Probabilistic Accident Consequence Uncertainty Analysis

A Joint Report Prepared by U.S. Nuclear Regulatory Commission and Commission of European Communities

NUREG/CR-6526, Vol. 2

Uncertainty Assessment for Deposited Material and External Doses

Volume 2 Appendices

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Abstract

The development of two new probabilistic accident consequence codes, MACCS and COSYMA, was completed in 1990. These codes estimate the risks presented by nuclear installations based on postulated frequencies and magnitudes of potential accidents. In 1991, the US Nuclear Regulatory Commission (NRC) and the European Commission (EC) began a joint uncertainty analysis of the two codes. The ultimate objective was to develop credible and traceable uncertainty distributions for the input variables of the codes.

The study was formulated jointly and was limited to the current code models and to physical quantities that could be measured in experiments. An elicitation procedure was devised from previous US and EC studies with refinements based on recent experience. Elicitation questions were developed, tested, and clarified. Internationally recognized experts were selected using a common set of criteria. Probability training exercises were conducted to establish ground rules and set the initial and boundary conditions. Experts developed their distributions independently.

After the first feasibility study on atmospheric dispersion and deposition parameters, a second expert judgment exercise was carried out on food chain and external dose (calculation) parameters. This report refers only to the external dose part of the study. The work relating to food chains is described in a companion report. The goal again was to develop a library of uncertainty distributions for the selected consequence parameters. Following this work, a panel of ten experts on deposited material and related doses was chosen. They represent nine countries and the results of their assessments are presented here. Their results were processed with an equal-weighting aggregation method, and the aggregated distributions were processed into the code input variables of the external dose models in COSYMA and for MACCS.

Further expert judgment studies are being undertaken to examine the uncertainty in other aspects of probabilistic accident consequence codes. Finally, the uncertainties will be propagated through the codes and the uncertainty in the code predictions will be quantified.

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Contents

Preface vii

Acknowledgments ix

List of Acronyms xi

Appendix A. Summary of the MACCS and COSYMA Consequence Codes A-1

Appendix B. Structure Document and Elicitation Questionnaire for the Expert Panel on Deposited Material and External Doses B-1

Appendix C. Rationales and Responses of the Expert Panel on Deposited Material and External Doses C-1
- Expert A C-3
- Expert B C-37
- Expert C C-73
- Expert D C-109
- Expert E C-147
- Expert F C-181
- Expert G C-213
- Expert H C-243
- Expert I C-275
- Expert J C-303

Appendix D. Short Biographies of the Deposited Material Experts D-1

Appendix E. Aggregated Results of the Expert Responses E-1

Preface

This volume is the second of a two-volume document that summarizes a joint project conducted by the US Nuclear Regulatory Commission and the European Commission to assess uncertainties in the MACCS and COSYMA probabilistic accident consequence codes. These codes were developed primarily for estimating the risks presented by nuclear reactors based on postulated frequencies and magnitudes of potential accidents. This document reports on an ongoing project to assess uncertainty in the MACCS and COSYMA calculations for the offsite consequences of radionuclide releases by hypothetical nuclear power plant accidents. A panel of ten experts was formed to compile credible and traceable uncertainty distributions for the deposited material and external dose code input variables that affect calculations of offsite consequences. The expert judgment elicitation procedure and its outcomes are described in these volumes. Other panels were formed to consider uncertainty in other aspects of the codes. Their results are described in companion reports.

Volume 1 contains background information and a complete description of the joint consequence uncertainty study along with a summary of the results of this aspect of the study. Volume 2 contains appendices that include (1) a summary of the MACCS and COSYMA consequence codes, (2) the elicitation questionnaires and case structures, (3) the rationales and results for the panel on deposited material and external doses, (4) short biographies of the experts, and (5) the aggregated results of their responses.

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The authors would like to acknowledge all the participants in the expert judgment election process, in particular the expert panel on deposited material and external doses. While we organized the process, processed the results, and wrote and edited the report, the experts provided the technical content that is the foundation of this report. Dr. Detlof von Winterfeldt is acknowledged for his contribution as elicitor in several expert sessions. We would also like to express our thanks for the support and fruitful remarks of Dr. G. N. Kelly (EC/DG XII).

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On January 22, 1996, Peter Roelofsen, manager of the risk analysis group at the Netherlands Energy Research Foundation (ECN), died after a long period of illness. Peter prepared the first discussion documents for the early health effects expert panel, and provided valuable comments on early versions of the documents on deposited materials and related doses. He will be missed by the project staff, and in particular by the staff at ECN.

List of Acronyms

ACA	accident consequence analysis
CDF	cumulative distribution function
COSYMA	code system from MARIA (method for assessing the radiological impact of accidents)
DF	dose conversion factor
EC	European Commission
LHS	Latin hypercube sampling
MACCS	MELCOR accident consequence code system
NRC	Nuclear Regulatory Commission
TIAC	time-integrated air concentration

APPENDIX A

Summary of the MACCS and COSYMA Consequence Codes

Summary of the MACCS and COSYMA Consequence Codes

Introduction

The information developed in this study will be used to perform uncertainty studies using the European Commission (EC) consequence code COSYMA and the US Nuclear Regulatory Commission (USNRC) code MACCS. COSYMA and MACCS model the offsite consequences of postulated severe reactor accidents that release a plume of radioactive material to the atmosphere. These codes model the transport and deposition of radioactive gases and aerosols into the environment and the potential resulting human health and economic consequences. They calculate the health effects, impact of countermeasures and economic costs of the releases. The processes considered in the calculations, and the routes of exposure following accidental releases to atmosphere, are illustrated in Figure A-1. The calculations are divided into a number of steps, illustrated in Figure A-2. COSYMA and MACCS are modular codes, with different modules addressing the different stages of the calculation. However, while Figure A-1 illustrates the steps in the calculation, the modules of the codes do not correspond exactly with the boxes shown.

The following sections give brief descriptions of the COSYMA and MACCS codes.

Brief Description of MACCS and COSYMA Dispersion and Deposition Models

COSYMA and MACCS both employ a Gaussian plume model (GPM) for atmospheric dispersion. At a given downwind distance and given atmospheric conditions, the Gaussian model predicts the time-integrated concentration at various horizontal and vertical displacements from the center-line of the plume. When the plume is not constrained by the ground or the inversion layer, the basic Gaussian plume equation for determining the concentration relative to the release rate is:

$$\frac{\chi}{Q} = \frac{1}{2\pi\sigma_y\sigma_z\bar{u}}\, exp\left(-\frac{y^2}{2\sigma_y^2}\right) exp\left(-\frac{(z-h)^2}{2\sigma_z^2}\right)$$

where:

χ = time integrated air concentration,
Q = the source strength,
y = the horizontal displacement relative to the plume centerline,
z = the vertical displacement,
h = the vertical height of the plume centerline,
$\bar{U}$ = the average wind velocity, and
σ_y and σ_z are plume expansion parameters.

In MACCS and COSYMA, the plume expansion parameters, σ_y and σ_z, are modeled by the following power law:

$$\sigma_y = a_y x^{b_y} \; ; \sigma_z = a_z x^{b_z}$$

where x = the downwind distance from the plume release point.

Currently, constant values for a_y, b_y and a_z, b_z are provided in the codes. The values for the parameters are determined by the atmospheric stability class and the roughness length of the terrain.

Two types of deposition are modeled in the MACCS and COSYMA codes: wet and dry. Dry deposition incorporates removal from the plume by diffusion, impaction, and settling; it is modeled through a dry deposition velocity, which is a user input. The dry deposition velocity depends on particle size; therefore, if the aerosol size distribution is divided into ranges, a dry deposition velocity must be specified for each range. The washout of radioactive material from the plume, wet deposition, is modeled as dependent on the rain intensity. The fraction of material, f_w, that remains in the plume is given by:

$$f_w = exp\left\{-a\, I^b\, \Delta t\right\}$$

where I is the rain intensity and Δt is the amount of time the plume is exposed to the rain. The parameters a and b are the user-specified parameters that determine the amount of material washed from the plume as a result of rain intensity. Rainout, in which droplets nucleate on the aerosol particles, is not modeled.

Summary of the MACCS Radiological Consequence Code

The MACCS code was originally developed under NRC sponsorship to estimate the offsite consequences of

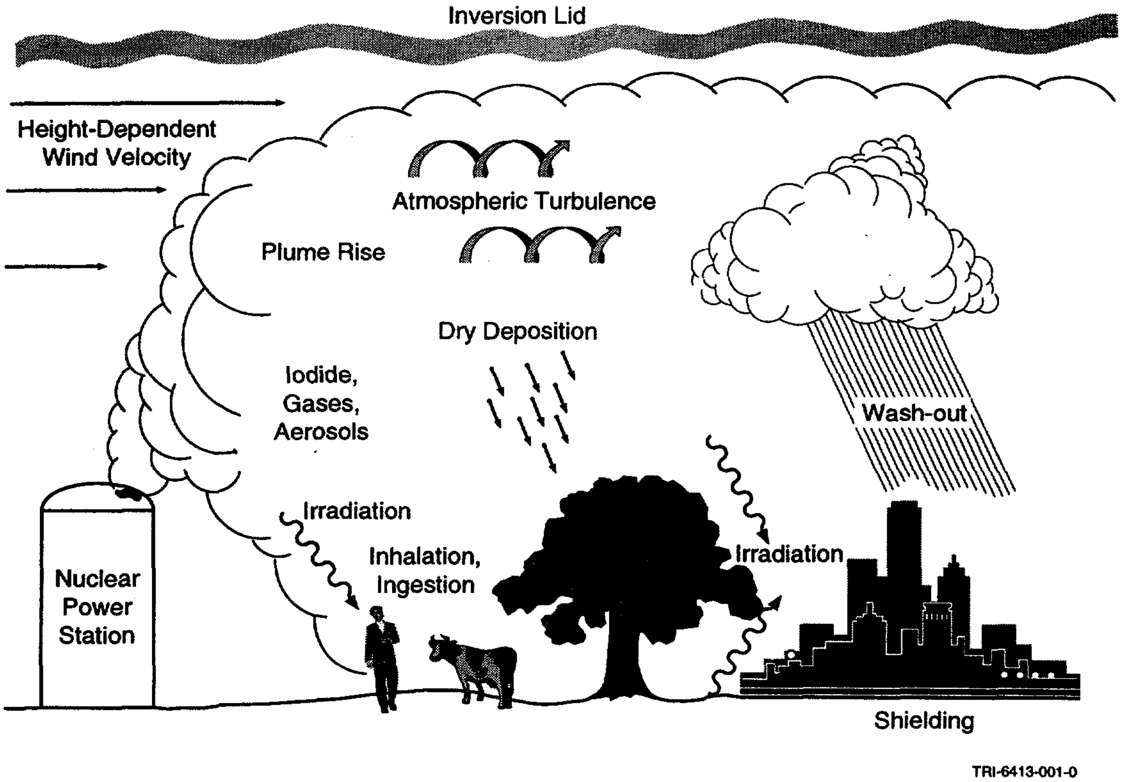

Figure A-1. Dispersion and deposition phenomena considered in an accident consequence analysis.

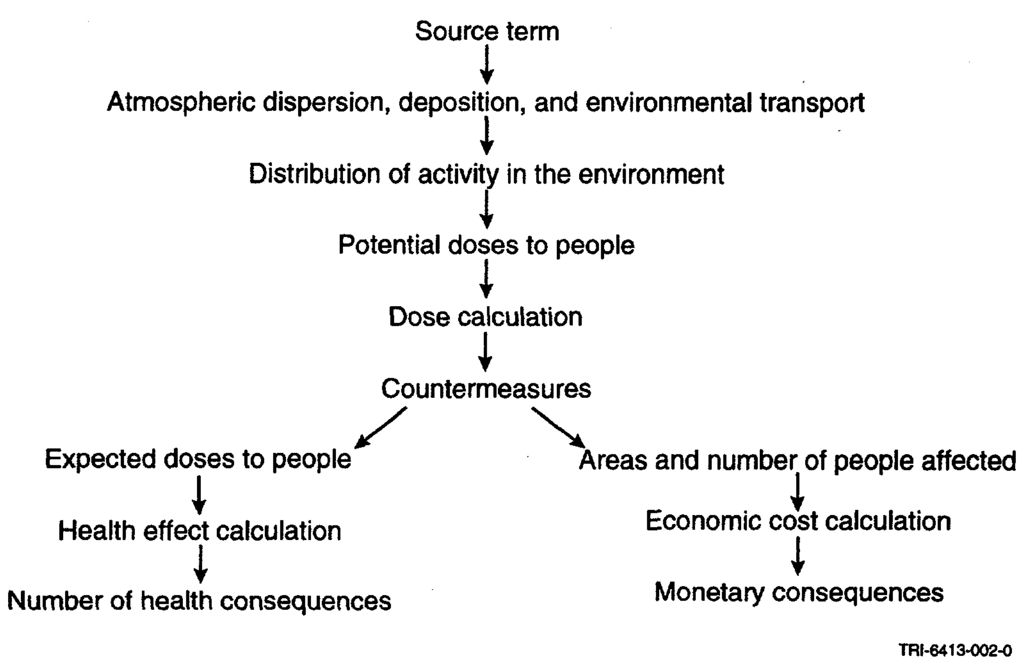

Figure A-2. Basic features and relationships of an accident consequence analysis.

potential severe accidents at nuclear power plants by using meteorological data that varies on an hourly basis. The code models the transport and dispersion of plumes of radioactive material released from the facility to the atmosphere. As the plumes travel through the atmosphere, material may be deposited on the ground via wet and dry deposition processes. There are seven pathways through which the general population can be exposed: cloudshine, groundshine, direct inhalation, resuspension inhalation, ingestion of contaminated food, ingestion of contaminated water, and deposition on skin. Emergency response and protective action guides for both the short and long term are also considered as means for mitigating the extent of the exposures. As a final step, the economic costs that would result from the mitigative actions are estimated. Variability in consequences as a result of weather may be obtained in the form of a complementary cumulative distribution function.

MACCS is organized into three modules. The ATMOS module performs the atmospheric transport and deposition portion of the calculation. The EARLY module estimates the consequences of the accident immediately following the incident (usually within the first week), and the CHRONC module estimates the long-term consequences of the accident. A schematic representation of these modules and the input files that provide information to them is shown in Figure A-3. The following sections describe the phenomena modeled in MACCS in more detail.

Atmospheric Dispersion and Transport

The release of radioactive materials to the atmosphere can be divided into successive plume segments, which can have different compositions, release times, durations, release heights, and amounts of sensible heats. The plume segment lengths are determined by the product of the segment's release duration and the average windspeed during release. The initial vertical and horizontal dimensions of each plume segment are user-specified.

A lift-off criterion based on a critical windspeed determines whether or not a plume is subject to buoyant plume rise. Momentum plume rise is not modeled. If the windspeed at release is greater than the critical windspeed, plume rise is prevented.

After release from the facility, windspeed determines the rates at which plume segments transport in the downwind direction, and the wind direction at the time of release determines the direction of travel. MACCS neglects wind trajectories, as do most other consequence codes. Sixteen compass-sector population distributions are assumed to constitute a representative set of downwind exposed populations. The exposure probability of each of the 16 compass-sector population distributions is assumed to be given by the frequency with which the wind blows from the site into the sector. During transport, dispersion of the plume in the vertical and horizontal directions is estimated using an empirical model, the GPM. In this model, dispersion depends on atmospheric stability and windspeed. Horizontal dispersion of the plume segments is unconstrained. However, vertical dispersion is bounded by the ground and by the mixing layer, which are both modeled as totally reflecting layers. A single value for the mixing layer is specified by the user for each season of the year and is constant during a calculation. Eventually the vertical distribution of each plume segment becomes uniform and is so modeled.

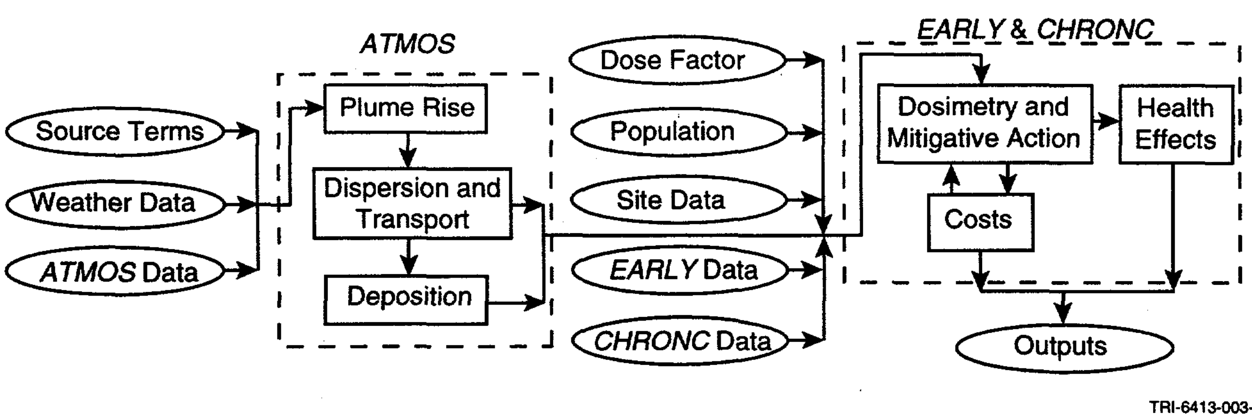

Figure A-3. Progression of a MACCS consequence calculation.

Deposition, Weathering, Resuspension, and Decay

As noted earlier, two types of deposition are modeled in MACCS: wet deposition and dry deposition. Weathering, resuspension, washoff, and radioactive decay decrease the deposited concentrations of radioactive materials. Radioactive decay treats only first generation daughter products.

Weather

Plume rise, dispersion, downwind transport, and deposition depend on the prevailing meteorological conditions. These conditions can be modeled as time-invariant or as varying hour-by-hour. If they are modeled as variable, the user may specify them directly or through an input file.

Dosimetry

The MACCS dosimetry model consists of three interacting processes: (1) the projection of individual exposures to radioactive contamination for each of the seven exposure pathways modeled over a user-specified time, (2) mitigation of these exposures by protective-measure actions, and (3) calculation of the actual exposures incurred after mitigation by protective-measure actions. For each exposure pathway, MACCS models the radiological burden for the pathway as reduced by the actions taken to mitigate that pathway dose. The total dose to an organ is obtained by summing the doses delivered by each of the individual pathways.

Dose Mitigation

The time after accident initiation is divided into three phases: (1) an emergency phase, (2) an optional intermediate phase, and (3) a long-term phase. During the emergency phase, which can last up to seven days, doses are reduced by evacuation, sheltering, and temporary relocation of people. During the intermediate phase, doses may be avoided by temporary relocation of people. During the long-term phase, doses are reduced by decontamination of property that is not habitable, by temporary interdiction of property that cannot be restored to habitability by decontamination alone, by condemnation of property that cannot be restored to habitability at a cost below or equal to the worth of the property, by disposal of contaminated crops, and by banning farming on contaminated farmland.

Exposure Pathways

MACCS models seven exposure pathways: (1) exposure to the passing plume (cloudshine), (2) exposure to materials deposited on the ground (groundshine), (3) exposure to materials deposited on skin, (4) inhalation of materials directly from the passing plume (inhalation), (5) inhalation of materials resuspended from the ground by natural and mechanical process (resuspension inhalation), (6) ingestion of contaminated foodstuffs (food ingestion), and (7) ingestion of contaminated water (water ingestion). Ingestion doses do not contribute to the doses calculated for the emergency phase of the accident. Only groundshine and inhalation of resuspended materials produce doses during the optional intermediate phase of the accident. Long-term doses are caused by groundshine, resuspension inhalation, water ingestion, and food ingestion. Ingestion of contaminated food or water generates doses to people who reside at unknown locations both on and off of the computational grid.

Population Cohorts

People on the computational grid are assigned to three groups: (1) evacuees, (2) people actively taking shelter, and (3) people who continue normal activities. Shielding factors for each of the groups are specified by the user.

Health Effects

Health effects are calculated from doses to specific organs using dose conversion factors. Early injuries and fatalities (those occurring within one year of the accident) are estimated using nonlinear dose-response models. Latent cancers are estimated using a piecewise linear dose-response model that is discontinuous. Two equations are implemented in the code, one for high exposures and one for low exposures.

Economic Effects

Economic consequences result from the implementation of mitigative actions. The following costs are considered in this estimate: (1) evacuation costs, (2) temporary relocation costs, (3) costs of decontaminating land and buildings, (4) lost return-on-investments from temporarily interdicted properties, (5) value of crops destroyed or not grown, and (6) value of condemned property. Costs associated with damage to the reactor, the purchase of replacement power, medical care, life-shortening, and litigation are not considered.

Summary of COSYMA Radiological Consequence Code

COSYMA was developed by the National Radiological Protection Board (NRPB) of the UK and Forschun–

gszentrum Karlsruhe (FZK) of Germany, as part of the European Commission's MARIA project (KfK and NPRB, 1991). It represents a fusion of ideas from the NRPB program MARC (Hill et al., 1988), the FZK program system UFOMOD (Ehrhardt et al., 1988) and input from other MARIA contractors. The program package was first made available in 1990 for use on mainframe computers, and several updates have been released since then. A PC version was first released in 1993 and has since been updated (Jones et al., 1995).

COSYMA is a system of programs and data bases, rather than a single program. The mainframe version contains three main accident consequence assessment programs together with a number of preprocessing and evaluation programs. The three main sub-systems of COSYMA are known as the NE, NL and FL sub-systems (Figure A-4). The NE (near, early) sub-system is limited to calculating early health effects and the influence of emergency actions to reduce those effects and applies to the region near the accident site. The NL (near, late) subsystem is limited to calculating late health effects and the associated countermeasures, and applies mainly to the region near the site. The FL (far, late) sub-system calculates late health effects and appropriate countermeasures at greater distances from the site. Each of these programs is subdivided into a series of modules for the various steps in the calculation. PC COSYMA incorporates the NE and NL sub-systems of the mainframe version.

The main endpoints of COSYMA are the numbers of health effects, the impact of countermeasures, and the economic costs resulting from the accidental release. A large number of intermediate results are obtained in the process of calculating the major endpoints; these results include activity concentrations, individual and collective doses, and the countermeasures assumed at different locations. COSYMA contains a series of evaluation programs that allow these results to be presented in a variety of ways.

