	Same as above	Same as above

Fire hosing of roofs, wet deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Semi-detached	5 - 11% reduction in life time dose (70 year) For an estimated life time dose of <u>64 mSv</u> this will give a reduction of 3 - 7 mSv.	Same as above	Same as above	Same as above	Same as above	Same as above
Terrace houses	2 - 5 % reduction in life time dose (70 year) For an estimated life time dose of <u>37 mSv</u> this will give a reduction of 1 - 2 mSv.	Fire brigade Civil defense units House owners (Note the security considerations concerning working on roofs) specialists in working on roofs 4 man-days/1000 m²	Hosing equipment Water supplies High pressure equipment Sky lifts Ladders sequrity equipment	Same as above	Same as above	Same as above

Remarks: For details see NKS/EKO-5 (96) 18, page 37, 49, 61 and 74.

The dose reduction on the surfaces where the radioactivity can be hosed off effectively . For other surfaces, the life time dose reduction will be less. The hosing must be done very carefully, even if the surface of the roof appears to be smooth. Caesium contamination will be located in micro-pores rather than in visible cavities.

Vacuum sweeping of roads and pavements, wet deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Terrace houses	2 - 10 % reduction in life time dose (70 year) For an estimated life time dose of 37 mSv this will give a reduction of 2 - 4 mSv.	Vacuum road sweeper personnel 4 man-days / 100 000 m²	Vacuum road sweeper	At least 7 m³ waste will be produced per 100 000 m². depending of time of the year. It can be considerably more The waste must be considered as low activity waste and must be treated and stored in accordance with relevant regulations	5000 MBq/m³ of waste in the tank. This can give a dose to the driver of about 0,5 mSv during a 8 hour working period Consider also doses to other involved personnel	After house cleaning efforts, if possible
Multi-storey blocks	5 - 24 % reduction in life time dose (70 year) For an estimated life time dose of 29 mSv this will give a reduction of 1 - 7 mSv.	Same as above	Same as above	Same as above	Same as above	Same as above

Remarks: For details see NKS/EKO-5 (96) 18, page 75 and 89.

The activity and doses given in the table are based on a ground deposition of 1 MBq/m².

Lawn mowing, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Detached, woo-den	60 % reduction in life time dose (70 year) For an estimated life time dose of 186 mSv this gives a reduction of 112 mSv	House owner for the mowing Organised teams in some cases Centralised transportation and deposition 0.2 man-day per 1000 m²	Lawn mowers, prefe-rably with a collector Not all types will do, the grass must be collected Trucks for the trans-portation	The grasscut must be put into plastic bags and placed where it can easily be collected. Modern mowers that fragmentise the grass must not be used (the crasscut can not be collected) The waste must be col-lected as soon as possible and taken to a central deposition site The waste must be consi-dered as low activity waste and handled and stored in accordance to relevant regulations.	Clothes covering the whole body, gloves, boots Consider the doses to people when cutting, transporting and handling at the deposition site	Lawn mowing should be the first of the actions taken
Detached, brick	55 % reduction in life time dose (70 year) For an estimated life time dose of 121 mSv this gives 66 mSv	Same as above	Same as above	Same as above	Same as above	Same as above

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Semi-detached	68 % reduction in life time dose (70 year) For an estimated life time dose of <u>70</u> mSv this gives a reduction of 48 mSv	House owner for the mowing Organised teams in some cases Centralised transportation and deposition 0.2 man-day per 1000 m²	Lawn mowers, prefe-rably with a collector Not all types will do, the grass must be collected Trucks for the trans-portation Ordinary garbage transport trucks can in many cases be suitable	Same as above	Same as above	Same as above
Terrace houses	65 % reduction in life time dose(70 year) For an estimated life time dose of 42 mSv this gives a reduction of 26 mSv	Local inhabitants, entrepreneurs or other organised teams, supported by the society Centralised transportation and deposition 0.2 man-day per 1000 m²	Lawn mowers, prefe-rable with a collector Not all types will do, the grass must be collected Trucks for the trans-portation	The grasscut must be collected and transported to a deposition site as soon as possible. Modern mowers that fragmentise the grass must not be used (the crasscut can not be collected) The waste must be consi-dered as low activity waste and handled and stored in accordance with relevant regulations.	Same as above	Same as above
Multi-storey blocks	69 % reduction in life time dose (70 year) For an estimated life time dose of 33 mSv this gives 23 mSv	Same as above	Same as above	Same as above	Same as above	Same as above

Remarks: For details see NKS/EKO-5 (96) 18, page 29, 41, 53, 65 and 80.