Following an accidental release to atmosphere, people can be irradiated by a number of exposure paths. Those considered in COSYMA are cloudshine, groundshine, exposure to materials deposited on skin, direct inhalation of plume material, inhalation of resuspended materials, and ingestion of contaminated foods.

COSYMA includes some models directly within the various modules or subsidiary programs, such as atmospheric dispersion models. In other cases, COSYMA uses data libraries giving the results of other models which are not part of COSYMA itself, but whose uncertainty is considered within the current study.

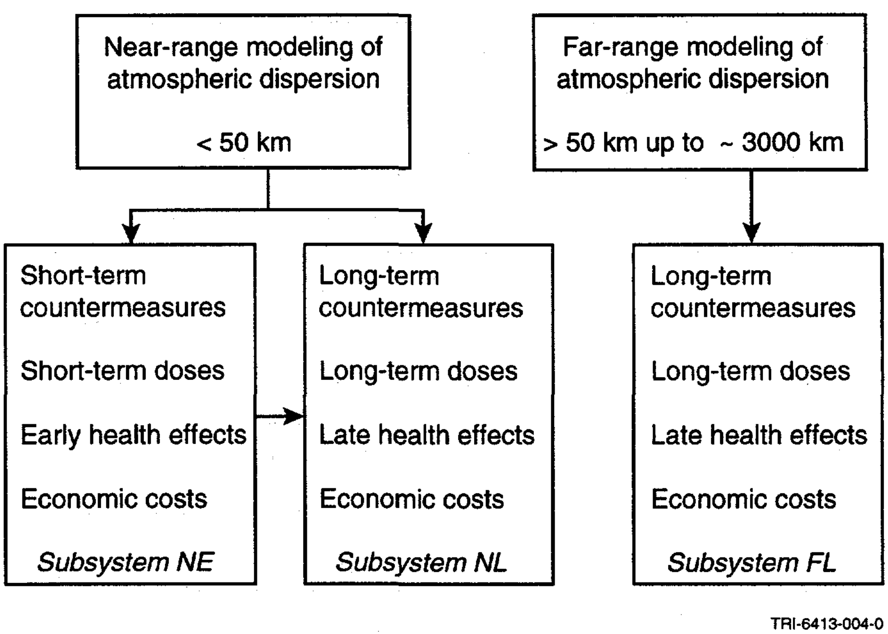

Figure A-4. General structure of the COSYMA program system.

Atmospheric dispersion and deposition

Mainframe COSYMA contains five different models of atmospheric dispersion that are appropriate for different applications or are based on different assumptions and approximations (Panitz et al., 1989).

The NE and NL sub-system include the MUSEMET (Straka et al., 1981) model, originally written at Forschungsanlage Julich and extensively modified at FZK for use with COSYMA. This is a segmented Gaussian plume model allowing for changes of atmospheric conditions and wind direction during plume travel. This model derives the sequences of atmospheric conditions affecting the plume from hourly averages for wind speed and direction, stability category, precipitation intensity and mixing layer depth. It allows for the effects on the subsequent dispersion of plume rise and buildings near the release point. It also includes the effects of wet and dry deposition of the dispersing material. This model is also included in PC COSYMA.

The NE and NL sub-systems can also be used with the COSGAP or RIMPUFF dispersion models, which are provided as separate programs. COSGAP (Jones and Charles, 1982) is a Gaussian plume dispersion model, which is similar to MUSEMET but does not consider changes of wind direction during plume travel. It is based on the dispersion model in MARC. RIMPUFF (Mikkelsen et al., 1984), developed by Risø National Laboratory, Denmark, is a Gaussian puff trajectory model which derives the atmospheric conditions affecting the plume by interpolating between data from a number of meteorological stations in the region of interest.

The NL sub-system also contains the ISOLA (Hübschmann and Raskob) model for very long release durations. This uses statistics of atmospheric conditions and is only appropriate for releases that are sufficiently small that no countermeasures and no early health effects would be expected.

The FL sub-system is linked to the Mesos model (ApSimon and Goddard, 1983), developed by Imperial College, UK. This is a trajectory model for dispersion over long distances using meteorological data for a large area, such as the whole of Europe.

Accident consequence assessment programs need to consider that the accident could occur in any of a wide range of atmospheric conditions. It is not possible to calculate the consequences for every sequence of conditions that might arise, so a method of sampling a representative set of conditions from those possible is needed. Both the mainframe and PC versions of COSYMA include a flexible program to conduct this sampling.

Dose calculations

As stated earlier, COSYMA does not include dosimetric models but uses information from data libraries which are calculated with these models. The libraries include information on doses from 197 nuclides.

The data library used for calculating external exposure from activity deposited on the ground contains outdoor doses per unit deposit for a series of times. These doses are mitigated by location factors describing the reduction in exposure due to shielding by buildings. The library is drawn from a number of sources, using results of models developed at NRPB (Charles et al., 1982; Crick and Brown, 1990) and Forschungszentrum für Umwelt und Gesundheit (GSF) (Jacob et al., 1988), Germany. The doses for major contributing nuclides in a fission reactor accident are derived from a model describing the deposition patterns in urban areas and the subsequent transfer of material between the different surfaces.

The doses from internal irradiation following ingestion or inhalation are calculated using data libraries of dose per unit intake derived using models which are consistent with those in International Commission on Radiological Protection (ICRP) publications 56, 67 and 69 (ICRP, 1990, 1994, 1995). COSYMA requires information on the dose received during different periods after the accident, which is included in the data libraries. Because the method used for calculating doses and risks of health effects in the mainframe version of COSYMA allows for the variation of dose per unit intake with age at intake, the libraries contain information on doses for different age groups in the population. The PC version, however, uses a simpler method which only considers the doses to adults.

Food chain models

COSYMA requires information on the concentration of material in foods as a function of time after the accident. It does not include a food chain model, but uses the results of such models through data libraries which give concentrations for a range of radionuclides in a number of foods at a series of times following unit deposition. The concentration of material in foods depends on the time of year at which the deposition occurs. COSYMA uses two data libraries for deposition in summer and in winter.

COSYMA uses libraries derived from the NRPB model FARMLAND (Brown and Simmonds, 1995) and the GSF model ECOSYS (Matthies et al., 1982). The libraries were created using accepted values for the food chain parameters for application within the EC, but differences exist because of other modeling assumptions made and because of the foods considered in each. The foods which can be considered with FARMLAND are: milk; meat and liver from cattle; pork; meat and liver from sheep; green vegetables; grain products; and potatoes and other root vegetables. The foods which can be considered with ECOSYS are: milk; beef; pork; grain products; potatoes and other root vegetables; and leafy and non-leafy green vegetables.

The intakes of these foods are calculated within COSYMA using one of two assumptions about the distribution of food between harvest and consumption. One method assumes that all food consumed is produced locally, and is used in calculating individual ingestion doses. The other method uses information on the amount of food produced in the area of interest, and calculates collective doses on the assumption that all food produced is consumed somewhere.

Countermeasures

COSYMA allows the user to consider the effects of a wide range of countermeasures in reducing the exposure of the population, and gives the user considerable freedom in specifying the criteria at which the actions will be imposed or withdrawn (Hasemann and Ehrhardt, 1994).

Sheltering alone or combined with evacuation may be implemented automatically or on the basis of dose. The distribution of iodine tablets, automatically or on the basis of dose, can also be considered. These actions are assumed to be implemented sufficiently rapidly to reduce the risks of both early and late health effects. Relocation is considered as an action to reduce doses and risks over longer time periods. It can be implemented on a dose criterion, as can return from evacuation or relocation. The effects of decontamination in reducing the period of relocation can be considered. If these actions are initiated on the basis of dose, the user can specify the intervention levels, organs and pathways to be considered, and the time over which the dose is to be integrated. The behavior of the population considered in the dose criteria can also be described using location factors.

Food bans can also be considered (Steinhauer, 1992). They can be implemented or withdrawn on the basis of doses received within specified time periods or on the basis of the instantaneous concentration of radionuclides in foods.

Health effects

COSYMA considers both early and late health effects in the population, using methods recommended by NRPB (Edwards, pers. comm; NPRB, 1993), the USNRC (Evans et al., 1990) and GSF (Paretzke et al., 1991).

The risk of early health effects is calculated using "hazard functions". The method allows for the variation of risk with the rate at which dose is accumulated over the first few days following the accident. Ten different fatal and non-fatal effects are considered.

The risk of late health effects is calculated using the linear dose response relationship. COSYMA considers the risk of fatal and non-fatal cancers in ten organs, as well as the risk of leukemia. It also considers the risk of hereditary effects. The method adopted in the mainframe version of COSYMA allows for the variation of risk with age at exposure (Ehrhardt et al., 1995). PC COSYMA uses a simpler method which only considers the doses and risks to adults. The mainframe version of COSYMA can provide information on the numbers of cancers in the people alive at the time of the accident, and in their descendants. It also gives information on the times at which the cancers occur.

Economic effects

COSYMA can calculate the off-site economic effects of the accident, considering the costs arising from the countermeasures and the costs of health effects. The assumptions and models are described in Haywood et al. (1991) and Faude (1992). The countermeasures for which costs are considered are movement of the population, food restrictions, and decontamination. The costs arising from lost production in the area from which people are moved can be assessed in terms of the per capita contribution of the relocated population to gross domestic product (GDP) or in terms of the value of the land affected. For longer periods of relocation, the lost capital value of the land and its assets may be calculated. The costs of food bans include contributions to GDP as well as the lost capital value and the disposal costs of the food affected. The cost arising from health effects may be calculated in terms of the treatment costs and the lost economic productivity of the affected individuals, or an estimation of the cost of health effects may be obtained using a more subjective approach to the valuation of life.

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APPENDIX B

Structure Document and Elicitation Questionnaire for the Expert Panel on Deposited Material and External Doses

ELICITATION QUESTIONS

Structure Document and Elicitation Questionnaire for the Expert Panel on Deposited Material and External Doses

EC/USNRC Joint Project on
Uncertainty Analysis of Consequence Assessment Programs

Jacqui Boardman
AEA Consultancy Services, UK

Parameters Chosen

It was not only considered important to choose those parameters for elicitation which are potentially measurable but also to choose those which would be of most use to PCA codes in the future. Model-specific parameters have therefore been avoided as much as possible and the following parameter list is suggested for consideration:

External Gamma Doses:

- Absorbed dose-rate in air at 1m above a uniform, flat and open lawned area at several times following initial deposition of 1 Bq/m^2 of ^{95}Zr/^{95}ZNb, ^{106}Ru/^{106}Rh, ^{131}I and ^{137}Cs/^{137m}Ba to the ground. Average deposition conditions together with both dry and wet deposition mechanisms are considered separately;
- Effective dose-rate and Effective Dose to an adult outdoors in "typical" urban and rural (open field) environments, at several times following initial deposition of 1 Bq/m^2 of ^{95}Zr/^{95}ZNb, ^{106}Ru/^{106}Rh, ^{131}I and ^{137}Cs/^{137m}Ba to the lawned areas of the ground;
- Ratio of adult external dose indoors to that received outdoors in an open lawned area shortly after an initial deposition of 1 Bq/m^2 to the ground (lawns) of ^{95}Zr/^{95}ZNb, ^{106}Ru/^{106}Rh, ^{131}I and ^{137}Cs/^{137m}Ba for several locations within buildings of various levels of shielding;
- Ratio of adult external dose inside a vehicle to the outdoor dose in an open lawned area following initial deposition of 1 Bq/m^2 to the ground of ^{95}Zr/^{95}ZNb, ^{106}Ru/^{106}Rh, ^{131}I and ^{137}Cs/^{137m}Ba for a "typical" car and bus;

Indoor Inhalation Doses:

- Ratio of time integrated air concentration indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for ^{240}Pu (particulate, representative of $\approx 10\ \mu m$), ^{137}Cs (particulate, representative of $\approx 1\ \mu m$) and ^{131}I (gaseous, forms I_2 and CH_3I) for two situations (i) doors or windows normally open for ventilation and (ii) all doors and windows closed;

Behavioral Parameters:

- Fraction of an average population in expert's own country that would be classed as (i) agricultural and other outdoor workers, (ii) indoor workers, (iii) non-active adult population and (iv) schoolchildren;
- Fraction of time each population group, (i) to (iv) above, spend indoors in various types of housing and in cars/buses, considering both a typical urban environment and a representative rural area (open fields);
- Fraction of time an "average" member of the population in the expert's own country spends indoors in various types of housing and in cars/buses;

Format of the Questions

For each of the above parameters an explicit question has been derived and tables are given on the attached pages for each expert to complete. There is only a total of 13 Questions to answer although the tables span quite a few pages. These questions will be handed out at the expert training meeting to be held in January 1995, but the experts are not expected to complete the questionnaire at that point. They will be given time to consider their responses and will be free to use whatever models or tools that they feel appropriate to answer the questions. They are encouraged, however, to write down all assumptions made and methods used during this process, together with a clear statement of all the uncertainties they have considered in the assessments (in the so-called **rationale**). The actual elicitation sessions will be carried out some weeks later during a private meeting between the expert and up to two analysts, one specializing in probability assessment and the other in the specific aspect of consequence modeling under consideration.

The tables provide a standardized format on which to elicit the information required, but as much additional information should be provided by the expert in their rationale as possible. It is assumed that the expert will have completed this questionnaire and finalized their rationale **prior to the elicitation session**. The elicitation session will then be used to discuss the detailed assumptions behind the expert's individual assessments, in order to help the probability and consequence analysts fully understand the rationale. In addition, the expert may feel that during the discussions some other issues have been raised which they had not previously considered. The elicitation session would then provide the opportunity to modify any of their assessments in the light of these new issues. At the end of the elicitation session it is intended that the assessment will be final and the results can then be taken away for further processing by the probability analyst. All assessments will be kept anonymous; hence the name of the expert will not be related to the answers to each of the questions below in any of the publicly available documentation.

This document will be provided on floppy disk, in WordPerfect 5.2 for Windows format, and can be edited by the experts as an alternative way of completing the questionnaire. It is requested that, if possible, the rationale document should be provided on disk by the expert, as well as a hard copy which will be used for discussion during the elicitation session.

General Issues

As discussed in the "Case Structure Document", it is important to remember that the uncertainties of interest in this study are those relating to possible variations in the "average values" of the elicitation parameters, and not uncertainties defined by the possible range of the particular parameter for single individuals in the population or for single environments.

Correlations between the uncertainties expressed for several parameters, within the same question or between questions, may obviously exist, and where possible questions have been derived to illustrate the experts opinions on these correlations. Any other correlations which are not explicitly discussed, but which are considered important to note, should be stated in the **rationale** provided by the expert during the elicitation sessions. In particular, it is important to identify those areas where the expert's assessments of the uncertainties between questions are identical.

Extreme events, such as snow or floods, should not be considered when assessing the likely ranges in the parameters below, and the variations should also be restricted to those typical of a warm temperate climate, for example North-Western Europe and North-Eastern/South-Eastern USA.

In answering the following questions it is assumed that no modification of the behavior of the population (either self-imposed or otherwise) will occur as a result of the accident, and hence sheltering or any other protective measures should not be considered in the assessment of uncertainties.

Finally, where the dose to an adult outdoors is being considered, it is assumed that the dose will be estimated for an idealized phantom which remains outdoors for the whole of the period of interest.

EXPERT: ______________________________

PROBABILITY ANALYST: ______________________________

CONSEQUENCE ANALYST: ______________________________

DATE/PLACE OF ELICITATION SESSION: ______________________________

Question 1

What is the gamma dose-rate (Gy s^{-1}) in air at 1m above a uniform, flat and open lawned area at the time of deposit and at several times following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95[1], Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground?

Note: Only the gamma dose from deposited material is being considered in this question, and the initial deposition is by dry deposition mechanisms only. The dose rate of interest is that observed on average over a variety of conditions, which will be used to estimate the collective dose to the population as a whole. The grass is assumed to be short/clipped prior to deposition and will not change with time.

Items not specified: weather conditions, soil type

Nuclide Zr-95

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
10 days			
30 days			
100 days			
1 year			

Nuclide Ru-106

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
30 days			
100 days			
1 year			
3 years			

Nuclide I-131

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
1 day			
3 days			
10 days			
30 days			
100 days			

1. Consider that 100% of the deposit at time 0 is Zr and model ingrowth. For the remainder of the pairs, the equilibrium assumption is adequate.

Nuclide Cs-137

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Please discuss the processes you have considered in making each of the estimates at each time step. In particular, state if you feel there are any correlations between the estimates you have given at each time or any correlations that exist between each nuclide, or between the answers you have given in questions 2 - 7:

Question 2

What is the gamma dose-rate (Gy s^{-1}) in air at 1m above a uniform, flat and open lawned area at the time of deposit and at several times following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground?

Note: Only the gamma dose from deposited material is being considered in this question, and the initial deposition is by wet deposition mechanisms only.. The dose rate of interest is that observed on average over a variety of conditions, which will be used to estimate the collective dose to the population as a whole. The grass is assumed to be short/clipped prior to deposition and will not change with time.

Items not specified: weather conditions, soil type

Nuclide Zr-95

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
10 days			
30 days			
100 days			
1 year			

Nuclide Ru-106

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
30 days			
100 days			
1 year			
3 years			

Nuclide I-131

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
1 day			
3 days			
10 days			
30 days			
100 days			

Nuclide Cs-137

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Please discuss the processes you have considered in making each of the estimates at each time step. In particular, state if you feel there are any correlations between the estimates you have given at each time or any correlations that exist between each nuclide, or between the answers you have given in questions 1 and 3 - 7:

Question 3

What is the gamma dose-rate (Gy s^{-1}) in air at 1m above a uniform, flat and open lawned area at the time of deposit and at several times following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground?

Note: Only the gamma dose from deposited material is being considered in this question, with average deposition conditions. The dose rate of interest is that observed on average over time which will be used to estimate the collective dose to the population as a whole. The grass is assumed to be short/clipped prior to deposition and will not change with time.

Items not specified: weather conditions, soil type, deposition mechanisms

Nuclide Zr-95

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
10 days			
30 days			
100 days			
1 year			

Nuclide Ru-106

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
30 days			
100 days			
1 year			
3 years			

Nuclide I-131

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
1 day			
3 days			
10 days			
30 days			
100 days			

Nuclide Cs-137

Dose-Rate (Gy s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Please discuss the processes you have considered in making each of the estimates at each time step. In particular, state if you feel there are any correlations between the estimates you have given at each time or any correlations that exist between each nuclide, or between the answers you have given in questions 1 and 2, or 4 - 7:

Question 4

What is the Effective Dose Rate (Sv s^{-1}) to an adult outdoors in a typical "urban" environment at the time of deposit and at several times following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground? and what is the Effective Dose in Sv integrated to each of those times? Additionally for Cs-137, what is the Effective Dose Rate and integrated Effective Dose in an average "rural" area, e.g., open fields? Please state how your basic assumptions differ, if at all, from those in question 1 for the open lawned area.

Note: The adult is assumed to be out of doors continuously during the period of interest, and only the external dose from deposited material is being considered in this question. The activity is deposited initially by dry deposition mechanisms. The dose rate of interest is that observed on average over time which will be used to estimate the collective dose to the population as a whole.

Items not specified: weather conditions, surface/soil types, proximity and type of buildings

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
10 days			
30 days			
100 days			
1 year			

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days			
30 days			
100 days			
1 year			

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
30 days			
100 days			
1 year			
3 years			

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days			
100 days			
1 year			
3 years			

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
1 day			
3 days			
10 days			
30 days			
100 days			

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day			
3 days			
10 days			
30 days			
100 days			

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Please discuss the processes you have considered in making each of the estimates at each time step. In particular, state if you feel there are any correlations between the estimates you have given at each time or any correlations that exist between each nuclide. Please state also how your basic assumptions differ, if at all, from those in question 1 for the open lawned area and if there are any correlations between the answers you have given here and in questions 1 - 3 or 5 - 7:

Question 5

What is the Effective Dose Rate (Sv s^{-1}) to an adult outdoors in a typical "urban" environment at the time of deposit and at several times following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground? and what is the Effective Dose in Sv integrated to each of those times? Additionally for Cs-137, what is the Effective Dose Rate and integrated Effective Dose in an average "rural" area, e.g., open field? Please state how your basic assumptions differ, if at all, from those in question 1 for the lawned area.

Note: The adult is assumed to be out of doors continuously during the period of interest, and only the external dose from deposited material is being considered in this question. The activity is deposited initially by wet deposition mechanisms. The dose rate of interest is that observed on average over time which will be used to estimate the collective dose to the population as a whole.

Items not specified: weather conditions, surface/soil types, proximity and type of buildings

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
10 days			
30 days			
100 days			
1 year			

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days			
30 days			
100 days			
1 year			

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
30 days			
100 days			
1 year			
3 years			

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days			
100 days			
1 year			
3 years			

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
1 day			
3 days			
10 days			
30 days			
100 days			

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day			
3 days			
10 days			
30 days			
100 days			

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Please discuss the processes you have considered in making each of the estimates at each time step. In particular, state if you feel there are any correlations between the estimates you have given at each time or any correlations that exist between each nuclide. Please state also how your basic assumptions differ, if at all, from those in question 1 for the open lawned area, and if there are any correlations between the answers you have given here and in questions 1 - 4 or 6 - 7:

Question 6

What is the Effective Dose Rate (Sv s^{-1}) to an adult outdoors in a typical "urban" environment at the time of deposit and at several times following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground? and what is the Effective Dose in Sv integrated to each of those times? Additionally for Cs-137, what is the Effective Dose Rate and integrated Effective Dose in an average "rural" area, e.g., an open field? Please state how your basic assumptions differ, if at all, from those in question 1 for the lawned area.

Note: The adult is assumed to be out of doors continuously during the period of interest. Only the gamma dose from deposited material is being considered in this question, with average deposition conditions. The dose rate of interest is that observed on average over time which will be used to estimate the collective dose to the population as a whole.

Items not specified: weather conditions, surface/soil types, proximity and type of buildings, deposition mechanisms

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
10 days			
30 days			
100 days			
1 year			

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days			
30 days			
100 days			
1 year			

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv s^{-1})	5th Quantile	Median	95th Quantile
Immediately after Deposition			
30 days			
100 days			
1 year			
3 years			

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days			
100 days			
1 year			
3 years			

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
1 day			
3 days			
10 days			
30 days			
100 days			

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day			
3 days			
10 days			
30 days			
100 days			

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult ($Sv\ s^{-1}$)	5th Quantile	Median	95th Quantile
Immediately after Deposition			
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months			
1 year			
3 years			
10 years			
30 years			
100 years			

Please discuss the processes you have considered in making each of the estimates at each time step. In particular, state if you feel there are any correlations between the estimates you have given at each time or any correlations that exist between each nuclide. Please state also how your basic assumptions differ, if at all, from those in question 1 for the open lawned area, and if there are any correlations between the answers you have given here and in questions 1-5:

Question 7

The following nuclides are of significance to the estimation of external dose and the consequences of accidental releases from commercial nuclear plants:

Ru-103/Ru-105, Cs-134/Cs-136, Ba-140, Te-131m/Te-132, I-132/133/134/135, Mo-99, Ce-144

In your opinion, are any of the processes that you have considered in answering the questions above, e.g., initial run-off, soil migration, long-term weathering etc., similar to those for any of these additional nuclides? If so, could you group particular nuclides together (by associating them with one of the original Zr, Ru, I or Cs isotopes) in order to help estimate the magnitude of the uncertainties involved in calculating external dose for these new nuclides? The question has been divided into two sections to allow alternative responses for an urban environment and an open lawned area.

Note: Only the External Dose from Deposited Material is Being Considered in this Question
Any General Comments Should Be Included in The Rationale.

Open Lawned Area

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Cs-137 / Ru-106 / I-131 / Zr-95	
Cs-134/Cs-136	Cs-137 / Ru-106 / I-131 / Zr-95	
Ba-140	Cs-137 / Ru-106 / I-131 / Zr-95	
Te-131m/Te-132	Cs-137 / Ru-106 / I-131 / Zr-95	
I-132/I-133/ I-134/I-135	Cs-137 / Ru-106 / I-131 / Zr-95	
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	
Ce-144	Cs-137 / Ru-106 / I-131 / Zr-95	

Urban Environment

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Cs-137 / Ru-106 / I-131 / Zr-95	
Cs-134/Cs-136	Cs-137 / Ru-106 / I-131 / Zr-95	
Ba-140	Cs-137 / Ru-106 / I-131 / Zr-95	
Te-131m/Te-132	Cs-137 / Ru-106 / I-131 / Zr-95	
I-132/I-133/ I-134/I-135	Cs-137 / Ru-106 / I-131 / Zr-95	
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	
Ce-144	Cs-137 / Ru-106 / I-131 / Zr-95	

Question 8

What is the ratio of the Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m^2 of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground (lawn)? This ratio is often called the location factor.

Please provide a separate answer for each of the following locations of the individual:

(i) inside a low shielding building, e.g., a wooden framed house

(ii) inside a medium shielding building, e.g., a typical brick family house

(iii) inside a high shielding building, e.g., a tall multi-story building

(iv) inside the basement of a single family house

(v) in the basement of a multi-story building

(vi) in a typical car on a suburban street

(vii) in a typical bus on a suburban street

Note: Only the External Gamma Dose from Deposited Material is Being Considered in this Question

Not Specified: Locations within building, characteristics of the buildings (e.g., mass per unit area of walls, numbers and locations of windows etc.), deposition mechanisms or relative deposition distributions for the various surfaces (including internal surfaces).

In particular please discuss in your rationale if any correlations exist between the location factors for each of the nuclides under consideration or between values for particular locations or building types.

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Question 9

Do you feel strongly that the location factor is time dependent? If so, state the reasons why and suggest what your alternative answers to question 8 would be at 1 and 10 years after the initial deposit using the tables below. If your values at 1 and 10 years are simply scaled using a constant factor for each nuclide then please just quote that factor. i.e., ANSWER EITHER PART A or B below:

Part A: Constant Factors to modify Location Factors given above in Question 8, for 1 and 10 years after initial deposition.

1 YEAR After Initial Deposition	Scaling Factor to Modify Initial Location Factors				
Nuclide:	Zr- 95	Ru-106	I-131	Cs-137	Ce-144
(i) low shielding building					
(ii) medium shielding building					
(iii) high shielding building					
(iv) basement family house					
(v) basement of multi-story block					
(vi) inside typical car					
(vii) inside typical bus					

10 YEARS After Initial Deposition	Scaling Factor to Modify Initial Location Factors				
Nuclide:	Zr- 95	Ru-106	I-131	Cs-137	Ce-144
(i) low shielding building					
(ii) medium shielding building					
(iii) high shielding building					
(iv) basement family house					
(v) basement of multi-story block					
(vi) inside typical car					
(vii) inside typical bus					

Part B: Location Factors for 1 and 10 Years following Initial Deposition (Please ignore if you have already answered Part A)

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building						
(ii) medium shielding building						
(iii) high shielding building						
(iv) basement family house						
(v) basement of multi-story block						
(vi) inside typical car						
(vii) inside typical bus						

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building						
(ii) medium shielding building						
(iii) high shielding building						
(iv) basement family house						
(v) basement of multi-story block						
(vi) inside typical car						
(vii) inside typical bus						

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building						
(ii) medium shielding building						
(iii) high shielding building						
(iv) basement family house						
(v) basement of multi-story block						
(vi) inside typical car						
(vii) inside typical bus						

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building						
(ii) medium shielding building						
(iii) high shielding building						
(iv) basement family house						
(v) basement of multi-story block						
(vi) inside typical car						
(vii) inside typical bus						

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building						
(ii) medium shielding building						
(iii) high shielding building						
(iv) basement family house						
(v) basement of multi-story block						
(vi) inside typical car						
(vii) inside typical bus						

Question 10

How would the estimates of the location factors you have given in answer to Question 8 for the urban environment differ if the deposition had occurred as a result of dry or wet deposition mechanisms only?

Please discuss in the rationale and include alternative predictions if possible:

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building			
(ii) medium shielding building			
(iii) high shielding building			
(iv) basement family house			
(v) basement of multi-story block			
(vi) inside typical car			
(vii) inside typical bus			

Question 11

What is the ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 µm), Cs-137 (particulate, representative of ≈ 1 µm) and I-131 (gaseous, forms I_2 and CH_3I) for two situations (i) doors or windows normally open for ventilation and (ii) all doors and windows closed? Are there any correlations between the answers you have given for each nuclide?

Ratio TIAC Indoors/Outdoors

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240			
Cs-137			
I_2			
CH_3I			

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240			
Cs-137			
I_2			
CH_3I			

Question 12

The following nuclides are of significance to the estimation of inhalation dose and the consequences of accidental releases from commercial nuclear plants:

Ru-103, Ru-106, Te-129m,Te-132, Cs-134, Ba-140, Ce-144, Pu-238, Pu-241, Cm-242

In your opinion, are there any similarities between the estimates of the ratios of TIAC indoors/outdoors for these nuclides and any of the original nuclides in question 11? If so, could you group particular nuclides together (by associating them with one of the original Pu, I or Cs isotopes) in order to help estimate the magnitude of the uncertainties involved for these new nuclides?

Any General Comments should be included in the rationale.

Ratio TIAC Indoors/Outdoors

Nuclide	Similar Ratio To (delete as appropriate)	Specific Comments
Ru-103/Ru-106	Cs-137 / Pu-240 / I_2 / CH_3I	
Te-129m/Te-132	Cs-137 / Pu-240 / I_2 / CH_3I	
Cs-134	Cs-137 / Pu-240 / I_2 / CH_3I	
Ba-140	Cs-137 / Pu-240 / I_2 / CH_3I	
Ce-144	Cs-137 / Pu-240 / I_2 / CH_3I	
Pu-238/Pu-241	Cs-137 / Pu-240 / I_2 / CH_3I	
Cm-242	Cs-137 / Pu-240 / I_2 / CH_3I	

Question 13

What fraction of an average population in your own country would be classed as (i) agricultural and other outdoor workers, (ii) indoor workers, (iii) non-active adult population and (iv) schoolchildren? [In addition, if you are happy to make an estimate for the whole of North-Western Europe or for North-Eastern/South-Eastern USA then please do so].

POPULATION FRACTION	5th Quantile	Median	95th Quantile
(i) agricultural and other outdoor workers			
(ii) indoor workers			
(iii) non-active adult population[a]			
(ii) schoolchildren			

a. All adults are considered to be in category i, ii, or iii. The non-active adult population are those that are not agricultural and outdoor workers or indoor workers. Activity here refers to employment not amount of energy expended.

What is the long-term annual-average fraction of time that each population group, (i) to (iv) above, spend indoors in various types of housing and in cars or buses? Consider people living within either a typical urban environment or a representative rural area.

People Working Outdoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

People Working Indoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

Non-Active Adult Population Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

Schoolchildren Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

People Working Outdoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

People Working Indoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

Non-Active Adult Population Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

Schoolchildren Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

What is the long-term annual-average fraction of time that an "average" member of the population in your country spends indoors in various types of housing and in cars or buses? [In addition, if you are happy to make an estimate for the whole of North-Western Europe or for North-Eastern/South-Eastern USA then please do so].

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses			
(ii) medium shielding, e.g., single brick family house			
(iii) high shielding, e.g., multi-story office block			
(iv) basement of single family house			
(v) basement multi-story office block			
(vi) inside typical car			
(vii) inside typical bus			

APPENDIX C

Rationales and Responses of the Expert Panel on Deposited Material and External Doses

Rationales and Responses of the Expert Panel on Deposited Material and External Doses

EXPERT A

Question 1

Conversion of an activity per unit area value for a particular radionuclide to a dose rate at 1 meter above the ground was made using specific factors that have been published in ICRU (1994). For a half-space source geometry, the conversion factor will depend only on the source depth distribution and soil attenuation properties. The transport codes used to derive these factors assume a standard soil mix to which the factors are fairly insensitive. The actual distribution with depth is modeled with a negative exponential with mass depth, i.e., mass per unit area. The mass per unit area relaxation depth, β, then becomes the single parameter of concern. It can be expected to be close to zero for fresh deposition and increase thereafter as the effects of advection and diffusion progressively move the radioactivity downward.

Values of β which have been measured in various studies have been summarized in ICRU (1994). Using these data, Table 1.1 was constructed to apply to various times following a fresh dry deposition event.

Although some differences in the mobility of various nuclides have been noted, it was not deemed sufficient nor consistent enough among studies to warrant treating the individual nuclides any differently in their rate of downward movement in the soil. Transport for these nuclides can be considered to be driven by physical rather them chemical processes. Thus, the differences in the dose rate values can be traced purely to the gamma energies and intensities. In particular, lower energy gamma rays would be more severely attenuated as time passes due to the deeper "average" depth of the radionuclide and the greater path length of the gamma rays through the soil. The general characteristic of the dose rate data generated for this question is that there tends to be an initially quick fall in dose rate in the first few years followed by a slower term change over the course of decades.

The values for ^{95}Zr also exhibit a phenomenon where they do not fall off as quickly as the radionuclides in the first few months. This is due to the build-in of ^{95}Nb which has been accounted for in the calculation.

The values for ^{106}Ru, which do not appear in ICRU (1994), were calculated based on data in Beck et al. (1972) for that nuclide with extrapolation to deeper profiles performed using ^{137}Cs as a normalization guide since it is close in energy.

Table 1.1 Values of β (g cm^{-2}) assumed for an original dry deposition

Time	5th percentile	Median	95th percentile
at deposition time	1	0.2	0
1 day	2	0.2	0
3 days	2	0.3	0
10 days	2	0.3	0.1
30 days	3	0.5	0.2
3 months	4	1	0.3
100 days	4	1	0.3
1 year	5	2	0.5
3 years	7.5	3	1
10 years	15	10	1.5
30 years	20	15	2
100 years	30	20	3

Question 2

To account for a wet deposition process, a slightly greater penetration into the soil is assumed at the time of initial deposition. The value of β is then greater and consequently the dose rate is lower in the early stages as compared to the case of dry deposition. However, the effects of precipitation, which can be expected on a regular basis in a moist climate, lead to the same depth profile after the first few days for both the case of initial dry and wet deposition process. Table 2.1 gives the values of β that were used in place of those in Table 1.1 for the early times.

Table 2.1 Values of β (g cm^{-2}) assumed for an original wet deposition

Time	5th percentile	Median	95th percentile
at deposition time	2	0.5	0.1
1 day	2	0.5	0.1
3 days	2	0.5	0.1
10 days	2	0.5	0.1
- values at 30 days and beyond are same as for dry deposition.			

Question 3

For the case of an unspecified deposition process, β values between those used for dry and wet cases were adopted for the early period following initial deposition for the median. The values for the 5th and 95th percentile are the same as those for the case of wet deposition. They are given in Table 3.1.

Table 3.1 Values of β (g cm^{-2}) assumed for an unspecified ("average") deposition.

Time	5th percentile	Median	95th percentile
at deposition time	2	0.3	0.1
1 day	2	0.3	0.1
3 days	2	0.3	0.1
- values at 10 days and beyond are the same as for dry deposition.			

Question 4

In order to estimate dose rates and integrated doses in an urban environment, a simple model was constructed using three components, or sources, of deposited activity. One is undisturbed areas where the dose rate is assumed to behave the same as for an open lawn. The second is disturbed areas where the initial deposition and dose rates are the same as for lawns but where the soil undergoes tilling, harrowing or other homogenizing type activity over time. The third is eroded surfaces such as hard pavement where the initial deposition is different from that of a lawned area and where it washes away with time.

The model can be expressed as:

$$D_u = f_l D_l + f_d D_d + f_e D_e$$

where

D_u is the dose rate in an "average" urban environment,
D_l is the dose rate over an undisturbed lawn area as given in Question 1,
D_d is the dose rate over a disturbed area,
D_e is the dose rate over an eroded surface, and
f_l, f_d, and f_e represent the fractions of time spent in each area.

The dose rate in a disturbed area is allowed to exponentially decrease from that for a lawned area to that for a deeply distributed source (β = 50 g cm^{-2}), which essentially represents that for a homogeneous distribution in surface soil. This is expressed as

$$D_d = D_l e^{-at} + D_h (1 - e^{-at})$$

where

D_h is the dose rate where β = 50 g cm^{-2}, and
a is the time constant for soil turnover.

The dose rate for the eroded (hard surface) area can be expressed as

$$D_e = x D_p e^{-bt}$$

where

D_p is the dose rate from a plane source, i.e., β = 0,
b is the erosion time constant, and
x is the fraction of the deposition on a lawned area which is deposited on the hard surface.

Table 4.1 presents values of the model parameters used. The median values selected are for an environment which is actually more suburban in nature rather central city since this the most typical for the U.S. The 5th and 95th percentile values then bracket a wide range to allow for a larger uncertainty than in the result given for questions 1-3. To a large extent, the final dose rates are driven by the values of f. The 5th percentile would provide the lowest dose rates as the most time is spent over eroded surfaces. The 95th percentile represents the other extreme where most of the time is spent over undisturbed areas.

For the case of ^{137}Cs in a rural environment, a value of 0.5 is given to both f_l and f_d, i.e., the time is equally divided between undisturbed and disturbed areas with no time spent in eroded areas.

To account for effective dose, a conversion factor of 0.7 Sv/Gy was used for the median. This value has been adopted by the UNSCEAR. Values of 6.5 and 7.5 were applied for the 5th and 95th percentiles, respectively. This then approximately brackets the range computed in the past for environmental radiation.

To compute integrated doses, the geometric mean between each calculated dose rate at the various time intervals was used. In effect, this is just a step-wise exponential fit between the discrete points calculated from the original assumptions on the value of β.

Table 4.1 Values of model parameters used for an initial dry deposition

Factor	5th percentile	Median	95th percentile
fl	0.1	0.3	0.7
fd	0.2	0.4	0.2
fe	0.7	0.3	0.1
a (years)	0.25	1	5
b (years)	0.01	0.05	1
x	0.1	0.2	1

Question 5

The model used for dry deposition is also used for wet deposition. The values of D_l are taken from the results of question 2, however, and the values of *x*, the deposition fraction on hard surfaces, were modified as follows:

	5th percentile	Median	95th percentile
x	0	0.4	1

The higher value for the median in this case reflects the higher deposition which can occur on a flat surface as compared to a dry deposit (IAEA, 1994). On the other hand, the uncertainty, as measured by the value of zero at the 5th percentile, reflects the possibility of complete washoff during heavy precipitation.

Question 6

The same model is again used and the values of D_l are taken from the results of question 3. The value of *x* for the median is set between that of a pure dry deposit and that of a pure wet deposit. The extremes, 0 and 1, remain the same to reflect the uncertainty.

	5th percentile	Median	95th percentile
x	0	0.3	1

Question 7

As stated in the question 1 rationale, no significant differences are assumed among the nuclides for soil migration. However, it is recognized that the volatile elements would tend to be associated with smaller particles and the refractory elements with larger particles. This might tend to produce some observable differences in migration rates and deposition velocities.

No differences have been assumed for Questions 4-6, relating to urban surfaces. It is recognized however that runoff from hard surfaces could be different. The uncertainty is reflected in the wide range of the value *x* used in the model to compute dose for the urban environment.

Question 8

The location factors derived for these cases were based on the data published by Burson and Profio (1977). For single family houses (cases i and ii), corrections were made as the assumed spectrum used in their calculations had a substantial high energy component (above 1 MeV) and experimental results were conducted with a ^{60}Co source (average energy of 1.25 MeV). To account for the spectrum differences, the location factors for wood and masonry houses and basements in these type of structures were scaled according to the formula:

$$R_e = 0.2R + 0.8AR$$

where

R_e is the effective location factor,
R is the location (dose reduction) factor given for the high energy spectrum case and
A is a spectrum weighting factor.

This formula allows for attenuation of 80% of the outside dose rate. The remaining 20% is assumed to pass through materials of negligible mass (e.g., windows) and is therefore unaffected. The value of *A* was calculated based on data published in Beck and de Planque (1968) which can be used to estimate the relative decrease in dose rate at various energies as a function of mass thickness of shielding (in effect, height above ground). An average mass thickness of 10 g cm^{-2} was used for wooden houses and 30 g cm^{-2} for masonry houses and basements within single family houses. The same correction was used for the radionuclides ^{137}Cs, ^{106}Ru, and ^{95}Zr since their primary gamma energies are all relatively close (0.62 - 0.77 MeV). Higher attenuation was applied to the case of ^{131}I (mostly 0.36 MeV) and still higher to ^{144}Ce (0.14 MeV). Overall, the values of *A* were in the range of 0.1 to 0.66 for all of these cases.

For massive buildings, no distinction was made among the radionuclides. In principle, higher attenuation could be expected for the lower energy emitters; however, the value of the location factors are exceedingly low to begin with and are only order-of-magnitude approximations. The 5th and 95th percentile represent a suitably large enough range to encompass the different radionuclides.

For the case of the car and bus, no distinction is made among the radionuclides since a substantial fraction of the dose receives minimum attenuation. The fraction of the half space shielded by the vehicle provides the occupants with a high degree of attenuation for all energies.

Question 9

Constant scaling factors have been applied to account for the time dependence of the initial location factors given in Question 8. There is little information on which to base these factors; however, some reasonable assumptions can be made. For the case of homes, information collected in a study in Novozybkov, Russia four years after the Chernobyl accident is used (Miller et al., 1991). The indoor/outdoor ratios measured there indicated somewhat lower location factors than those derived in Question 8. It is believed that human activities around homes would tend to more deeply distribute radioactivity over time and thus lower the dose rates around a dwelling and thus within it. As the precision in the estimate is poor, a rough factor of 0.75 is used for 1 year after and 0.5 for ten years after. The dose rates for large buildings are assumed to be unaffected. For vehicles, washoff from a roadbed is assumed to occur within the first year, resulting in a scaling factor of 0.5 thereafter. This accounts for the loss of the source term (i.e., reduction in half-space) given an average size road.

Question 10

Based on the likelihood that dry deposition would result in a higher deposit to building surfaces relative to the case of wet deposition where some washoff would occur, it would be expected that the location factors would be somewhat higher for dry vs. wet deposition, at least for the case of small buildings where minimum attenuation occurs. Data published by Jacob (1989) suggest a 30% difference. This, however, is not a substantial difference given the level of uncertainty in the location factor to begin with. The 5th and 95th percentile values given in Question 8 provide a margin of inclusion to account for the differences between dry and wet deposition. Coupled with the fact that some degree of washoff can be expected with the first precipitation, no changes are given from the data provided in Question 8. These location factors as well as the scaling factors for time given in Question 9 include to some degree the effects from redistribution of the deposited activity. As a further justification for not specifying any differences between wet and dry deposition, the possibility of runoff from roofs associated with precipitation would cause excess activity to be deposited around the outside of a house. The effect on dose rates from this change in source geometry is difficult to assess with any certainty; however, a higher dose could occur in certain situations inside the structure depending upon the relative roof and wall attenuation.

Question 11

Data have been compiled in Cohen and Cohen (1980) and Alzona et al. (1979) which can be used estimate the ratio of indoor to outdoor time integrated air concentrations (inverse of protection factors). For Pu, their results for large particles are used, and for Cs, small particles. The variations measured in their study are used to estimate the 5th and 95th percentiles.

The gaseous forms are assumed to behave in the extreme with the indoor/outdoor ratio approaching one. As a lower bound on the uncertainty (5th percentile), the median for small particles is used. No difference is assumed between methyl and molecular iodine. In principle, the molecular form would be more reactive, and in the presence of metallic ions (as driven off in cooking), a reduction could be achieved. However, the uncertainty is too large to quantitate this effect.

Question 12

The behavior is based on the association with particle size. It is assumed that low melting/boiling points lead to smaller particles as would be the case for Cs. The experience of measuring hot particles from Chernobyl indicates an association with fuel/cladding/refractories.

Question 13

Information that can be used to directly answer and help infer the answers to the questions posed here can be found in USBC (1994). Specific tables relating to general population characteristics, housing, labor force, school enrollment and transportation can be found in this reference. The values used were nationwide; however, this is deemed quite representative of the area under investigation, to wit, the northeastern, southeastern and central states based on the regional breakdowns presented.