Pruning of trees and bushes, felling trees. Dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Detached, woo-den	9 - 18 % reduction in life time dose (70 year) For an estimated life time dose of 186 mSv this gives a reduction of 17 - 34 mSv	Local inhabitants and authorised teams, organised and supported by the society 1- 8 man-days per 500 m²	Chain saws Axes Cutters Ropes Ladders Sky lifts Chippers (see next column) Special trucks for transportation	The waste comprises of stems, big and small branches and leaves. Before deposition it should be chipped. The waste must be consi-dered as low activity waste and stored in accordance with relevant regulations.	Protective clot-hes and masks should be worn by the workers. Consider doses to personnel when felling, pruning, chip-ping and trans-portation	If it is possible that this action should be performed after the mowing of the lawn in order to save doses to the workers.
Detached, brick	10 - 20 % reduction in life time dose (70 year) For an estimated life time dose of 121 mSv this gives a reduction of 12 - 24 mSv	Same as above	Same as above	Same as above	Same as above	Same as above

Pruning of trees and bushes, felling trees. Dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Semi-detached	7 - 14 % reduction in life time dose (70 year) For an estimated life time dose of 70 mSv this gives a reduction of 5- 10 mSv	Local inhabitants and authorised teams, organised and supported by the society 1- 8 man-days per 500 m²	chain saws Axes Cutters Ropes Ladders Sky lifts Chippers (see next column) Special trucks for transportation	Same as above	Same as above	Same as above
Terrace houses	6 - 12 % reduction in life time dose (70 year) For an estimated life time dose of 42 mSv this gives a reduction of 3- 5 mSv	Same as above	Same as above	Same as above	Same as above	Same as above
Multi-storey blocks	4 - 8 % reduction in life time dose (70 year) For an estimated life time dose of 33 mSv this gives a reduction of 1- 2 mSv	Organised teams supported by the society 1 - 8 man-days per 500 m²	Wood harvesters Chain saws, axes Sky lifts, ladders Chippers Special trucks for transportation	Same as above	Same as above	Same as above

Remarks: For details see NKS/EKO-5 (96) 18, page 30, 42, 54, 66 and 81.

Pruning and felling of trees (ruining gardens and parks) will probably have negative psychological effects. Aggressive actions will enhance peoples feelings of the severeness of the accident. The severe loss of aesthetic values must be considered.

Removal of snow, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Detached, woo-den	66 - 71 % reduc-tion in life time dose (70 year) For an estimated life time dose of 186 mSv this gives a reduction of 123 - 132 mSv	House owner if the garden is not too big. Organised teams, local entrepeneurs and municipal workers 0.1 - 1 man-day per 1000 m²	Bobcats tractors with snowblades Frontloaders Spades, shovels Snow transport trucks	It can be a problem to take the machi-nery into the gar-dens 200 - 400 m³ of snow, containing about 1000 MBq, has to be transpor-ted and deposited per 1000 m² garden Normally used snow deposition sites can probably not be used (they will be too small and the melting water must be controlled)	General dose recommen-dations for the workers	Removal of snow from roofs, if any, should be carried out before the removal in the gardens
Detached, brick	64 - 70% reduc-tion in life time dose (70 year) For an estimated life time dose of 121 mSv this gives a reduction of 77 - 85 mSv	Same as above	Same as above	Same as above	Same as above	Same as above

Removal of snow, dry deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Semi-detached	80 % reduction in life time dose (70 year) An estimated life time dose of 70 mSv gives a reduction of 56 mSv	Same as above	Same as above	Same as above	Same as above	Same as above
Terrace houses	81 % reduction in life time dose For an estimated life time dose of 42 mSv this gives a reduction of 34 mSv	Organised teams, local entrepeneurs and municipal workers 0.1 - 1 man-day per 1000 m²	Bobcats Tractors with snowblades Frontloaders Spades, shovels Snow transport trucks	Same as above	Same as above	Same as above
Multi-storey blocks	83 % reduction in life time dose For an estimated life time dose of 33 mSv this gives a reduction of 27 mSv	Same as above	Same as above	Same as above	Same as above	Same as above

For detailes: see NKS/EKO-5 (96) 18, page 28, 40, 52, 64 and 79.