The size of the labor force engaged in outdoor work was estimated by summing the number of agriculture and mining workers as well as half of the total workers in the construction, transportation, communication, public utility and entertainment/recreation industries. Other job categories pointed to essentially indoor work. The non-active adult population was inferred from the difference between the labor force and the non-institutional population (i.e., no children). Schoolchildren included all enrolled students (including college). It must be noted that some students also are in the labor force; however, children under age five have not been included in the Question 13 categories and they amount to 7.6% of the population. As pure coincidence, the four categories of the population posed in Question 13 add up to 100% without the pre-schoolers being included, which suggests that 7.6% of the population is in both the labor force and school category. To some extent, the proportions are balanced by the fact that many pre-schoolers are enrolled in day care, nursery, and kindergarten programs so that they can be considered schoolchildren for purposes of shielding estimates.

The breakdown of households by type between small one-to four-family homes (including 7% mobile homes and trailers) and larger structures was found to be 83% vs. 17%. The larger structures were not considered for the rural home category. Urban population for the U.S. is 75% and rural, 25%. The fractions of wood and brick/masonry (i.e., low vs medium shielding) among the small house category was taken to be 70% and 30%, based on the results of an indoor radiation survey (Miller, 1992).

Averaged over a year, the portion of time spent in homes was estimated to be 57% for workers, 75% for non-active adults, and 63% for schoolchildren. Indoor workers were estimated to spend 21% of their time in a large building. All people were considered to spend 4% of their time in large buildings for shopping, entertainment, etc. Schoolchildren are estimated to spend 12.5% (6 hours per day, 180 days per year) of their time in schools which are in the large building category.

Time spent in basements are crude estimates, although some unpublished information collected in the Miller (1993) study was used to estimate these values based on the room type in basements. The preponderance of play rooms in basements resulted in children having a higher time fraction spent in basements as opposed to adults.

A datum gleaned from a TV advertisement by the Buick Division of the General Motors Corporation, aired in April, 1995, was used a basis for the car value. For the average American, 500 hours per year is spent in automobiles. This is not inconsistent with the 2.24×10^{12} miles driven (USBC, 1994), an average of 2 people per vehicle, and a 35 mile per hour average speed. Outdoor workers were assumed to spend twice the average time in cars and non-active adults and children half the average.

Bus travel is minimal in the U.S. relative to car travel. Data in USBC (1994) indicates only 5.3% of workers commute by public transportation. The estimates provided are rough; however it is recognized that schoolchildren would likely spend some measurable time in buses (15 minutes one way per school day - 180 school days per year). Because of the greater distances, rural children are estimated to spend twice this amount.

The final average for all people was calculated by weighting the values in each of the 8 parts of the question according to the percentage in each population group.

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Note: Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.

Question 1. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	5.9	7.6	9
10 days	5.2	7.7	8.7
30 days	4.8	7.4	8.4
100 days	3	4.6	5.7
1 year	0.22	0.3	0.41

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.6	2	2.4
30 days	1.1	1.7	1.9
100 days	0.85	1.3	1.6
1 year	0.47	0.66	0.9
3 years	0.12	0.14	0.2

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.1	4.1	4.8
1 day	2.4	3.7	4.4
3 days	2	3	3.7
10 days	1.1	1.6	1.8
30 days	0.17	0.27	0.31
100 days	0.00037	0.00056	0.0007

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.8	6.3	7.4
3 months	3.2	4.8	5.9
1 year	2.8	3.9	5.4
3 years	2.3	3.3	4.5
10 years	1.4	1.7	3.5
30 years	0.69	0.87	2
100 years	0.1	0.14	0.35

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.9	6.7	8.1
10 days	5.2	7.1	8.7
30 days	4.8	7.4	8.4
100 days	3	4.6	5.7
1 year	0.22	0.3	0.41

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.3	1.8	2.2
30 days	1.1	1.7	1.9
100 days	0.85	1.3	1.6
1 year	0.47	0.66	0.9
3 years	0.12	0.14	0.2

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	3.6	4.4
1 day	2.4	3.3	4
3 days	2	2.8	3.4
10 days	1.1	1.5	1.8
30 days	0.17	0.27	0.31
100 days	0.00037	0.00056	0.0007

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	5.5	6.7
3 months	3.2	4.8	5.9
1 year	2.8	3.9	5.4
3 years	2.3	3.3	4.5
10 years	1.4	1.7	3.5
30 years	0.69	0.87	2
100 years	0.1	0.14	0.35

Question 3. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.9	7.2	8.1
10 days	5.2	7.7	8.7
30 days	4.8	7.4	8.4
100 days	3	4.6	5.7
1 year	0.22	0.3	0.41

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.3	1.9	2.2
30 days	1.1	1.7	1.9
100 days	0.85	1.3	1.6
1 year	0.47	0.66	0.9
3 years	0.12	0.14	0.2

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	3.9	4.4
1 day	2.4	3.5	4
3 days	2	3	3.4
10 days	1.1	1.6	1.8
30 days	0.17	0.27	0.31
100 days	0.00037	0.00056	0.0007

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	6	6.7
3 months	3.2	4.8	5.9
1 year	2.8	3.9	5.4
3 years	2.3	3.3	4.5
10 years	1.4	1.7	3.5
30 years	0.69	0.87	2
100 years	0.1	0.14	0.35

Question 4. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.6	4.1	6.8
10 days	1	4	6.6
30 days	0.84	3.7	6.4
100 days	0.43	2.1	4.3
1 year	0.022	0.11	0.29

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.1×10^{-10}	3.5×10^{-10}	5.8×10^{-10}
30 days	2.7×10^{-10}	1×10^{-9}	1.7×10^{-9}
100 days	6.3×10^{-10}	2.7×10^{-9}	4.9×10^{-9}
1 year	8.5×10^{-10}	3.8×10^{-9}	7.4×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.42	1.1	1.8
30 days	0.19	0.84	1.4
100 days	0.12	0.58	1.2
1 year	0.048	0.25	0.64
3 years	0.012	0.041	0.13

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	7.3×10^{-11}	2.5×10^{-10}	4.1E $\times 10^{-10}$
100 days	1.6×10^{-10}	6.7×10^{-10}	1.2×10^{-9}
1 year	3.4×10^{-10}	1.5×10^{-9}	3.2×10^{-9}
3 years	3.9×10^{-10}	2.2×10^{-9}	5×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.82	2.2	3.6
1 day	0.63	2	3.3
3 days	0.48	1.6	2.8
10 days	0.22	0.83	1.4
30 days	0.03	0.13	0.23
100 days	0.000052	0.00025	0.00052

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	6.2×10^{-12}	1.8×10^{-11}	3×10^{-11}
3 days	1.6×10^{-11}	4.9×10^{-11}	8.2×10^{-11}
10 days	3.5×10^{-11}	1.2×10^{-10}	2×10^{-10}
30 days	4.9×10^{-11}	1.8×10^{-10}	3×10^{-10}
100 days	5×10^{-11}	1.8×10^{-10}	3.1×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.3	3.4	5.6
3 months	0.46	2.2	4.4
1 year	0.29	1.5	3.8
3 years	0.23	0.97	2.9
10 years	0.16	0.51	2
30 years	0.09	0.28	1.1
100 years	0.015	0.049	0.19

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	6×10^{-10}	2.1×10^{-9}	3.9×10^{-9}
1 year	1.5×10^{-9}	6.4×10^{-9}	1.4×10^{-8}
3 years	3.1×10^{-9}	1.4×10^{-8}	3.5×10^{-8}
10 years	7.3×10^{-9}	3×10^{-8}	8.8×10^{-8}
30 years	1.5×10^{-8}	5.3×10^{-8}	1.8×10^{-7}
100 years	2.3×10^{-8}	7.9×10^{-8}	2.8×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.1	4.1	5.6
3 months	1.7	3.1	4.4
1 year	1.2	2.2	3.8
3 years	0.96	1.5	2.9
10 years	0.63	0.79	1.8
30 years	0.34	0.43	0.89
100 years	0.055	0.073	0.16

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.8×10^{-9}	2.9×10^{-9}	3.9×10^{-9}
1 year	5.2×10^{-9}	9.1×10^{-9}	1.4×10^{-8}
3 years	1.2×10^{-8}	2.1×10^{-8}	3.5×10^{-8}
10 years	2.9×10^{-8}	4.5×10^{-8}	8.5×10^{-8}
30 years	5.8×10^{-8}	8.1×10^{-8}	1.6×10^{-7}
100 years	8.8×10^{-8}	1.2×10^{-7}	2.5×10^{-7}

Question 5. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.96	4	6.1
10 days	0.97	4	6.6
30 days	0.83	3.8	6.4
100 days	0.43	2.1	4.3
1 year	0.022	0.11	0.29

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	8.3×10^{-11}	3.5×10^{-10}	5.5×10^{-10}
30 days	2.4×10^{-10}	1×10^{-9}	1.7×10^{-9}
100 days	6×10^{-10}	2.7×10^{-9}	4.8×10^{-9}
1 year	8.2×10^{-10}	3.8×10^{-9}	7.4×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.25	1.1	1.7
30 days	0.19	0.87	1.4
100 days	0.12	0.59	1.2
1 year	0.048	0.25	0.64
3 years	0.012	0.041	0.13

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	5.6×10^{-11}	2.5×10^{-10}	4×10^{-10}
100 days	1.5×10^{-10}	6.9×10^{-10}	1.2×10^{-9}
1 year	3.2×10^{-10}	1.6×10^{-9}	3.2×10^{-9}
3 years	4.7×10^{-10}	2.2×10^{-9}	5×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.51	2.2	3.3
1 day	0.47	2	3
3 days	0.39	1.6	2.6
10 days	0.21	0.84	1.4
30 days	0.029	0.14	0.23
100 days	0.000052	0.00025	0.00052

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	4.2×10^{-12}	1.8×10^{-11}	2.7×10^{-11}
3 days	1.2×10^{-11}	4.9×10^{-11}	7.5×10^{-11}
10 days	2.9×10^{-11}	1.2×10^{-10}	1.9×10^{-10}
30 days	4.2×10^{-11}	1.8×10^{-10}	2.9×10^{-10}
100 days	4.3×10^{-11}	1.8×10^{-10}	3×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.78	3.3	5.1
3 months	0.46	2.2	4.4
1 year	0.29	1.5	3.8
3 years	0.23	0.97	2.9
10 years	0.16	0.51	2
30 years	0.09	0.28	1.1
100 years	0.015	0.049	0.19

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	4.7×10^{-10}	2.1×10^{-9}	3.7×10^{-9}
1 year	1.3×10^{-9}	6.4×10^{-9}	1.3×10^{-8}
3 years	3×10^{-9}	1.4×10^{-8}	3.4×10^{-8}
10 years	7.2×10^{-9}	3×10^{-8}	8.8×10^{-8}
30 years	1.5×10^{-8}	5.3×10^{-8}	1.8×10^{-7}
100 years	2.3×10^{-8}	7.9×10^{-8}	2.8×10^{-7}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	3.9	5.1
3 months	1.7	3.1	4.4
1 year	1.2	2.2	3.8
3 years	0.96	1.5	2.9
10 years	0.63	0.79	1.8
30 years	0.34	0.43	0.89
100 years	0.055	0.073	0.16

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.6×10^{-9}	2.7×10^{-9}	3.7×10^{-9}
1 year	5×10^{-9}	8.9×10^{-9}	1.3×10^{-8}
3 years	1.2×10^{-8}	2×10^{-8}	3.4×10^{-8}
10 years	2.9×10^{-8}	4.4×10^{-8}	8.5×10^{-8}
30 years	5.8×10^{-8}	8.1×10^{-8}	1.6×10^{-7}
100 years	8.8×10^{-8}	1.2×10^{-7}	2.5×10^{-7}

Question 6. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.96	4.1	6.1
10 days	0.97	4.1	6.6
30 days	0.83	3.7	6.4
100 days	0.43	2.1	4.3
1 year	0.023	0.11	0.28

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	8.3×10^{-11}	3.5×10^{-10}	5.5×10^{-10}
30 days	2.4×10^{-10}	1×10^{-9}	1.7×10^{-9}
100 days	6×10^{-10}	2.7×10^{-9}	4.8×10^{-9}
1 year	8.3×10^{-10}	3.8×10^{-9}	7.4×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.25	1.1	1.7
30 days	0.19	0.85	1.4
100 days	0.12	0.59	1.2
1 year	0.048	0.25	0.64
3 years	0.012	0.041	0.13

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	5.6×10^{-11}	2.5×10^{-10}	4×10^{-10}
100 days	1.5×10^{-10}	6.8×10^{-10}	1.2×10^{-9}
1 year	3.2×10^{-10}	1.6×10^{-9}	3.2×10^{-9}
3 years	4.7×10^{-10}	2.2×10^{-9}	5×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.51	2.2	3.3
1 day	0.47	2	3
3 days	0.39	1.7	2.6
10 days	0.21	0.86	1.4
30 days	0.029	0.14	0.23
100 days	0.000052	0.00025	0.00052

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	4.2×10^{-12}	1.8×10^{-11}	2.7×10^{-11}
3 days	1.2×10^{-11}	5.0×10^{-11}	7.5×10^{-11}
10 days	2.9×10^{-11}	1.2×10^{-10}	1.9×10^{-10}
30 days	4.2×10^{-11}	1.8×10^{-10}	2.9×10^{-10}
100 days	4.3×10^{-11}	1.9×10^{-10}	3×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.78	3.4	5.1
3 months	0.46	2.2	4.4
1 year	0.29	1.5	3.8
3 years	0.23	0.97	2.9
10 years	0.16	0.51	2
30 years	0.09	0.28	1.1
100 years	0.015	0.049	0.19

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	4.7×10^{-10}	2.1×10^{-9}	3.7×10^{-9}
1 year	1.3×10^{-9}	6.4×10^{-9}	1.3×10^{-8}
3 years	3×10^{-9}	1.4×10^{-8}	3.4×10^{-8}
10 years	7.2×10^{-9}	3×10^{-8}	8.8×10^{-8}
30 years	1.5×10^{-8}	5.3×10^{-8}	1.8×10^{-7}
100 years	2.3×10^{-8}	7.9×10^{-8}	2.8×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	4.2	5.1
3 months	1.7	3.1	4.4
1 year	1.2	2.2	3.8
3 years	0.96	1.5	2.9
10 years	0.63	0.79	1.8
30 years	0.34	0.43	0.89
100 years	0.055	0.073	0.16

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.6×10^{-9}	2.8×10^{-9}	3.7×10^{-9}
1 year	5×10^{-9}	9×10^{-9}	1.3×10^{-8}
3 years	1.2×10^{-8}	2×10^{-8}	3.4×10^{-8}
10 years	2.9×10^{-8}	4.5×10^{-8}	8.5×10^{-8}
30 years	5.8×10^{-8}	8.1×10^{-8}	1.6×10^{-7}
100 years	8.8×10^{-8}	1.2×10^{-7}	2.5×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Cs-137 / Ru-106 / I-131 / Zr-95	would likely track Ru-106 oxide of Ru can act as volatile
Cs-134/Cs-136	Cs-137 / Ru-106 / I-131 / Zr-95	would likely track Cs-127
Ba-140	Cs-137 / Ru-106 / I-131 / Zr-95	less volatile than Cs
Te-131m/Te-132	Cs-137 / Ru-106 / I-131 / Zr-95	similar to Ba
I-132/I-133/ I-134/I-135	Cs-137 / Ru-106 / I-131 / Zr-95	would likely track I-131
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	refractory most similar to Zr
Ce-144	Cs-137 / Ru-106 / I-131 / Zr-95	refractory most similar to Zr

Urban Environment

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Cs-137 / Ru-106 / I-131 / Zr-95	
Cs-134/Cs-136	Cs-137 / Ru-106 / I-131 / Zr-95	Higher Cs binding to clay roofs and asphalt surfaces is possible
Ba-140	Cs-137 / Ru-106 / I-131 / Zr-95	
Te-131m/Te-132	Cs-137 / Ru-106 / I-131 / Zr-95	
I-132/I-133/ I-134/I-135	Cs-137 / Ru-106 / I-131 / Zr-95	Due to solubility, greater runoff is possible from hard surfaces
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	
Ce-144	Cs-137 / Ru-106 / I-131 / Zr-95	

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m^2 of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.14	0.28	0.34
(ii) medium shielding building	0.01	0.09	0.19
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.03	0.07
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.09	0.18	0.22
(ii) medium shielding building	0.01	0.06	0.11
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.005	0.02	0.04
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.113	0.218	0.27	0.075	0.145	0.18
(ii) medium shielding building	0.015	0.083	0.165	0.01	0.055	0.11
(iii) high shielding building	0.001	0.01	0.1	0.001	0.01	0.1
(iv) basement family house	0.0075	0.03	0.06	0.005	0.02	0.04
(v) basement of multi-story block	0.0005	0.005	0.01	0.0005	0.005	0.01
(vi) inside typical car	0.15	0.25	0.35	0.15	0.25	0.35
(vii) inside typical bus	0.1	0.2	0.25	0.1	0.2	0.25

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.113	0.218	0.27	0.075	0.145	0.18
(ii) medium shielding building	0.015	0.083	0.165	0.01	0.055	0.11
(iii) high shielding building	0.001	0.01	0.1	0.001	0.01	0.1
(iv) basement family house	0.0075	0.03	0.06	0.005	0.02	0.04
(v) basement of multi-story block	0.0005	0.005	0.01	0.0005	0.005	0.01
(vi) inside typical car	0.15	0.25	0.35	0.15	0.25	0.35
(vii) inside typical bus	0.1	0.2	0.25	0.1	0.2	0.25

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.105	0.21	0.255	0.07	0.14	0.17
(ii) medium shielding building	0.0075	0.0675	0.1425	0.005	0.045	0.095
(iii) high shielding building	0.001	0.01	0.1	0.001	0.01	0.1
(iv) basement family house	0.0075	0.0225	0.0525	0.005	0.015	0.035
(v) basement of multi-story block	0.0005	0.005	0.01	0.0005	0.005	0.01
(vi) inside typical car	0.15	0.25	0.35	0.15	0.25	0.35
(vii) inside typical bus	0.1	0.2	0.25	0.1	0.2	0.25

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.113	0.218	0.27	0.075	0.145	0.18
(ii) medium shielding building	0.015	0.083	0.165	0.01	0.055	0.11
(iii) high shielding building	0.001	0.01	0.1	0.001	0.01	0.1
(iv) basement family house	0.0075	0.03	0.06	0.005	0.02	0.04
(v) basement of multi-story block	0.0005	0.005	0.01	0.0005	0.005	0.01
(vi) inside typical car	0.15	0.25	0.35	0.15	0.25	0.35
(vii) inside typical bus	0.1	0.2	0.25	0.1	0.2	0.25

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.0675	0.135	0.165	0.045	0.09	0.11
(ii) medium shielding building	0.0075	0.045	0.0825	0.005	0.03	0.055
(iii) high shielding building	0.001	0.01	0.1	0.001	0.01	0.1
(iv) basement family house	0.00375	0.015	0.03	0.0025	0.01	0.02
(v) basement of multi-story block	0.0005	0.005	0.01	0.0005	0.005	0.01
(vi) inside typical car	0.15	0.25	0.35	0.15	0.25	0.35
(vii) inside typical bus	0.1	0.2	0.25	0.1	0.2	0.25

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.14	0.28	0.34
(ii) medium shielding building	0.01	0.09	0.19
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.03	0.07
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.09	0.18	0.22
(ii) medium shielding building	0.01	0.06	0.11
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.005	0.02	0.04
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.14	0.28	0.34
(ii) medium shielding building	0.01	0.09	0.19
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.03	0.07
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.15	0.29	0.36
(ii) medium shielding building	0.02	0.11	0.22
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.01	0.04	0.08
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.09	0.18	0.22
(ii) medium shielding building	0.01	0.06	0.11
(iii) high shielding building	0.001	0.01	0.1
(iv) basement family house	0.005	0.02	0.04
(v) basement of multi-story block	0.0005	0.005	0.01
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 μm), Cs-137 (particulate, representative of ≈ 1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.2	0.5	0.8
Cs-137	0.5	0.8	1
I_2	0.7	0.95	1
CH_3I	0.7	0.95	1

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.05	0.2	0.5
Cs-137	0.2	0.5	0.7
I_2	0.5	0.9	1
CH_3I	0.5	0.9	1

Question 12

Nuclide	Similar Ratio To (delete as appropriate)	Specific Comments
Ru-103/Ru-106	Cs-137 / Pu-240	oxide form volatile - small otherwise refractory - large
Te-129m/Te-132	Cs-137	
Cs-134	Cs-137	
Ba-140	Cs-137	
Ce-144	Cs-137 / Pu-240	oxide refractory - large otherwise volatile - small
Pu-238/Pu-241	Pu-240	fuel particle - large
Cm-242	Pu-240	fuel particle - large

Question 13. *Population Fractions.*

POPULATION FRACTION	5th Quantile	Median	95th Quantile
(i) agricultural and other outdoor workers	0.03	0.05	0.1
(ii) indoor workers	0.4	0.45	0.5
(iii) non-active adult population[a]	0.2	0.25	0.3
(ii) schoolchildren	0.2	0.25	0.3

a. All adults are considered to be in category i, ii, or iii. The non-active adult population are those that are not agricultural and outdoor workers or indoor workers. Activity here refers to employment not amount of energy expended.

People Working Outdoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.25	0.34	0.45
(ii) medium shielding, e.g., single brick family house	0.1	0.13	0.2
(iii) high shielding, e.g., multi-story office block	0.1	0.14	0.2
(iv) basement of single family house	0.01	0.03	0.05
(v) basement multi-story office block	0.0001	0.001	0.01
(vi) inside typical car	0.05	0.12	0.2
(vii) inside typical bus	0.001	0.003	0.01

People Working Indoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.25	0.34	0.45
(ii) medium shielding, e.g., single brick family house	0.1	0.13	0.2
(iii) high shielding, e.g., multi-story office block	0.25	0.33	0.45
(iv) basement of single family house	0.01	0.03	0.05
(v) basement multi-story office block	0.001	0.01	0.02
(vi) inside typical car	0.03	0.06	0.09
(vii) inside typical bus	0.001	0.003	0.01

Non-Active Adult Population Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.3	0.44	0.5
(ii) medium shielding, e.g., single brick family house	0.1	0.17	0.3
(iii) high shielding, e.g., multi-story office block	0.15	0.23	0.3
(iv) basement of single family house	0.01	0.03	0.05
(v) basement multi-story office block	0.0001	0.001	0.01
(vi) inside typical car	0.01	0.03	0.06
(vii) inside typical bus	0.001	0.002	0.01

Schoolchildren Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.25	0.37	0.5
(ii) medium shielding, e.g., single brick family house	0.1	0.14	0.2
(iii) high shielding, e.g., multi-story office block	0.2	0.28	0.4
(iv) basement of single family house	0.02	0.04	0.06
(v) basement multi-story office block	0.0001	0.001	0.01
(vi) inside typical car	0.01	0.03	0.06
(vii) inside typical bus	0.003	0.01	0.02

People Working Outdoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.3	0.4	0.5
(ii) medium shielding, e.g., single brick family house	0.1	0.17	0.25
(iii) high shielding, e.g., multi-story office block	0.02	0.04	0.06
(iv) basement of single family house	0.01	0.03	0.05
(v) basement multi-story office block	0.0001	0.001	0.005
(vi) inside typical car	0.06	0.12	0.18
(vii) inside typical bus	0.0001	0.001	0.002

People Working Indoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.3	0.4	0.5
(ii) medium shielding, e.g., single brick family house	0.1	0.17	0.25
(iii) high shielding, e.g., multi-story office block	0.15	0.25	0.35
(iv) basement of single family house	0.01	0.03	0.05
(v) basement multi-story office block	0.0001	0.001	0.01
(vi) inside typical car	0.03	0.06	0.09
(vii) inside typical bus	0.0001	0.001	0.002

Non-Active Adult Population Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.4	0.53	0.65
(ii) medium shielding, e.g., single brick family house	0.15	0.23	0.3
(iii) high shielding, e.g., multi-story office block	0.05	0.13	0.2
(iv) basement of single family house	0.01	0.03	0.05
(v) basement multi-story office block	0.0001	0.001	0.01
(vi) inside typical car	0.01	0.03	0.06
(vii) inside typical bus	0.0001	0.001	0.002

Schoolchildren Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.3	0.44	0.6
(ii) medium shielding, e.g., single brick family house	0.1	0.19	0.3
(iii) high shielding, e.g., multi-story office block	0.1	0.17	0.3
(iv) basement of single family house	0.02	0.04	0.06
(v) basement multi-story office block	0.0001	0.001	0.01
(vi) inside typical car	0.01	0.03	0.05
(vii) inside typical bus	0.005	0.02	0.03

Estimated Dosages from Outdoor Exposure in Sample Countries

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.3	0.39	0.5
(ii) medium shielding, e.g., single brick family house	0.1	0.15	0.2
(iii) high shielding, e.g., multi-story office block	0.15	0.26	0.35
(iv) basement of single family house	0.01	0.03	0.05
(v) basement multi-story office block	0.001	0.003	0.01
(vi) inside typical car	0.03	0.06	0.09
(vii) inside typical bus	0.002	0.005	0.01

EXPERT B

1. General Approach

I have approached answering the questions with the objective of providing robust values for use in assessments which include the effects of the important processes both in soil and urban areas. Where I believe the differences are small between doses following wet or dry deposition, I have taken the approach of providing a single set of values with uncertainty ranges which encompass both possibilities, while bearing in mind the need to provide the uncertainty on "average" values for the population, rather than trying to distinguish between the two. Where I believe the differences are significant, two sets of answers are provided. A similar approach is taken for the behavior of different radionuclides in the urban environment and for location factors. This reflects, to some extent, my understanding of the external doses to the population in an urban environment as a whole and my smaller degree of confidence in providing a very detailed breakdown for parts of the "whole" question.

Details of the approach taken for each question and the major data sources used are described below for each question or set of questions.

2. Questions 1 - 3: Gamma dose-rate in air above a lawn

The gamma dose-rates in air have been estimated taking into account the attenuation of the gamma dose-rate in air due to surface roughness and migration into soil as a function of time after deposition. A compartment model has been used to represent layers in the soil, and migration down the soil column is represented by transfer rates (Crick et al., 1990).

The same values are provided for Questions 1 - 3. My judgement is that the differences are small between dose-rates over a lawned area following wet and dry deposition and I have taken the approach of providing a single set of values with uncertainty ranges which encompass both possibilities, while bearing in mind the need to provide the uncertainty on the "average" value, rather than trying to distinguish between the two. There is some evidence that the dose-rates over the first few weeks to months may be lower by about 20% following wet deposition; this is included in the uncertainty ranges at short times.

The soil type assumed is biased toward clay soils or those containing clay. These soils display slow migration of cesium because of fixation. My judgement is, however, that values for sandy soils are within the range of values given. Post-Chernobyl measurements (Jacob and Meckbach, 1992) suggest that iodine and ruthenium behave like cesium in the first few weeks following deposition and it is assumed that this continues over the time scales considered for the required nuclides. Zirconium is also assumed to behave like cesium although the uncertainty ranges have been increased to reflect the lack of knowledge of the migration behavior of this element.

The 50th percentile values for dose-rates in air have been based on the model in EXPURT. Dose-rates for cesium after 10 years have been modified to take account of fixation of cesium in the soil based on a review of recent research and estimates of predicted dose-rates over tens of years (Jacob, 1994; Miller et al., 1990).

The uncertainty ranges have been determined by considering the uncertainty on the average migration rate used in the model and the available measured data from Scandinavia, the former Soviet Union, and from other literature. The 95th percentile has been increased to include the possibility that dry deposition could give rise to higher doses in the first few months. The large uncertainty range for cesium at long times reflects the lack of understanding of the behavior of the migration of deposited material in the long term.

2.1. References

Crick, M.J. and Brown, J. 1990. *EXPURT: A model for evaluating exposure from radioactive material deposited in the urban environment*, NRPB-R235 (London HMSO).

Gale, H.J., Humphreys, D.L.O. et al. 1964. "Weathering of cesium in soil," *Nature* 4916, 257-261.

Jacob, P. and Meckbach, R. 1990. "External exposure from deposited radionuclides," in Proc. Seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens, May 1990, CEC Brussels, EUR 13013.

Jacob, P. and Meckbach, R. 1992. *Recent developments in in situ gamma spectrometry*, IRPA 8, Worldwide Achievement in Public and Operational Health Protection against Radiation, Montreal, ISBN I-55048-657-8-9, 305-308.

Jacob, P. et al. 1994. "Attenuation effects on the kerma rates in air after cesium deposition on grasslands," *Radiat. Env. Biophysics*. 33, 251-267.

Karlberg, O. 1987. "Weathering and migration of Chernobyl fallout in Sweden," *Rad. Prot. Dos.* 21 (1-3), 75.

Konoplev, A.V. et al. 1992. "Behavior of long lived Chernobyl radionuclides in a soil-water system," *Analyst* 117, 1041-1047.

Miller, K.M., Kuiper, J.L. and Helfer, I.K. 1990. "Cesium-137 fallout depth distributions in forest versus field sites: implication for external gamma dose-rates," *J. Environ. Rad.* 12, 23-47.

3. Questions 4 - 6: Effective dose-rate outdoors in an urban environment

The same values are provided for Questions 4-6. My judgement is that the differences are small between effective dose-rates outdoors in an urban area following wet and dry deposition (Crick et al., 1990). The same approach has therefore been taken as for Questions 1-3.

The starting point has been the use of the EXPURT model using default assumptions for a typical urban environment. Values for dry deposition velocities to urban surfaces, fraction of wet deposition intercepted by urban surfaces, and weathering rates have been based on pre- and post-Chernobyl literature. Overall, initial dose-rates in an urban area have been calculated to be about 50% of those over an open lawn due to the reduced deposition velocity to paved surfaces found in urban areas.

For zirconium there is some evidence that deposition velocities to urban surface are higher than those for cesium, ruthenium, and iodine because zirconium is less volatile (IAEA,1994). The effect of increasing deposition velocities has been considered; however, due to the uncertainty in the behavior of zirconium, values have been taken that fall between the two sets of results obtained using lower and higher deposition velocities.

The chemical form is not specified for iodine. Historically, it has been assumed that iodine released from reactors is mainly in an elemental form; however, there is increasing evidence that it is released as cesium iodide, i.e., particulate. Post-Chernobyl measurements made in Bavaria suggest that the release from Chernobyl was 50% particulate and 50% iodide; this ratio has been assumed here. It has been assumed that elemental iodine deposits 10 times more on all surfaces compared to particulates (IAEA,1994; Roed and Jacob, 1990). The deposition of ruthenium is assumed to be similar to cesium (IAEA, 1994).

There is no evidence that suggests that there is a significant difference between the fraction of wet-deposited cesium, iodine, and ruthenium intercepted by urban surfaces. For iodine, retention on paved areas and roofs may be a bit lower than cesium (IAEA, 1994) but it has been assumed here to be the same. This has been extended to zirconium in light of no better information.

The EXPURT model does not include trees, and calculations using other models (Roed, 1990; Jacob, 1987) have shown that a large number of trees can increase outdoor doses in urban areas by up to a factor of 2. No adjustment has been made to the best estimate as my judgement is that in an average urban environment the effect of trees is small. The possible higher doses are taken into account in the uncertainty ranges given.

The effect of neighboring buildings on outdoor doses in an urban area is assumed to be small for an average urban environment (IAEA, 1994).

For iodine and ruthenium, it has been assumed that the weathering from urban surfaces is not significantly different than that for cesium, although there is some evidence that these elements could weather off paved surfaces a little faster. This could reduce the doses from paved surfaces for these elements relative to cesium. My judgement is, however, that the overall effect of this is small given the fraction of paved land and the time scales involved.

The uncertainty ranges immediately after deposition take into account the uncertainty about the fraction of the area that is paved vs. soil, the relative dry deposition velocities to paved and soil surfaces, and the fraction of activity retained on paved surfaces relative to soil for wet deposition. The uncertainty about weathering from paved surfaces has been considered in the longer term, as well as the uncertainty about the migration in soil taken from Question 1.

At long times, the uncertainty range for cesium is increased, reflecting the importance of doses from soil in the long term and the uncertainty in the migration of cesium in soil as discussed above.

The effective dose-rates for cesium in a rural environment have been calculated assuming that "rural" is equivalent to a large lawned surface. Dose conversion factors assuming rotational geometry have been used.

Following wet deposition, measurements suggest that the initial dose-rates in an urban area may be up to about 50% higher than those seen following dry deposition due to the partitioning and retention of activity on urban surfaces. However, this is not seen at longer times as the doses are then dominated by those from soil. If wet deposition was considered separately, the uncertainty ranges could be narrowed for short times following deposition because the initial distribution of activity is better understood from studies of runoff from and retention of rain on urban surfaces. My judgement is that for an average urban environment, the dose from wet deposition is typically of the same order as dry deposition and any initially higher dose-rates are incorporated in the uncertainty ranges given.

The dose-rates for wet deposition fall well within the ranges for dry deposition, and using the assumption that it is dry for approximately 90% of the time, it is reasonable to use the data for dry deposition (Question 4) for an unknown initial deposition (Question 6). If account is taken of the fact that wet deposition is higher relative to dry deposition, then this would bias the values more towards those for wet deposition; however, due to the similarity of the results these would still be within the uncertainty range given. A robust approach of providing one set of data has therefore been taken.

3.1. References

Crick, M.J. and Brown, J. 1990. *EXPURT: A model for evaluating exposure from radioactive material deposited in the urban environment*, NRPB-R235 (London HMSO).

International Atomic Energy Agency (IAEA). 1994. *Modeling the deposition of airborne radionuclides into the urban environment.* First report of the VAMP Urban Working Group, Vienna, IAEA-TECDOC-760.

International Atomic Energy Agency (IAEA). To be published. *External and Inhalation Dose Assessment in the urban environment*, Second report of the VAMP Urban Working Group, Vienna.

Jacob, P. and Meckbach, R. 1987. "Shielding factors and external dose evaluation." *Rad. Prot. Dos.* 21 (1/3), 79.

Jacob, P. and Meckbach, R. 1990. "External exposure from deposited radionuclides," in Proc. Seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens, May 1990, CEC Brussels, EUR 13013.

Roed, J. 1990. *Deposition and removal of radioactive substances in an urban area*, Nordic Liaison Committee for atomic energy. Final report of the NKA Project AKTU-245.

Roed, J. and Jacob, P. 1990. "Deposition on urban surfaces and subsequent weathering," in Proc. Seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens, May 1990, CEC Brussels, EUR 13013.

Roed, J. and Sandalls, J. 1990. "Decontamination in the urban area," in Proc. Seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens, May 1990, CEC Brussels, EUR 13013.

4. Question 7: Similarity of nuclides for estimating external dose

I have assumed that there is no difference between lawned and urban surfaces for this question, and knowledge of the behavior in both environments has been used.

For open lawned surfaces, the important factor in determining similar behavior is the migration of the radionuclide in soil and its disposition to fixation. All radionuclides have been assumed to be the same except for cesium in the long term. The grouping for this question has been based on the deposition and retention behavior in urban areas as discussed in previous questions. I am not aware of any data for molybdenum and I would assume, as a default, that it behaves like cesium.

4.1. References

International Atomic Energy Agency (IAEA). 1994. *Modeling the deposition of airborne radionuclides into the urban environment.* First report of the VAMP Urban Working Group, Vienna, IAEA-TECDOC-760.

5. Question 8: Indoor location factors

This question has been answered using results from the EXPURT model on indoor/outdoor ratios for low, medium and high shielded buildings and values from a review of the literature.

EXPURT takes account of the shielding provided by typical buildings in the categories low, medium and high shielding as a function of gamma energy. The shielding code, GRINDS, is used to provide the dose per gamma energy per unit deposit on a surface at a range of locations within a building; the differences in location factor for occupancy in different locations within a building have been taken into account in the uncertainty distributions where I believe it to be important.

Many of the data available in the literature are for cesium. Account has been taken of the different gamma energies of the radionuclides for which values are requested based on EXPURT and graphs given by Meckbach (1988) on the effect of gamma energy on location factor for a number of building types. For low and medium shielded buildings, there is no significant difference between location factors for different gamma energies across the range of radionuclides considered. For high shielded buildings, the difference is very dependent on the story of the building; factors of 2 across the energy range considered can be seen for the ground floor, increasing up to a factor of about 5 for upper stories. The shielding in basements is highly dependent on gamma energy and this has been taken into account in the answers given.

The uncertainty for the average location factor will be dependent on the uncertainty of the size of an average building, the position of the person within that building, the number of windows and the building materials. The relative importance of these factors depends on the type of building being considered. By looking at the literature and the range of different building types considered, some judgement can be made on the effect of these factors. The GRINDS shielding code has also been used to look at the difference in location factor depending on the position in the building, and this has been built into the uncertainty distribution.

For the location factors inside buildings, the effect of indoor deposition has been taken into account. This is particularly important for high shielded buildings where the exclusion of indoor deposition can result in up to 10 times better protection (Crick et al., 1990; Meckbach, 1988). This is of particular significance for dry deposition where indoor deposition is a significant contributor to the indoor dose and therefore leads to a higher location factor. For basements, it is assumed that indoor deposition is not significant unless there are aboveground windows or light shafts.

From the literature, account has been taken of building types typical in Germany, the UK, France, and Denmark, and values used in the US regulatory studies have also been considered.

For high shielded buildings, the uncertainty range is larger, reflecting the uncertainty on indoor deposition and the position within the building. Meckbach (1988) does not consider indoor deposition in the estimation of location factors for wet and dry deposition; these values are considered to be around the 5th percentile of the distribution given.

The EXPURT model does not consider basements, and the values given are based on the literature. The data of Meckbach (1988) is comparable to other sources, supporting the assumption that indoor deposition will not be significant for basements unless there are windows aboveground. Values for location factors for basements with and without windows have been considered in estimating the 5th and 95th percentiles.

The available literature (Roed, 1990) suggests that there is no significant difference between cars and buses. Possible differences for low energy gamma emitters could be the size of the vehicle and the shielding by other people in the car or bus. My judgement is that the uncertainty distribution given reflects these possible differences and the lack of knowledge in this area. The same values are used for all radionuclides.

Zirconium-95 and ruthenium-106 have been assumed to behave like cesium-137 as the gamma energies are similar. For iodine-131 the same assumption has been made for all building types except for basements. In this case, the lower energy of iodine-131 could lead to more protection; the reduction is based on Meckbach (1988) and the location factor is taken as being a factor of 2 lower. Cerium-144 has a much lower average gamma energy. The location factors given are scaled down from cesium using the effect of location factor on gamma energy given by Meckbach (1988). For cars, in the absence of any information, it is assumed that the protection offered would be similar to that for cesium. For low and medium shielded buildings, no difference from cesium is assumed. For high shielded buildings, the 50th percentile is assumed to be the same as cesium and my judgement is that the large uncertainty range given encompasses the possible difference in shielding that might be found for cerium-144. For basements in houses, the location factor is lowered by a factor of 3 and for multistory blocks by a factor of 2.

6. Question 9: Time-dependence of location factor

I do not, in general, feel strongly that the location factor is time dependent except for the case of high shielded buildings. Based on the results of EXPURT for the low and medium shielded buildings for the radionuclides under consideration, the difference between location factors immediately following deposition and at 1 and 10 years is typically no more than 50% for either wet or dry deposition. This is supported by the work of Meckbach (1988). However, for high shielded buildings, EXPURT estimates that there is a difference in location factor of about a factor of 5 between the time immediately after deposition and longer times for dry deposition, and up to a factor of 10 for wet deposition. A difference is also found by Meckbach (1988), although it is not so significant; this is probably due to the fact that for dry deposition, indoor deposition is not considered. A robust value of a factor of 5 is chosen as the reduction in location factor which is biased towards the value for dry deposition, reflecting the fraction of the time that it is dry. This reduction factor is a constant factor.

The same value is given for all radionuclides.

7. Question 10: Location factors as a function of wet and dry deposition

In general I do not believe that the difference in location factor for wet and dry deposited material is significant and the values given in Question 8 are applicable for both deposition conditions. Small differences are observed between location factors following wet or dry deposition but these are typically less than a factor of 2 and my judgement is that this is not significant given the lack of data to substantiate this finding. The difference is also very dependent on the location of people within buildings.

There are, however, two exceptions:

- 5th percentile for high shielded buildings for dry deposition.

  The values in Question 8 are for either wet or dry deposition, although they are biased towards dry conditions as it is assumed that it is dry at the time of deposition for about 90% of the time. Values for dry deposition from Crick et al. (1990) and Meckbach (1988) are within the ranges given. However, in Question 8, a much larger uncertainty range in location factors has been given for high shielded buildings to encompass the difference between wet and dry deposition. For dry deposition, my judgement is that the 5th percentile would be higher by a factor of 2, reducing the uncertainty range. This difference is expected for all the radionuclides considered.

- high shielded buildings for wet deposition

  Because of the differences seen between location factors for wet and dry deposited material for high shielded buildings and the bias in Question 8 towards dry deposition, it is my judgement that the location factor for high shielded buildings would be lower for wet deposition by a factor of about 10 based on the EXPURT model. The values for wet deposition are supported by Meckbach (1988) although in his study the differences between dry and wet deposition are not so large because of the exclusion of indoor deposition. This difference is expected for all the radionuclides considered.

For other building types, basements, and cars the difference is not significant.

7.1. References

The following references are given for Sections 5, 6, and 7:

Brown, J. 1988. "The effectiveness of sheltering as a countermeasure in the event of an accident," *NRPB Radiological Protection Bulletin* 97, November 1988.

Brown, J. and Jones, J.A. 1993. "Location factors for modification of external radiation doses," *NRPB Radiological Protection Bulletin* 144, July 1993.

Crick, M.J. and Brown, J. 1990. *EXPURT: A model for evaluating exposure from radioactive material deposited in the urban environment*, NRPB-R235, (London HMSO).

Meckbach, R. and Jacob, P. 1988. "Gamma exposures due to radionuclides deposited in urban environments. Part II: location factors for different deposition patterns," *Rad. Prot. Dos.* 25 (3), 181.

Roed, J. 1990. *Deposition and removal of radioactive substances in an urban area*, Final report of the NKA Project AKTU-245. Nordic Liaison Committee for atomic energy.

8. Question 11: Ratio of indoor to outdoor time-integrated air concentrations

The approach taken has been to use the model of Roed et al. (1991) as a basis for the estimation. This model relates the indoor and outdoor integrated air concentrations as a function of the air exchange, indoor deposition rate, and a filtration factor.

The expression used is: $DR = f\lambda_r/(\lambda_r + \lambda_d)$

where f = filtration factor,
λ_r = air exchange rate, and
λ_d = indoor deposition rate.

Information on the parameter values chosen are given below.

Over the air exchange rates considered appropriate for this question, the dominant process is indoor deposition and the ratio of indoor to outdoor integrated air concentration is not very sensitive to the air exchange rate used within this range. The 5th and 95th percentiles have been estimated taking into account possible ranges in average air exchange rates and measured deposition velocities.

8.1. Air exchange rates

For normal ventilation, exchange rates typical for northwestern Europe have been used. No account has been taken of Mediterranean countries. Values representative of conditions averaged over summer and winter have been estimated. It has been assumed that air exchange rates of less than 0.3 h^{-1} lead to an unhealthy living environment and so this has been used as a lower limit and is assumed to be representative of "tight" houses. Air exchange rates of around 0.7 h^{-1} to 0.8 h^{-1} have been used as typical.

For the case where all doors and windows are closed, a typical value of about 0.4 h^{-1} is used. A lower limit of 0.2 h^{-1} is used and values more appropriate for representative winter conditions have been used to guide the upper limit.

8.2. Indoor deposition

Values for indoor deposition have been based on experimental work and post-Chernobyl measurements, primarily carried out in Denmark and the UK. Bias has been placed on data for furnished houses as it is assumed that the average member of the population indoors is in a furnished environment. Data for a range of particle sizes have been considered. For cesium-137, measured values for 1 μm particles have been used. For plutonium-240, measurements for 2 and 4 μm particles have been used and some extrapolation made for larger particles. For iodine, it has been assumed that deposition indoors will be larger than for particulate material as seen for grass and on smooth indoor surfaces and a value in the range of 5 - 10 times higher than cesium has been used. For CH_3I it has been assumed that no deposition occurs indoors.

8.3. Filtration factors

Based on experimental data values of f of 0.85 for cesium-137, 0.5 for plutonium-240, 0.85 for iodine and 1 for CH_3I have been used. This factor is dependent, to some extent, on the air exchange rate, but it has been assumed that this is not a dominant contributor to the uncertainty.