Pruning of trees and bushes, felling trees. Wet deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Detached, wooden	1 - 2 % reduction in life time dose (70 year) For an estimated life time dose of 170 mSv this gives a reduction of 2 - 3 mSv	Local inhabitants and authorised teams, organised and supported by the society 1- 8 man-days per 500 m²	Chain saws Axes Cutters Ropes Ladders Sky lifts Chippers (see next column) Special trucks for transportation	The waste comprises of stems, big and small branches and leaves. Before deposition it should be chipped. The waste must be considered as low activity waste and stored in accordance to relevant regulations.	Protective clothes and masks should be worn by the workers. Consider doses to personnel when felling, pruning, chipping and transportation	If it is possible this action should be performed after mowing the lawn in order to minimize doses to the workers.
Detached, brick	1 - 2 % reduction in life time dose (70 year) For an estimated life time dose of 111 mSv this gives a reduction of 1 - 2 mSv	Same as above	Same as above	Same as above	Same as above	Same as above
Semi-detached	1 - 2 % reduction in life time dose (70 year) For an estimated life time dose of 64 mSv this gives a reduction of 1 mSv	Local inhabitants and authorised teams, organised and supported by the society 1- 8 man-days per 500 m²	Chain saws Axes Cutters Ropes Ladders Sky lifts Chippers (see next column) Special trucks for transportation	Same as above	Same as above	Same as above

Remarks: For details see NKS/EKO-5 (96) 18, page 36, 48 and 60.

The pruning and felling of trees (ruining gardens and parks) will probably have negative psychological effects. Aggressive actions will enhance peoples feelings of the severeness of the accident. The severe loss of aesthetic values must be considered.

Removal of snow, wet deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Detached, woo-den	88 - 90 % reduc-tion in life time dose (70 year) For an estimated life time dose of <u>170</u> mSv this gives a reduction of 150 - 153 mSv	House owner if the garden is not too big. Organised teams, local entrepeneurs and municipal workers 0.1 - 1 man-day per 1000 m²	Bobcats Tractors with snowblades Frontloaders Spades, shovels Snow transport trucks	It can be a problem to take the machi-nery into the gar-dens 200 - 400 m³ of snow, containing about 1000 MBq, has to be transpor-ted and deposited per 1000 m² garden Normally used snow deposition sites can probably not be used (they will be too small and the melting water must be controlled)	General dose recommen-dations for the workers.	Removal of snow from roofs, if any, should be carried out before the removal in the gardens.
Detached, brick	81 - 86 % reduc-tion in life time dose (70 year) For an estimated life time dose of <u>111</u> mSv this gives a reduction of 90 - 95 mSv	Same as above	Same as above	Same as above	Same as above	Same as above

Removal of snow, wet deposition

House type	Expected effects	Staffing and costs	Equipment and costs	Practicability, waste	Protection	Influences on other procedures
Semi-detached	88 % reduction in life time dose (70 year) For an estimated life time dose of 64 mSv this gives a reduction of 56 mSv	Same as above	Same as above	Same as above	Same as above	Same as above
Terrace houses	87 % reduction in life time dose For an estimated life time dose of 37 mSv this gives a reduction of 32 mSv	Organised teams, local entrepeneurs and municipal workers 0.1 - 1 man-day per 1000 m²	Bobcats Tractors with snowblades Frontloaders Spades, shovels Snow transport trucks	Same as above	Same as above	Same as above
Multi-storey blocks	89 % reduction in life time dose For an estimated life time dose of 29 mSv this gives a reduction of 25 mSv	Same as above	Same as above	Same as above	Same as above	Same as above

For details: see NKS/EKO-5 (96) 18, page 35, 47, 59, 73 and 88.