8.4. References

Byrne, M.Q., Lange, C. et al. 1993. "Indoor aerosol deposition measurements for exposure assessment calculations," *Proc of Indoor air* 1993, Vol. 3, p. 415.

Roed, J. and Cannell, R.J. 1997. "Relationship between indoor and outdoor aerosol concentration following the Chernobyl accident," *Rad. Prot. Dos.*, Vol. 1-3, p. 107.

Roed, J., Goddard, A.H.J., et al. 1991. *Reduction of the dose from radioactive matter ingressed in buildings*, EUR 14469, Cadarache.

9. Question 12: Similarity of nuclides for estimating inhalation dose

No information is given on the particle sizes for the radionuclides listed. With limited experience on the forms in which these radionuclides are released from reactors, I would assume that they all behave like cesium.

10. Question 13: Population groups and occupancy factors

10.1. Fraction of population in various groups

The fractions of the population in the defined groups have been given for the UK. I would not be confident in saying that these data are appropriate for the whole of northwestern Europe although I would expect the values for these countries to lie within the uncertainty bounds given.

The estimates for each population group have been based on data from the UK census given in the latest publication of *Social trends*. The data are based on 1992 - 1993 figures, although trends have been studied to provide data which are generally applicable over a number of years. The fraction of the population who are under 5 have not been included in the figure for school children.

The fraction of the population who work outdoors is based on the fraction of the population in employment who work in agriculture and the construction industry. The fraction of the population who work indoors is based on the remaining employed population.

The fraction of the population who are nonactive is based on the size of the civilian labor force excluding those people in employment and also including those adults over the age of 65.

The fraction of the population who are school children is based on available data on the fraction of under-18's who are at school.

The 5th and 95th percentiles have been determined based on judgement and the fluctuation of the fraction of the population in these groups over the last 10 years.

10.2. Time spent in different locations

The approach taken was to first consider the fraction of time spent outdoors by each of these groups. The overall time spent indoors and outdoors is less uncertain than the fraction of the time spent indoors in the range of locations given, and some data are available on different population groups such as agricultural workers and housewives. Some general assumptions have been made in the habits of the population. These are:

- fractions of the different building types in a typical urban environment have been based on the default fractions of buildings in cities, suburban and rural areas assumed in the EXPURT model and assuming that in general, based on population density, about 75% of people live in a "city" environment (>1000 people/km^2) and 25% in a "suburban" environment(>25 and <1000 people/km^2).
- for people living in rural areas, it is assumed that people do not live in high shielded buildings, so for outdoor workers and nonactive adults this category has not been considered and is effectively zero.
- no distinction has been made between the fraction of time spent in cars and buses because it was judged unrealistic to split the two categories, as the times spent in both were judged to be very small.
- In general, it has been assumed that indoor workers and school children spend their working day in high shielded buildings.
- account has been taken of the difference between winter and summer, weekdays and weekends, and some allowance has been made for holidays when estimating the fraction of time spent at work or at school.
- no estimates are made for basements for the UK population as very few houses have basements.

The 5th and 95th percentiles have been obtained using judgement. Account has been taken of the variation that could occur in the fraction of different building types within the different environments and the weighting of these to obtain typical average urban and rural living environments. Account has also been taken of the possible variation in working environment.

<u>Living in an urban environment</u>

For people working outdoors and living in a rural area, the above fractions of buildings have been modified as it has been assumed that a higher fraction of people working outdoors would live in suburban areas and not inner cities. Time spent in farm vehicles is not included explicitly but is considered as part of the fraction of time spent outdoors.

Nonactive adults are assumed on average to spend more time in cars and buses than the working population. The time indoors is assumed to be spent at home.

School children are assumed to spend less time in cars and buses than adults due to the school being more likely to be near the home. It is assumed that 1.5 hours is the 95 percentile of the average time that a school child would spend in cars or buses.

<u>Living in a rural environment</u>

The 50 percentile of the fraction of time in cars and buses is increased over the urban case to account for the probable increase of travel due to living in a rural area. The 5th and 95th percentiles remain the same.

The long-term annual average fraction of time that an average member of the population spends in each location in the UK has been determined from the groups considered. Weight has been placed on the population who live in urban areas (about 98 - 99%) and on people who spend most of their time indoors (typically 90 - 92%). The 5th and 95th percentiles have been estimated from the bounds for the larger individual groups.

10.3. References

Brown, J. and Jones, J.A. 1994. *Incorporation of the results of the EXPURT external dose model into the accident consequence assessment system COSYMA*, Chilton, NRPB-M510.

Brown, L. 1983. "National Radiation Survey in the UK: Indoor occupancy factors," *Rad. Prot. Dos.* 5 (4), 203.

Francis, E.A. 1986. *Patterns of building occupancy for the general public*. Chilton, NRPB-M129.

Crick, M.J. and Brown, J. 1990. *EXPURT: A model for evaluating exposure from radioactive material deposited in the urban environment*, NRPB-R235 (London HMSO).

Government Statistical Office. 1993. *Social trends*, No. 22, London, HMSO.

Note: **Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.**

Question 1. *Gamma dose-rate ($Gy \bullet s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \bullet s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	5.8	7
10 days	4	5.8	7
30 days	2	6.4	7
100 days	3	4.5	8
1 year	0.1	0.32	0.7

Nuclide Ru-106

Dose-Rate ($Gy \bullet s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.7	2
30 days	0.8	1.6	2
100 days	0.7	1.3	2
1 year	0.2	0.74	1
3 years	0.07	0.15	0.5

Nuclide I-131

Dose-Rate ($Gy \bullet s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2	3.3	5
1 day	2	3	5
3 days	1.5	2.6	5
10 days	0.8	1.4	4
30 days	0.1	0.25	0.5
100 days	0.0002	0.00059	0.001

Nuclide Cs-137

Dose-Rate ($Gy \bullet s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	4.5	6
3 months	2.5	4.3	6
1 year	2	3.9	4.5
3 years	1	3	3.5
10 years	0.5	1.5	3
30 years	0.05	1	3
100 years	0.05	1	3

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	5.8	7
10 days	4	5.8	7
30 days	2	6.4	7
100 days	3	4.5	8
1 year	0.1	0.32	0.7

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.7	2
30 days	0.8	1.6	2
100 days	0.7	1.3	2
1 year	0.2	0.74	1
3 years	0.07	0.15	0.5

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2	3.3	5
1 day	2	3	5
3 days	1.5	2.6	5
10 days	0.8	1.4	4
30 days	0.1	0.25	0.5
100 days	0.0002	0.00059	0.001

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	4.5	6
3 months	2.5	4.3	6
1 year	2	3.9	4.5
3 years	1	3	3.5
10 years	0.5	1.5	3
30 years	0.05	1	3
100 years	0.05	1	3

Question 3. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	5.8	7
10 days	4	5.8	7
30 days	2	6.4	7
100 days	3	4.5	8
1 year	0.1	0.32	0.7

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.7	2
30 days	0.8	1.6	2
100 days	0.7	1.3	2
1 year	0.2	0.74	1
3 years	0.07	0.15	0.5

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2	3.3	5
1 day	2	3	5
3 days	1.5	2.6	5
10 days	0.8	1.4	4
30 days	0.1	0.25	0.5
100 days	0.0002	0.00059	0.001

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	4.5	6
3 months	2.5	4.3	6
1 year	2	3.9	4.5
3 years	1	3	3.5
10 years	0.5	1.5	3
30 years	0.05	1	3
100 years	0.05	1	3

Question 4. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2	2.7	8
10 days	1.5	2.5	7.5
30 days	1.5	2.1	6
100 days	0.9	1.3	4
1 year	0.1	0.17	0.5

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.5×10^{-10}	2.2×10^{-10}	6×10^{-10}
30 days	4×10^{-10}	6.2×10^{-10}	2×10^{-9}
100 days	1×10^{-9}	1.6×10^{-9}	5×10^{-9}
1 year	2×10^{-9}	2.9×10^{-9}	9×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.5	0.76	1.5
30 days	0.5	0.7	1.5
100 days	0.4	0.6	1.5
1 year	0.2	0.32	0.8
3 years	0.04	0.059	0.15

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1×10^{-10}	1.9×10^{-10}	5×10^{-10}
100 days	4×10^{-10}	5.8×10^{-10}	1.5×10^{-9}
1 year	1×10^{-9}	1.6×10^{-9}	4×10^{-9}
3 years	1.5×10^{-9}	2.5×10^{-9}	6×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.6	4
1 day	0.9	1.4	4
3 days	0.8	1.2	3
10 days	0.4	0.65	2
30 days	0.08	0.12	0.3
100 days	0.0002	0.00027	0.0007

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	9×10^{-12}	1.3×10^{-11}	3×10^{-11}
3 days	2×10^{-11}	3.6×10^{-11}	9×10^{-11}
10 days	6×10^{-11}	9×10^{-11}	2×10^{-10}
30 days	9×10^{-11}	1.4×10^{-10}	4×10^{-10}
100 days	1×10^{-10}	1.6×10^{-10}	4×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	2	5
3 months	1	1.9	5
1 year	1	1.7	4
3 years	0.8	1.2	3
10 years	0.4	0.55	2
30 years	0.03	0.5	2
100 years	0.03	0.5	2

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1×10^{-9}	1.7×10^{-9}	4×10^{-9}
1 year	4×10^{-9}	5.8×10^{-9}	1.5×10^{-8}
3 years	1×10^{-8}	1.5×10^{-8}	4×10^{-8}
10 years	2×10^{-8}	3.2×10^{-8}	8×10^{-8}
30 years	2×10^{-8}	6.4×10^{-8}	2×10^{-7}
100 years	7×10^{-8}	1.7×10^{-7}	7×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3	3.7	5
3 months	2	3.6	5
1 year	1.5	3.2	4.5
3 years	1	2.5	3.5
10 years	0.5	1.2	3.5
30 years	0.05	1	3
100 years	0.05	1	3

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.5×10^{-9}	3.2×10^{-9}	4×10^{-9}
1 year	6×10^{-9}	1.1×10^{-8}	1.5×10^{-8}
3 years	1×10^{-8}	2.9×10^{-8}	4×10^{-8}
10 years	2×10^{-8}	6.7×10^{-8}	2×10^{-7}
30 years	3×10^{-8}	1.3×10^{-7}	3×10^{-7}
100 years	7×10^{-8}	3.5×10^{-7}	8×10^{-7}

Question 5. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2	2.7	8
10 days	1.5	2.5	7.5
30 days	1.5	2.1	6
100 days	0.9	1.3	4
1 year	0.1	0.17	0.5

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.5×10^{-10}	2.2×10^{-10}	6×10^{-10}
30 days	4×10^{-10}	6.2×10^{-10}	2×10^{-9}
100 days	1×10^{-9}	1.6×10^{-9}	5×10^{-9}
1 year	2×10^{-9}	2.9×10^{-9}	9×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.5	0.76	1.5
30 days	0.5	0.7	1.5
100 days	0.4	0.6	1.5
1 year	0.2	0.32	0.8
3 years	0.04	0.059	0.15

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1×10^{-10}	1.9×10^{-10}	5×10^{-10}
100 days	4×10^{-10}	5.8×10^{-10}	1.5×10^{-9}
1 year	1×10^{-9}	1.6×10^{-9}	4×10^{-9}
3 years	1.5×10^{-9}	2.5×10^{-9}	6×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.6	4
1 day	0.9	1.4	4
3 days	0.8	1.2	3
10 days	0.4	0.65	2
30 days	0.08	0.12	0.3
100 days	0.0002	0.00027	0.0007

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	9×10^{-12}	1.3×10^{-11}	3×10^{-11}
3 days	2×10^{-11}	3.6×10^{-11}	9×10^{-11}
10 days	6×10^{-11}	9×10^{-11}	2×10^{-10}
30 days	9×10^{-11}	1.4×10^{-10}	4×10^{-10}
100 days	1×10^{-10}	1.6×10^{-10}	4×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	2	5
3 months	1	1.9	5
1 year	1	1.7	4
3 years	0.8	1.2	3
10 years	0.4	0.55	2
30 years	0.03	0.5	2
100 years	0.03	0.5	2

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1×10^{-9}	1.7×10^{-9}	4×10^{-9}
1 year	4×10^{-9}	5.8×10^{-9}	1.5×10^{-8}
3 years	1×10^{-8}	1.5×10^{-8}	4×10^{-8}
10 years	2×10^{-8}	3.2×10^{-8}	8×10^{-8}
30 years	2×10^{-8}	6.4×10^{-8}	2×10^{-7}
100 years	7×10^{-8}	1.7×10^{-7}	7×10^{-7}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3	3.7	5
3 months	2	3.6	5
1 year	1.5	3.2	4.5
3 years	1	2.5	3.5
10 years	0.5	1.2	3.5
30 years	0.05	1	3
100 years	0.05	1	3

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.5×10^{-9}	3.2×10^{-9}	4×10^{-9}
1 year	6×10^{-9}	1.1×10^{-8}	1.5×10^{-8}
3 years	1×10^{-8}	2.9×10^{-8}	4×10^{-8}
10 years	2×10^{-8}	6.7×10^{-8}	2×10^{-7}
30 years	3×10^{-8}	1.3×10^{-7}	3×10^{-7}
100 years	7×10^{-8}	3.5×10^{-7}	8×10^{-7}

Question 6. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2	2.7	8
10 days	1.5	2.5	7.5
30 days	1.5	2.1	6
100 days	0.9	1.3	4
1 year	0.1	0.17	0.5

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.5×10^{-10}	2.2×10^{-10}	6×10^{-10}
30 days	4×10^{-10}	6.2×10^{-10}	2×10^{-9}
100 days	1×10^{-9}	1.6×10^{-9}	5×10^{-9}
1 year	2×10^{-9}	2.9×10^{-9}	9×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.5	0.76	1.5
30 days	0.5	0.7	1.5
100 days	0.4	0.6	1.5
1 year	0.2	0.32	0.8
3 years	0.04	0.059	0.15

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1×10^{-10}	1.9×10^{-10}	5×10^{-10}
100 days	4×10^{-10}	5.8×10^{-10}	1.5×10^{-10}
1 year	1×10^{-9}	1.6×10^{-9}	4×10^{-9}
3 years	1.5×10^{-9}	2.5×10^{-9}	6×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.6	4
1 day	0.9	1.4	4
3 days	0.8	1.2	3
10 days	0.4	0.65	2
30 days	0.08	0.12	0.3
100 days	0.0002	0.00027	0.0007

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	9×10^{-12}	1.3×10^{-11}	3×10^{-11}
3 days	2×10^{-11}	3.6×10^{-11}	9×10^{-11}
10 days	6×10^{-11}	9×10^{-11}	2×10^{-10}
30 days	9×10^{-11}	1.4×10^{-10}	4×10^{-10}
100 days	1×10^{-10}	1.6×10^{-10}	4×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	2	5
3 months	1	1.9	5
1 year	1	1.7	4
3 years	0.8	1.2	3
10 years	0.4	0.55	2
30 years	0.03	0.5	2
100 years	0.03	0.5	2

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1×10^{-9}	1.7×10^{-9}	4×10^{-9}
1 year	4×10^{-9}	5.8×10^{-9}	1.5×10^{-8}
3 years	1×10^{-8}	1.5×10^{-8}	4×10^{-8}
10 years	2×10^{-8}	3.2×10^{-8}	8×10^{-8}
30 years	2×10^{-8}	6.4×10^{-8}	2×10^{-7}
100 years	7×10^{-8}	1.7×10^{-7}	7×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3	3.7	5
3 months	2	3.6	5
1 year	1.5	3.2	4.5
3 years	1	2.5	3.5
10 years	0.5	1.2	3.5
30 years	0.05	1	3
100 years	0.05	1	3

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.5×10^{-9}	3.2×10^{-9}	4×10^{-9}
1 year	6×10^{-9}	1.1×10^{-8}	1.5×10^{-8}
3 years	1×10^{-8}	2.9×10^{-8}	4×10^{-8}
10 years	2×10^{-8}	6.7×10^{-8}	2×10^{-7}
30 years	3×10^{-8}	1.3×10^{-7}	3×10^{-7}
100 years	7×10^{-8}	3.5×10^{-7}	8×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	Also behaves like cesium over short term - no evidence to suggest this is not true over timescales of importance for Ru.
Cs-134/Cs-136	Cs-137	
Ba-140	Zr-95	
Te-131m/Te-132	Cs-137	For timescale of importance reasonable to assume same as Cs.
I-132/I-133/ I-134/I-135	I-131	Also behaves like cesium over short term - no evidence to suggest this is not true over timescales of importance for I.
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	Not known - would assume as a default that behaves as Cs.
Ce-144	Zr-95	

Urban Environment

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140	Zr-95	
Te-131m/Te-132	Cs-137	
I-132/I-133/ I-134/I-135	I-131	
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	Not known - would assume as a default that behaves as Cs.
Ce-144	Zr-95	

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m² of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.002	0.02	0.03
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.002	0.02	0.03
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.002	0.02	0.03
(iv) basement family house	0.00005	0.0005	0.02
(v) basement of multi-story block	0.00001	0.00005	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.6	0.95

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.002	0.02	0.03
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.002	0.02	0.03
(iv) basement family house	0.00003	0.0003	0.003
(v) basement of multi-story block	0.00001	0.00005	0.0005
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15	0.05	0.07	0.15
(iii) high shielding building	0.0004	0.004	0.006	0.0004	0.004	0.006
(iv) basement family house	0.0001	0.001	0.02	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.01	0.00002	0.0001	0.01
(vi) inside typical car	0.4	0.7	0.95	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95	0.4	0.7	0.95

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15	0.05	0.07	0.15
(iii) high shielding building	0.0004	0.004	0.006	0.0004	0.004	0.006
(iv) basement family house	0.0001	0.001	0.02	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.01	0.00002	0.0001	0.01
(vi) inside typical car	0.4	0.7	0.95	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95	0.4	0.7	0.95

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15	0.05	0.07	0.15
(iii) high shielding building	0.0004	0.004	0.006	0.0004	0.004	0.006
(iv) basement family house	0.00005	0.0005	0.02	0.00005	0.0005	0.02
(v) basement of multi-story block	0.00001	0.00005	0.001	0.00001	0.00005	0.001
(vi) inside typical car	0.4	0.7	0.95	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.6	0.95	0.4	0.6	0.95

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15	0.05	0.07	0.15
(iii) high shielding building	0.0004	0.004	0.006	0.0004	0.004	0.006
(iv) basement family house	0.0001	0.001	0.02	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95	0.4	0.7	0.95

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15	0.05	0.07	0.15
(iii) high shielding building	0.0004	0.004	0.006	0.0004	0.004	0.006
(iv) basement family house	0.00003	0.0003	0.003	0.00003	0.0003	0.003
(v) basement of multi-story block	0.00001	0.00005	0.0005	0.00001	0.00005	0.0005
(vi) inside typical car	0.4	0.7	0.95	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95	0.4	0.7	0.95

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.007	0.02	0.03
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.007	0.02	0.03
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.007	0.02	0.03
(iv) basement family house	0.00005	0.0005	0.02
(v) basement of multi-story block	0.00001	0.00005	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.6	0.95

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.007	0.02	0.03
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.007	0.02	0.03
(iv) basement family house	0.00003	0.0003	0.003
(v) basement of multi-story block	0.00001	0.00005	0.0005
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.001	0.002	0.005
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.001	0.002	0.005
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.001	0.002	0.005
(iv) basement family house	0.00005	0.0005	0.02
(v) basement of multi-story block	0.00001	0.00005	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.6	0.95

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.001	0.002	0.005
(iv) basement family house	0.0001	0.001	0.02
(v) basement of multi-story block	0.00002	0.0001	0.001
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.4	0.7
(ii) medium shielding building	0.05	0.07	0.15
(iii) high shielding building	0.001	0.002	0.005
(iv) basement family house	0.00003	0.0003	0.003
(v) basement of multi-story block	0.00001	0.00005	0.0005
(vi) inside typical car	0.4	0.7	0.95
(vii) inside typical bus	0.4	0.7	0.95

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 μm), Cs-137 (particulate, representative of ≈ 1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.05	0.1	0.35
Cs-137	0.25	0.5	0.7
I_2	0.05	0.2	0.35
CH_3I	0.9	0.99	0.995

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.025	0.1	0.25
Cs-137	0.2	0.35	0.5
I_2	0.05	0.1	0.35
CH_3I	0.9	0.99	0.995

Question 12

Nuclide	Similar Ratio To (delete as appropriate)	Specific Comments
Ru-103/Ru-106	Cs-137 / Pu-240 / I_2 / CH_3I	Unknown
Te-129m/Te-132	Cs-137 / Pu-240 / I_2 / CH_3I	Unknown
Cs-134	Cs-137	
Ba-140	Cs-137	
Ce-144	Cs-137 / Pu-240 / I_2 / CH_3I	Unknown
Pu-238/Pu-241	Pu-240	
Cm-242	Cs-137 / Pu-240 / I_2 / CH_3I	Unknown

Question 13. *Population Fractions.*

POPULATION FRACTION	5th Quantile	Median	95th Quantile
(i) agricultural and other outdoor workers	0.01	0.02	0.03
(ii) indoor workers	0.35	0.4	0.45
(iii) non-active adult population[a]	0.35	0.4	0.5
(ii) schoolchildren	0.1	0.12	0.15

a. All adults are considered to be in category i, ii, or iii. The non-active adult population are those that are not agricultural and outdoor workers or indoor workers. Activity here refers to employment not amount of energy expended.

People Working Outdoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.007	0.01	0.015
(ii) medium shielding, e.g., single brick family house	0.3	0.7	0.8
(iii) high shielding, e.g., multi-story office block	0.15	0.24	0.5
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.03	0.05	0.15
(vii) inside typical bus	NR	NR	NR

People Working Indoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.006	0.01	0.015
(ii) medium shielding, e.g., single brick family house	0.2	0.35	0.7
(iii) high shielding, e.g., multi-story office block	0.4	0.6	0.9
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.01	0.04	0.1
(vii) inside typical bus	NR	NR	NR

Non-Active Adult Population Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.005	0.01	0.02
(ii) medium shielding, e.g., single brick family house	0.25	0.45	0.65
(iii) high shielding, e.g., multi-story office block	0.35	0.5	0.8
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.01	0.04	0.1
(vii) inside typical bus	NR	NR	NR

Schoolchildren Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.005	0.008	0.01
(ii) medium shielding, e.g., single brick family house	0.25	0.38	0.65
(iii) high shielding, e.g., multi-story office block	0.35	0.6	0.85
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.01	0.02	0.06
(vii) inside typical bus	NR	NR	NR

People Working Outdoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.15	0.3	0.4
(ii) medium shielding, e.g., single brick family house	0.3	0.65	0.85
(iii) high shielding, e.g., multi-story office block	NR	NR	NR
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.015	0.05	0.15
(vii) inside typical bus	NR	NR	NR

People Working Indoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.2	0.3
(ii) medium shielding, e.g., single brick family house	0.25	0.5	0.7
(iii) high shielding, e.g., multi-story office block	0.15	0.25	0.5
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.01	0.05	0.1
(vii) inside typical bus	NR	NR	NR

Non-Active Adult Population Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.26	0.3
(ii) medium shielding, e.g., single brick family house	0.3	0.7	0.85
(iii) high shielding, e.g., multi-story office block	NR	NR	NR
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.01	0.04	0.1
(vii) inside typical bus	NR	NR	NR

Schoolchildren Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.25	0.3
(ii) medium shielding, e.g., single brick family house	0.3	0.55	0.8
(iii) high shielding, e.g., multi-story office block	0.1	0.17	0.3
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.01	0.03	0.07
(vii) inside typical bus	NR	NR	NR

Estimated Dosages from Outdoor Exposure in Sample Countries

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.005	0.008	0.01
(ii) medium shielding, e.g., single brick family house	0.25	0.45	0.7
(iii) high shielding, e.g., multi-story office block	0.25	0.5	0.8
(iv) basement of single family house	NR	NR	NR
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	0.01	0.03	0.1
(vii) inside typical bus	NR	NR	NR

EXPERT C

Question 1

Gamma dose-rates in air at 1 m above a uniform, flat and open lawned area were estimated from published values of kerma rates in air from radionuclides in the ground (Jacob et al., 1990), and applying various modifying factors. Assuming the parent radionuclides are deposited in equilibrium with their daughters, the kerma rate in air (Gy/s per Bq/m^2) at 1 m above ground, $K_{0.5}$, for an infinite plane source of a radionuclide parent/daughter pair, *r*, in the ground at a depth of 5 mm (density of soil: 1 g/cm^3) was calculated as follows:

$$K_{0.5} = \left(K_p + Q_a \cdot K_d\right) \times 2.8 \times 10^{-16} \qquad (1)$$

where K_p and K_d are the kerma rates in air at 1 m above ground for infinite plane sources of unit activity density of radioactive parent and daughter nuclides in the ground (nGy/h per kBq/m^2), and Q_a is the asymptotic ratio of activities of daughter and parent nuclide.

Table 1.

	Zr-95/ Nb-95	Ru-106/ Rh-106	I-131	Cs-137/ Ba-137m
K_p	2.21	0	1.18	0
K_d	2.3	0.623	0	1.82
Q_a	2.22	1	0	0.946
K_r	2.03E-15	1.73E-16	3.28E-16	4.78E-16

Data taken from Tables 1 and 3 of Jacob et al. (1990).

These values are then modified by scaling factors to take account of conditions appropriate for dry deposition, and the kerma rate in air immediately after dry deposition can be expressed, thus:

$$K_{grass}(0) = \frac{K_{0.5} \times f \times SR_{dry}}{RF_{0.5}} \qquad (2)$$

where *f* is a factor to express the uncertainty associated with the base values used (Jacob et al., 1990) compared with other authors; SR_{dry} is the reduction in dose rate following dry deposition to a lawned area compared with that over a uniform smooth infinite plane; $RF_{0.5}$ is the reduction in dose rate for a plane source at a depth of 0.5 g/cm^2 such as used by Jacob et al. (1990) compared with that over a uniform smooth infinite plane.

No further modification was applied to correct for a finite lawn area. The value of $K_{grass}(0)$ therefore applies for an idealized lawn area of infinite extent that is used in accident consequence assessment codes. To compare with a measurable quantity, a correction for the appropriate finite area should be made.

Subjective probability distributions were chosen using expert judgement for *f*, SR_{dry}, and $RF_{0.5}$ to express uncertainty in their values (Table 2).

The parameter values were assumed to be completely uncorrelated with each other.

Kerma rates at later times for each radionuclide were calculated using the following equation:

$$K_{grass}(t) = \left[\frac{K_{0.5} \times f}{RF_{0.5}}\right] \times RF_{mig}(t) \times e^{-\lambda t} \qquad (3)$$

where the term in the brackets represents the kerma rate above a uniformly contaminated infinite smooth plane; $RF_{mig}(t)$ is the ratio of the dose rate at time *t* (*d*) due to soil migration (excluding radioactive decay) compared with the dose rate above the infinite plane; and λ is the radioactive decay constant (d^{-1}). By definition, $RF_{mig}(0)=SR_{dry}$ for dry deposition.

Radioactive decay was applied assuming complete knowledge.

Distributions for the value of RF_{mig} at 10 d, 1 y, 3 y and 30 y were selected using expert judgement from data presented in IAEA (in press, b). The ranges given in the literature following nuclear weapons tests and after the Chernobyl accident were believed to cover perhaps 90% of the likely average values.

Because the values are meant to apply to the average over different soil types, weather conditions, times of year etc., normal distributions were assumed for each of the $RF_{mig}(t)$ at these times. These factors were applied to all radionuclides of interest introducing some mild additional uncertainty, especially at long times (which are fortunately rarely important for nuclides other than ^{137}Cs). The normal distributions were selected such that the literature ranges represented the 90% confidence intervals. In addition, a condition was imposed that the reduction factor must decrease with time. While there is some correlation between the attenuation at different depths, and relationships

Table 2.

	Subjective uncertainty distribution	Reasoning
f	Uniform distribution with a minimum of 0.93, a median of 1.00 and a maximum of 1.07; same value for each nuclide	p. 12 of Jacob et al. (1990) suggests that results of several authors for such calculations agree within 7%. Assumed that these errors are systematic across energies and radionuclides and hence that the distribution is uniform.
SR_{dry}	Step uniform distribution with a probability of 5% that value is between 0.7 and 0.75; 90% that value is between 0.75 and 0.85; and 5% that value is between 0.85 and 0.9; same value used for each nuclide	p. 6 of Jacob et al. (1990) suggests that dry deposition onto lawns corresponds to a reduction of 0.75-0.85 over the infinite smooth plane. Taking account that the grass in the lawn surface might be wet, or very dry, that the particle size might affect the effective depth to which a particle travels, and that there are variations in soil type, vegetation and roughness of lawn surface, the range has been extended somewhat considering the values presented in IAEA (in press, a) These effects are assumed to be the same for each radionuclide. The step uniform distribution seems reasonable to combine uncertainties in average quantities (e.g., soil type) and unknown effects (e.g., particle size)
$RF_{0.5}$	Uniform distribution with a minimum of 0.66; a median of 0.69 and a maximum of 0.72; independent value for each nuclide	p. 11 of Jacob et al. (1990) indicates that the reduction of the kerma rate in air above a lawn compared to the smooth infinite plane varies with energy in the range 0.69±0.03 for energies between 80 keV and 6 MeV. Assumed that the value for each radionuclide is independent of the value for others, and uniform because the actual value is unknown within this range.

between attenuation and solubility of the nuclide in soil have been proposed (IAEA, in press, b), there remains uncertainty in the nature of the particle that would be deposited and the matrix of fuel in which it would lie. The solubility of the radionuclides would vary with time in a way that is as yet unpredictable. No additional correlation has been assumed for the distributions other than the *de facto* one resulting from the condition imposed that the reduction factor must decrease with time. The subjective probability distributions used are given in Table 3.

Values of $RF_{mig}(t)$ for $0 < t < 10$ d, were estimated using log-linear interpolation; for $t > 30$ y, values were estimated using log-log extrapolation; for all other times, log-log interpolation was used. The empirical correlation coefficients between adjacent times (induced by the condition that values of RF_{mig} must decrease with time) are given in Table 4.

Reviewing these correlation coefficients gave no strong arguments for revising the distributions or correlations.

The distributions were combined using Crystal Ball® to express distributions on the requested parameters, from which 5%, 50% and 95% quantiles were extracted, as well as correlation coefficients.

Question 2

The same basic equation was used for wet deposition, i.e.,

$$K_{grass}(t) = \left[\frac{K_{0.5} \times f}{RF_{0.5}}\right] \times RF_{mig}(t) \times e^{-\lambda t} \qquad (4)$$

The same values and distributions were used for $K_{0.5}$, f, $RF_{0.5}$, λ, and $RF_{mig}(t)$ as for question 1 except for times between 0 and 10 d. For these times, $RF_{mig}(t)$ were set equal to $RF_{mig}(10\text{ d})$, thereby assuming that the attenuation for wet deposition is the same as that after 10 d independent of deposition mechanism. The implication is that within 10 d it is almost certain that some humidity or precipitation will have fallen, and that this would make any material wet and behave as if it had been initially deposited wet.

The Crystal Ball® program was again used to combine the distributions from which the requested *quantiles* were extracted.

Question 3

In order to simulate the uncertainty associated with an unknown deposition, the simulated uncertainty distributions for wet and dry deposition were combined by sampling from a binomial distribution, R, representing whether it was raining or not:

Table 3.

time	Subjective uncertainty distribution	Reasoning
10 d	Normal distribution with mean = 0.66, σ = 0.05. Truncated at 0 and SR_{dry}	Based on data in Section 2 of IAEA (in press, b), where it is given that the reduction factor for Cs-137, I-131 and Ru-103 after the Chernobyl accident was 0.58 - 0.74 in the first few weeks. This was judged to be a 90% confidence interval.
1 y	Normal distribution with mean = 0.57, σ = 0.1. Truncated at 0 and RF_{mig} (10 d)	IAEA (in press, b), section 2 gives a range of 0.40 -0.43 reduction in Sweden after the Chernobyl accident, and a range of 0.42 to 0.73 in Bavaria. Assumed 90% confidence that the value would lie between 0.40 and 0.73.
3 y	Normal distribution with mean = 0.45, σ = 0.14. Truncated at 0 and RF_{mig} (1 y)	Section 2 of IAEA (in press, b) gives a value of 0.43 from weapons fallout for 1 - 5 years after deposition. Fig. 2.1 of IAEA (in press, b) gives a range of 0.22 to 0.67 following the Chernobyl accident for 1 - 6 yrs. Assumed 90% confidence that the value would lie between 0.40 and 0.73.
30 y	Normal distribution with mean = 0.22, σ = 0.06. Truncated at 0 and RF_{mig} (3 y)	Fallout data gave range of 0.22 - 0.32 for six sites about 24 y after deposition. In sandy soil, 0.15 was observed. At test sites in Mississippi a range of 0.11 to 0.16 was observed. Assumed 90% confidence that the value would lie between 0.11 and 0.32.

Table 4.

t_1	0	1 d	3 d	10 d	30 d	100 d	1 y	3 y	10 y	30 y
t_2	1 d	3 d	10 d	30 d	100 d	1 y	3 y	10 y	30 y	100 y
Correlation	0.99	0.96	0.73	0.83	0.91	0.97	0.41	0.68	0.84	0.94

$$K_{unknown} = K_{wet} \quad if\ R=1 \qquad = K_{dry} \quad if\ R=0 \tag{5}$$

The binomial distribution is defined by a parameter, p_r, describing the mean probability of rain, and which is itself unknown and described by a subjective probability distribution (assumed to be lognormal with a mean of 0.1 and a standard deviation of 0.02, truncated at 0 and 1). Sampling from these distributions using Crystal Ball® yielded a subjective uncertainty distribution for an unknown deposition from which the requested quantiles were extracted.

Question 4

Effective dose-rates out-of-doors can be expressed as a sum of the dose-rates arising from activity on grass in urban areas, paved areas, and from trees. The nature of other surfaces has been neglected—all surfaces are assumed to behave like one of these. The effective dose-rate at time t can be expressed, thus:

$$\dot{H}_{out}(t) = \alpha \cdot F_{finite}\{K_{grass}(t) \cdot d_{grass} \cdot f_{grass} + K_{trees} \cdot d_{trees}(t) \cdot e^{-\lambda t} \cdot f_{trees} + K_{pave} \cdot d_{pave}(t) \cdot e^{-\lambda t} \cdot f_{pave}\} \tag{6}$$

where

λ	=	Radioactive decay constant (s^{-1})
α	=	Conversion factor from Kerma rate to effective dose rate (Sv/Gy)
F_{finite}	=	Reduction factor to take account that the source of activity is finite in extent (limited by buildings)
$K_{grass}(t)$	=	Kerma rate at time t over infinite grass slab per unit deposition including radioactive decay ($Gy \cdot s^{-1}/Bq \cdot m^{-2}$)
K_{trees}	=	Kerma rate under infinite tree-covered area per unit deposition ($Gy \cdot s^{-1}/Bq \cdot m^{-2}$)
K_{pave}	=	Kerma rate over infinite paved area per unit deposition ($Gy \cdot s^{-1}/Bq \cdot m^{-2}$)

d_{grass} = Initial deposition density on grass (Bq/m^2)

$d_{trees}(t)$ = Deposition density on trees at time t excluding radioactive decay (Bq/m^2)

$d_{pave}(t)$ = Deposition density on paved areas at time t excluding radioactive decay (Bq/m^2)

$f_{grass}, f_{trees}, f_{pave}$ = Fraction of the convolution between the urban area and time spent in various urban areas that arises from grass, trees and paved areas (The grass and paved areas sum to unity (i.e., f_{pave}=1-f_{grass}) but the area covered by trees is an additional independent contribution.)

Equation 6 can be expanded with Equation 3 and then re-arranged into a sum of terms that are more easily quantifiable. Furthermore, setting d_{grass} equal to 1 Bq/m^2:

$$\dot{H}_{out}(t) = \alpha \cdot F_{finite} \cdot K_{grass}(t) \cdot \left\{ \begin{array}{l} f_{grass} + \dfrac{1}{RF_{mig}(t)} \\ \left[\left(\dfrac{K_{trees}}{K_{pave}} \right) \cdot d_{trees}(t) \cdot f_{trees} + d_{pave}(t) \cdot \left(1 - f_{grass}\right) \right] \end{array} \right\} \quad (7)$$

Subjective uncertainty distributions for the various parameters in this equation were selected as given in Table 5.

These parameters were assumed to be independent of each other (i.e., no correlations).

The dose rates were integrated by assuming rates were exponential between the various timepoints considered and summing analytically evaluated integrals.

Several screening runs of Crystal Ball® were performed with looser distributions in order to confirm my initial identification of important parameter uncertainties. These confirmed that the uncertainty in the deposition, kerma, and density of trees were of key importance, as well as the reduction factor to account for a finite urban area, and the fraction of grassed land. Based on these screening runs the distributions were refined to those given above.

A "definitive" Crystal Ball® run was then performed and percentiles of the resulting distributions were extracted for the uncertainty in the output variables requested.

Outdoors "rural" environment

The "rural" environment is described as open fields. However, even in open fields there can be trees and hedges, which will preferentially trap material. This has been allowed for in the simulation [1]. The parameter distributions used were the same as those for the urban environment, with the modifications shown in Table 6.

Preliminary screening runs identified F_{finite} and soil migration parameters to be important.

The relevant Crystal Ball® runs were performed following refinement of the distributions for these parameters and the results extracted.

Question 5

To describe the wet deposition problem for both the urban and rural areas, modifications were made to the parameter distributions describing deposition density on trees and paved areas, and the results of question 2 were substituted for those of question 1. These modifications are reflected in Table 7.

In order to model the uncertainty for the rural environment following wet deposition, F_{finite}, F_{grass}, and F_{trees} were modified as in Question 4.

Crystal Ball® runs were performed for these distributions and percentiles extracted.

Question 6

The results of questions 5 and 6 were combined together in the same manner as question 3, taking into account the probability of rain.

1 It was not clear from the question whether the results should be evaluated for 1Bq/m^2 deposited to rural grass area, urban grass area, or to "open fields". I have assumed the deposition was to "open fields", and thus that differences in deposition velocities to various crops, grasses and plowed fields can be ignored. The shielding properties of these different surfaces are considered not to be very different from grass, and when averaged over the types of surface can be considered as "part" of the uncertainty in the fraction of land with trees.

Table 5.

Parameter	Subjective uncertainty distribution	Reasoning
α	Normal distribution with mean = 0.7 and σ = 0.04; truncated at 0.1 and 2.0	Based primarily on considerations of Figures 31 and 38 in Ref. [4]; both planar and isotropic geometries are relevant, since activity on trees are less planar.
F_{finite}	Step uniform distribution: 30% 0.6 - 0.9 55% 0.4 - 0.6 15% 0.3 - 0.4	Using Figure 3 of IAEA (in press, a), an estimate of the distribution of effective radii of disk sources was made, thus: 30% probability that radius was between 20 m and 100 m; 55% probability that radius was between 10 m and 20 m; and 15% probability that radius was between 5 m and 10 m. Making judgements about typical surface roughnesses, this distribution was subjectively translated into one in terms of a reduction factor.
$K_{grass}(t)$, $RF_{mig}(t)$	Distributions from Question 1, with same input parameter uncertainty distributions	
(K_{trees}/K_{pave})	Step uniform distribution: 80% 0.2 - 1.0 20% 1.0 - 2.0	Personal judgement based on consideration of the effective distance from the main source of activity, modified by shielding by canopy.
$d_{trees}(t)$	At t=0, step uniform distribution: 40% 1.0-3.0 30% 3.0-5.0 15% 5.0-10.0 15% 10.0-20.0; At t=1 y, Weibull distribution with location factor=0.5, scale=2, shape=2 and constrained so that the value is < $d_{trees}(0)$; for 0<t<1 y, log-linear interpolation; For t>1 y, $d_{trees}(t)=d_{trees}(1\ y)$. exp $(-\lambda_{trees}t)$ where λ_{trees} is a Weibull distribution, with a location factor of 30, scale=2000, shape=1.1 and truncated at 30 d and 5000 d	Based on estimates contained in Jacob and Meckbach (1987) and expert judgement of possible range; the accident is assumed to be able to occur at any time of the year, and it is assumed unknown whether deciduous trees are in leaf or not.
$d_{pave}(t)$	At t=0, Weibull distribution with location factor = 0.03, scale = 0.15 and shape = 2; at t=1 y, Weibull distribution with location factor = 0.01, scale = 0.1 and shape = 2; truncated at $d_{pave}(0)$; for 0<t<1a, log-linear interpolation; for t>1 y, $d_{pave}(t)=d_{pave}(1\ y)$. exp $(-\lambda_{pave}t)$ where λ_{pave} is a Weibull distribution with a location factor of 100, scale=3000, shape=1.1 and truncated at 100 and 10000	Based on estimates contained in Jacob and Meckbach (1987) and expert judgement of possible range.
f_{grass}	Step uniform distribution: 0.1%-5% 0.1 5%-25% 0.7 25%-40% 0.1 40%-75% 0.1	Subjective personal estimate of fraction of typical urban area that is grass.
f_{trees}	Weibull distribution with a location factor = 0, scale = 0.15 and shape = 2, truncated at 0 and 1.	Subjective personal estimate of fraction of typical urban area that has trees.

Table 6.

Parameter	Subjective uncertainty distribution	Reasoning
F_{finite}	Uniform distribution: min. 0.7 max 0.95	Using Figure 3 of IAEA (in press, a), a re-estimate of the distribution of effective radii of disk sources was made for the rural environment, thus that the effective radius would lie between 40 m and 100 m. Making judgements about typical surface roughnesses, this distribution was subjectively translated into one in terms of a reduction factor.
f_{grass}	Fixed at unity	The rural area is assumed to be 100% grass or grass equivalent surface.
f_{trees}	Weibull distribution with a location factor = 0, scale = 0.05 and shape = 1.1, truncated at 0 and 1.	Subjective personal estimate of fraction of typical rural area that has trees. Clearly in forests this would be higher, but because of the description of rural areas as open fields (although also with the objective of estimating collective dose to rural populations?) this distribution has been selected to be even narrower than for urban areas.

Question 7

I have presumed that the question relates to the physico-chemical form of the radionuclides and not to the physical radioactive decay data (which can be taken account of explicitly on the basis of the relevant energy spectra). In many cases, it is reasonable to assume that isotopes of the same element will have similar physical forms since they will be created from the decay of similar precursors (e.g., ^{137}Cs will often easily be released because ^{137}Xe, its precursor, is a noble gas as well as being volatile itself). There are potentially exceptions to this where the nuclide is created directly from the fission process itself and could be released in a different physical form (e.g., attached to a particle). My knowledge of reactor physics is not sufficient to distinguish between these cases, and I personally would assume that isotopes of the same element would probably have similar chemical forms and to a first approximation they will exhibit identical behavior in terms of migration, runoff, weathering etc.

With regard to the properties of different elements, I would make guesses as to which radionuclides they might mimic, but my knowledge of the chemistry of typical released radionuclides is not adequate to allow these guesses to be given much weight. I don't believe the selection of radionuclides with similar behavior would be strongly influenced by whether the environment is open fields or urban.

Table 7.

Parameter	Subjective uncertainty distribution	Reasoning
$K_{grass}(t)$, $RF_{mig}(t)$	Distributions from Question 2, with same input parameter uncertainty distributions	
$d_{trees}(t)$	At t=0, Weibull distribution with location parameter = 0.03, scale = 0.15, shape = 1.5 truncated at 0.03 and 1.0. At t=1 y, Weibull distribution with location factor=0.01, scale=0.05, shape=1.5 and constrained so that the value is $< d_{trees}(0)$; for $0<t<1$ y, log-linear interpolation; for $t>1$ y, $d_{trees}(t)=d_{trees}(1\ y)$. exp $(-\lambda_{trees}t)$, where λ_{trees} is a Weibull distribution, with a location factor of 30, scale=2000, shape=1.1 and truncated at 30 d and 5000 d	Based on estimates contained in Jacob and Meckbach (1987) and expert judgement of possible range; the accident is assumed to be able to occur at any time of the year, and it is assumed unknown whether deciduous trees are in leaf or not.
$d_{pave}(t)$	At t=0,Weibull distribution with location factor = 0.1, scale = 0.5 and shape = 3 truncated at 0 and 1; at t=1 y, Weibull distribution with location factor = 0.01, scale = 0.2 and shape = 2; truncated at $d_{pave}(0)$; for $0<t<1$ y, log-linear interpolation; for $t>1$ y, $d_{pave}(t)=d_{pave}(1\ y)$. exp $(-\lambda_{pave}t)$, where λ_{pave} is a Weibull distribution with a location factor of 100, scale=3000, shape=1.1 and truncated at 100 and 10000	Based on estimates contained in Jacob and Meckbach (1987) and expert judgement of possible range.

Questions 8, 9 and 10

I have a conceptual problem with the way the question is expressed here. The objective of such a question, presumably, is to assist in the evaluation within an accident consequence assessment of the distribution of individual doses within an exposed population. One prime way of assessing this is to use a frequency distribution of location factors. To express this distribution, one can subdivide the continuum of time-averaged location factors into well-defined groups (e.g., with location factors of 0.001 - 0.01; 0.01 - 0.1; 0.1 - 0.3; 0.3 - 1.0) and then ask for best estimates and uncertainty percentiles of the numbers of individuals in each interval. Alternative approaches can be used also, but the approach used in the question asks for location factors for several locations whose **interpretation** will vary significantly from region to region, and expert to expert. Thus an added uncertainty has been introduced into interpreting exactly what is meant by, for example, a "medium shielding building". This may prove to be unimportant provided the respondents have made estimates in Question 13 for the numbers of people living in these locations that are consistent with **their** understanding of the meaning of, for example, a "medium shielding building". Thus I would contend that the results of question 8 and question 13 should be combined for each respondent before averaging over respondents, rather than combining or even comparing responses for each question separately. I have nevertheless made estimates for the requested information on the basis of my own personal understanding of what the various classes of location factor represent.

Because of this reasoning, there is no justification for using complex models of the geometry of various building types. Instead, the following equation can be used to derive expressions of uncertainty in the ratio indoors in an urban area to that received outdoors in an open lawned area, taking account of the important influencing factors:

$$LF(t) = \frac{\dot{K}_{out}(t)}{\dot{K}_{grass}(t)} \left(SF + R_{(In/Out)}\right) \qquad (8)$$

where

LF	=	Location factor
SF	=	Shielding factor
$R_{(In/Out)}$	=	Ratio of deposition density indoors compared with that outdoors on grass
$K_{out}(t)$	=	Kerma rate outdoors in urban area (from questions 4 and 5) = $H_{out}(t)/\alpha$
$K_{grass}(t)$	=	Kerma rate above an open lawned area (from questions 1 and 2)

The shielding factor here is similar to the "old" concept of a shielding factor (i.e., the ratio of the dose rate inside a structure to that outside). Its main purpose is to represent the physical attenuation of gamma rays by the walls, roofs and windows. The ranges selected here take into account my assessment of the range of attenuation factors for a variety of building types in the class. The attenuation factor is assumed the same for all nuclides, except for cerium which has a significantly lower gamma energy than the rest. The ratio of deposition density indoors to that outdoors (separately for wet and dry deposition) allows for the model to take into account the dose from activity deposited indoors. The kerma rate in a room with unit activity density indoors is assumed to be of the same order as the kerma rate above an open field with the same activity density, i.e., the dominant uncertainty is in how much activity deposits indoors.

The ratios were calculated separately for wet and dry deposition and combined using the same probability of rain as in question 3. The results for wet and dry deposition were used directly in answering question 10. The main difference is for buildings with a high attenuation, such as multi-story buildings, where the ratio indoors/outdoors is much lower for wet deposition.

The results for question 9 at times of 1 year and 10 years were extracted from the spreadsheets directly according to Equation 8, noting that I assumed the denominator to be at time t as well as the numerator, rather than at the time of deposition. Any subsequent analysis of the elicitation should be careful to appreciate this detail.

All distributions were generated using Crystal Ball®; the percentiles were extracted accordingly.

Question 11

The basic model adopted for estimating the Time Integrated Air Concentration (TIAC) indoors compared with outdoors is that elaborated in IAEA (in press, b) and Roed and Cannell (1987), which describe the TIAC as follows:

$$TIAC_{in} = TIAC_{out} \frac{\lambda_r \cdot f}{\lambda_r + \lambda_d} \qquad (9)$$

where λ_r = air exchange rate (h^{-1}); f = the "filter" factor (i.e., the fraction of aerosol not retained in cracks and pores on the way in), and λ_d is the rate coefficient of deposition (h^{-1}).

Table 8.

Parameter	Subjective uncertainty distribution	Reasoning
SF_{low}	Weibull distribution with location parameter = 0.07, scale=0.25, shape=2, truncated at 0.07 and 0.70; for cerium, uniform distribution with min = 0.05, max = 0.30	Expert judgement based on considerations of wall and vehicle thicknesses and resulting attenuation effects, and the following data sources: Refs. [2, 5] and [6]. Consideration of the variation within a single building was also taken into account in deriving the ranges as well as the possible distribution of activity on building surfaces.
SF_{medium}	Weibull distribution with location parameter = 0.03, scale=0.08, shape=2, truncated at 0.03 and 0.25; for cerium, uniform distribution with min = 0.03, max = 0.10	
SF_{high}	Weibull distribution with location parameter = 0.01, scale=0.03, shape=2, truncated at 0.01 and 0.08; for cerium, uniform distribution with minimum = 1×10^{-5} and maximum = 0.01	
SF_{base}	Weibull distribution with location parameter = 3×10^{-4}, scale=5×10^{-3}, shape=2, truncated at 3×10^{-4} and 0.01; for cerium, uniform distribution with minimum = 1×10^{-5} and maximum = 1×10^{-4}	
$SF_{base(high)}$	Weibull distribution with location parameter = 1×10^{-4}, scale=2×10^{-3}, shape=2, truncated at 1×10^{-4} and 5×10^{-3}; for cerium, uniform distribution with minimum = 1×10^{-5} and maximum = 1×10^{-4}	
SF_{car}	Weibull distribution with location parameter = 0.20, scale=0.25, shape=2, truncated at 0.2 and 0.8; for cerium, uniform distribution with minimum = 0.10 and maximum = 0.60	
SF_{bus}	Weibull distribution with location parameter = 0.10, scale=0.25, shape=2, truncated at 0.1 and 0.7; for cerium, uniform distribution with minimum = 0.03 and maximum = 0.40	
$R_{(In/Out)}$	For wet deposition, Weibull distribution with location parameter = 1×10^{-3}, scale=1×10^{-2}, shape=2, truncated at 1×10^{-3} and 1.0; for dry deposition, Weibull distribution with location parameter = 1×10^{-2}, scale = 1×10^{-1} and shape = 2.0	Based on information presented in refs. [5] and [7].

Table 9.

Parameter	Subjective uncertainty distribution	Reasoning
λ_r	For normal ventilation, lognormal distribution with mean=0.65 and standard deviation of 0.27. For sheltered ventilation, mean=0.17 and standard deviation is 0.12. These parameter distributions are the same for all nuclides.	The normal ventilation distribution is based on information on ventilation rates for the UK with relatively "leaky" buildings (windows and doors contribute between 5% and 45% of total leakage) (Warren and Webb, 1980). The sheltered ventilation distribution is based on data for Swedish housing, traditionally more airtight (IAEA, in press, b). The most important factors affecting ventilation rates are wind effects (speed and direction); effects due to temperature differences between indoors and outdoors; and openings, such as windows and doors (IAEA, in press, b).
f	Uniform distributions as follows: Pu-240 from 0.50 to 0.85 Cs-137 from 0.70 to 0.95 I_2 from 0.80 to 1.00 CH_3I from 0.90 to 1.00	These distributions were estimated by subjective judgement and consideration of data in IAEA (in press, b) and Roed and Cannell (1987). The key factors are assumed to be particle size and chemical form.
λ_d	Uniform distributions as follows: Pu-240 from 1.0 to 10.0 Cs-137 from 0.7 to 1.1 I_2 from 0.5 to 1.5 CH_3I from 0.01 to 0.05	These distributions were estimated by subjective judgement and consideration of data in IAEA (in press, b) and Roed and Cannell (1987). The key factors are assumed to be particle size and chemical form. For each nuclide, f and λ_d are assumed to be correlated with a correlation coefficient of 0.5.

Crystal Ball® runs were performed to combine the uncertainties in the parameters and desired percentiles were extracted from the results.

Question 12

No general remarks. See results submitted for detailed comments.

Question 13

The ranges estimated in this section are not of good quality. They are based on very subjective judgements - I do not consider myself a real expert in deriving such ranges. However, I used the following data sources to assist me in coming to some sort of estimate: Francis (1987); CIA (1995); Crick and Brown (1990).

Correlations

The conditional probabilities requested were evaluated from the Crystal Ball® runs directly, by dividing the probability of both distributions simultaneously producing results greater than the median by 0.5. In some instances (relatively few) the probabilities were adjusted subjectively to take account of additional effects that were not directly simulated in the models.

References

The reference throughout to Crystal Ball® is to an add-on piece of software for Excel spreadsheets. This software rapidly allows Monte Carlo simulations to be performed for uncertain distributions, generates uncertainty distributions in the output of spreadsheet models and rapidly identifies parameters whose uncertainties are important (Decisioneering, 1993).

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Note: **Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.**

Question 1. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	21.1	23.5	26.2
10 days	15.1	17.4	19.9
30 days	11.2	13.1	15
100 days	4.56	5.75	6.77
1 year	0.22	0.3	0.375

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.8	2	2.22
30 days	1.24	1.46	1.67
100 days	0.95	1.2	1.41
1 year	0.48	0.68	0.83
3 years	0.06	0.12	0.18

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.4	3.78	4.23
1 day	3.07	3.41	3.79
3 days	2.5	2.76	3.05
10 days	1.14	1.32	1.51
30 days	0.19	0.22	0.25
100 days	0.0004	0.0005	0.0006

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.97	5.54	6.14
3 months	3.16	3.98	4.7
1 year	2.6	3.65	4.52
3 years	1.25	2.53	3.58
10 years	0.84	1.52	2.06
30 years	0.36	0.7	1.07
100 years	0.039	0.102	0.188

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	16.9	19.4	22.2
10 days	15.2	17.4	20
30 days	11.2	13.1	15
100 days	4.65	5.72	6.85
1 year	0.22	0.3	0.38

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.43	1.65	1.91
30 days	1.25	1.46	1.69
100 days	0.97	1.2	1.42
1 year	0.49	0.67	0.84
3 years	0.06	0.13	0.17

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.74	3.12	3.6
1 day	2.51	2.86	3.3
3 days	2.12	2.41	2.78
10 days	1.16	1.32	1.52
30 days	0.19	0.22	0.25
100 days	0.0004	0.0005	0.0006

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.97	4.55	5.25
3 months	3.17	3.96	4.71
1 year	2.63	3.62	4.53
3 years	1.23	2.53	3.48
10 years	0.79	1.51	2.05
30 years	0.33	0.7	1.04
100 years	0.035	0.103	0.18

Question 3. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	19	23.3	26
10 days	15	17.4	20
30 days	11.2	13.1	15.2
100 days	4.58	5.75	6.84
1 year	0.22	0.3	0.38

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.63	1.99	2.21
30 days	1.25	1.46	1.69
100 days	0.95	1.19	1.43
1 year	0.49	0.68	0.85
3 years	0.061	0.12	0.176

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.11	3.75	4.22
1 day	2.85	3.38	3.78
3 days	2.39	2.74	3.06
10 days	1.14	1.32	1.52
30 days	0.19	0.22	0.26
100 days	0.0004	0.0005	0.0006

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.55	5.5	6.14
3 months	3.18	3.98	4.71
1 year	2.62	3.65	4.51
3 years	1.24	2.49	3.6
10 years	0.85	1.5	2.05
30 years	0.34	0.7	1.07
100 years	0.034	0.1	0.187

Question 4. *Effective Dose Rate ($Sv \cdot s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.65	7.1	30
10 days	2.24	5.94	25.5
30 days	1.72	4.56	19.5
100 days	0.718	1.88	7
1 year	0.027	0.069	0.2

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.1×10^{-10}	5.6×10^{-10}	2.4×10^{-10}
30 days	5.5×10^{-10}	1.5×10^{-9}	6.3×10^{-9}
100 days	1.2×10^{-9}	3.3×10^{-9}	1.4×10^{-8}
1 year	1.7×10^{-9}	4.6×10^{-9}	1.8×10^{-8}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.227	0.607	2.57
30 days	0.19	0.51	2.12
100 days	0.15	0.39	1.46
1 year	0.06	0.153	0.44
3 years	0.0089	0.025	0.077

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	5×10^{-11}	1.4×10^{-10}	6×10^{-10}
100 days	1.5×10^{-10}	4.2×10^{-10}	1.69×10^{-9}
1 year	3.9×10^{-10}	1×10^{-9}	3.55×10^{-9}
3 years	5.7×10^{-10}	1.5×10^{-9}	4.8×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.43	1.14	4.83
1 day	0.39	1.04	4.36
3 days	0.33	0.87	3.62
10 days	0.17	0.45	1.92
30 days	0.028	0.077	0.32
100 days	0.0001	0.0002	0.0006

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	3×10^{-12}	1×10^{-11}	4×10^{-11}
3 days	1×10^{-11}	3×10^{-11}	1.1×10^{-10}
10 days	2×10^{-11}	6×10^{-11}	2.7×10^{-10}
30 days	4×10^{-11}	1×10^{-10}	4.2×10^{-10}
100 days	4×10^{-11}	1.1×10^{-10}	4.6×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.62	1.67	6.97
3 months	0.49	1.3	4.84
1 year	0.32	0.82	2.4
3 years	0.18	0.51	1.56
10 years	0.063	0.21	0.67
30 years	0.012	0.056	0.2
100 years	0.0008	0.0058	0.027

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	4.6E-10	1.3×10^{-9}	5.1×10^{-9}
1 year	1.4×10^{-9}	3.7×10^{-9}	1.28×10^{-9}
3 years	3.1×10^{-9}	8×10^{-9}	2.4×10^{-8}
10 years	6×10^{-9}	1.6×10^{-8}	4.5×10^{-8}
30 years	8.7×10^{-9}	2.3×10^{-8}	6.7×10^{-8}
100 years	1×10^{-8}	2.8×10^{-8}	8.3×10^{-8}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.8	3.7	6.9
3 months	1.9	2.6	4.7
1 year	1.6	2.3	3.4
3 years	0.81	1.5	2.5
10 years	0.5	0.9	1.3
30 years	0.2	0.4	0.64
100 years	0.021	0.058	0.11

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.8×10^{-9}	2.5×10^{-9}	4.6×10^{-9}
1 year	5.9×10^{-9}	8.1×10^{-9}	1.4×10^{-8}
3 years	1.4×10^{-8}	2×10^{-8}	3.1×10^{-8}
10 years	3×10^{-8}	4.6×10^{-8}	6.9×10^{-8}
30 years	5.4×10^{-8}	8.6×10^{-8}	1.24×10^{-7}
100 years	7.4×10^{-8}	1.25×10^{-7}	1.8×10^{-7}

Question 5. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.36	6.34	11.9
10 days	2.95	5.53	10.2
30 days	2.25	4.18	7.66
100 days	0.86	1.6	2.92
1 year	0.02	0.051	0.11

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.7×10^{-10}	5.1×10^{-10}	9.5×10^{-10}
30 days	7.2×10^{-10}	1.4×10^{-9}	2.5×10^{-9}
100 days	1.6×10^{-9}	3×10^{-9}	5.4×10^{-9}
1 year	2.2×10^{-9}	4×10^{-9}	7.3×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.29	0.54	1
30 days	0.25	0.46	0.86
100 days	0.18	0.33	0.61
1 year	0.046	0.11	0.25
3 years	0.0074	0.021	0.045

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	7×10^{-11}	1.3×10^{-10}	2.4×10^{-10}
100 days	2×10^{-10}	3.7×10^{-10}	6.9×10^{-10}
1 year	4.6×10^{-10}	8.3×10^{-10}	1.52×10^{-9}
3 years	6.1×10^{-10}	1.2×10^{-9}	2.3×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.54	1.02	1.9
1 day	0.49	0.94	1.73
3 days	0.41	0.78	1.45
10 days	0.22	0.42	0.77
30 days	0.038	0.069	0.13
100 days	0.00005	0.0001	0.0002

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	5×10^{-12}	1×10^{-11}	2×10^{-11}
3 days	1×10^{-11}	2×10^{-11}	4×10^{-11}
10 days	3×10^{-11}	6×10^{-11}	1.1×10^{-10}
30 days	5×10^{-11}	9×10^{-11}	1.7×10^{-10}
100 days	5×10^{-11}	1×10^{-10}	1.8×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.79	1.5	2.8
3 months	0.6	1.1	2.03
1 year	0.25	0.61	1.3
3 years	0.15	0.42	0.93
10 years	0.049	0.19	0.5
30 years	0.012	0.059	0.2
100 years	0.0008	0.0061	0.0256

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	6×10^{-10}	1.11×10^{-9}	2.03×10^{-9}
1 year	1.61×10^{-9}	3×10^{-9}	5.6×10^{-9}
3 years	3×10^{-9}	6.3×10^{-9}	1.24×10^{-8}
10 years	5.3×10^{-9}	1.3×10^{-8}	2.7×10^{-8}
30 years	7.4×10^{-9}	2×10^{-8}	4.6×10^{-8}
100 years	8.8×10^{-9}	2.5×10^{-8}	6.4×10^{-8}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.1	2.6	3.3
3 months	1.7	2.3	2.9
1 year	1.4	2.1	2.7
3 years	0.69	1.4	2.1
10 years	0.47	0.85	1.3
30 years	0.18	0.4	0.65
100 years	0.019	0.059	0.11

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.7×10^{-9}	2.1×10^{-9}	2.6×10^{-9}
1 year	5.3×10^{-9}	7.1×10^{-9}	9×10^{-9}
3 years	1.2×10^{-8}	1.8×10^{-8}	2.3×10^{-8}
10 years	2.6×10^{-8}	4.2×10^{-8}	5.8×10^{-8}
30 years	4.9×10^{-8}	8×10^{-8}	1.1×10^{-7}
100 years	7×10^{-8}	1.2×10^{-7}	1.8×10^{-7}

Question 6. *Effective Dose Rate ($Sv \cdot s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.62	6.65	25.6
10 days	2.17	5.5	20.7
30 days	1.68	4.21	15.3
100 days	0.7	1.7	5.5
1 year	0.025	0.052	0.16

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.1×10^{-10}	5.2×10^{-10}	2×10^{-9}
30 days	5.4×10^{-10}	1.4×10^{-9}	5×10^{-9}
100 days	1.2×10^{-9}	3×10^{-9}	1.1×10^{-8}
1 year	1.7×10^{-9}	4.2×10^{-9}	1.4×10^{-8}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.22	0.56	2.15
30 days	0.19	0.47	1.7
100 days	0.15	0.35	1.15
1 year	0.055	0.14	0.36
3 years	0.0063	0.022	0.063

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	5×10^{-11}	1.3×10^{-10}	4.9×10^{-10}
100 days	1.5×10^{-10}	3.8×10^{-10}	1.35×10^{-9}
1 year	3.8×10^{-10}	8.9×10^{-10}	2.8×10^{-9}
3 years	5.6×10^{-10}	1.3×10^{-9}	3.9×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv\ s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.42	1.06	4
1 day	0.38	0.96	3.6
3 days	0.32	0.8	3
10 days	0.17	0.42	1.57
30 days	0.028	0.07	0.26
100 days	0.00002	0.0001	0.0005

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	3×10^{-12}	1×10^{-11}	3×10^{-11}
3 days	1×10^{-11}	2×10^{-11}	9×10^{-11}
10 days	2×10^{-11}	6×10^{-11}	2.2×10^{-10}
30 days	4×10^{-11}	9×10^{-11}	3.5×10^{-10}
100 days	4×10^{-11}	1×10^{-10}	3.7×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv\ s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.61	1.54	5.9
3 months	0.49	1.16	3.73
1 year	0.3	0.74	2.03
3 years	0.13	0.44	1.3
10 years	0.038	0.18	0.61
30 years	0.0091	0.052	0.2
100 years	0.0007	0.0058	0.0245

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	4.6×10^{-10}	1.1×10^{-9}	4.1×10^{-9}
1 year	1.4×10^{-9}	3.3×10^{-9}	1×10^{-8}
3 years	2.9×10^{-9}	7×10^{-9}	2×10^{-8}
10 years	5.2×10^{-9}	1.4×10^{-8}	3.6×10^{-8}
30 years	7.1×10^{-9}	2×10^{-8}	5.9×10^{-8}
100 years	8.4×10^{-9}	2.6×10^{-8}	7.6×10^{-8}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv\ s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.5	3.5	6.1
3 months	1.9	2.6	4.4
1 year	1.6	2.3	3.3
3 years	0.73	1.5	2.4
10 years	0.48	0.89	1.3
30 years	0.18	0.4	0.63
100 years	0.019	0.057	0.11

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.8×10^{-9}	2.4×10^{-9}	4.3×10^{-9}
1 year	5.9×10^{-9}	8×10^{-9}	1.3×10^{-8}
3 years	1.4×10^{-8}	2×10^{-8}	2.9×10^{-8}
10 years	2.9×10^{-8}	4.6×10^{-8}	6.7×10^{-8}
30 years	5.1×10^{-8}	8.5×10^{-8}	1.2×10^{-7}
100 years	7.1×10^{-8}	1.2×10^{-7}	1.8×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	Slightly larger confidence interval, since not clear that physico-chemical production of the various isotopes are the same in a reactor.
Cs-134/Cs-136	Cs-137	Slightly larger confidence interval, since not clear that physico-chemical production of the various isotopes are the same in a reactor.
Ba-140	Cs-137	Larger confidence interval.
Te-131m/Te-132	I-131	Larger confidence interval.
I-132/I-133/ I-134/I-135	I-131	Almost the same physical/chemical properties. Assume same confidence interval.
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	No knowledge.
Ce-144	Cs-137 / Ru-106 / I-131 / Zr-95	Knowledge too poor to make useful contribution.

Urban Environment

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	Slightly larger confidence interval, since not clear that physico-chemical production of the various isotopes are the same in a reactor.
Cs-134/Cs-136	Cs-137	Slightly larger confidence interval, since not clear that physico-chemical production of the various isotopes are the same in a reactor.
Ba-140	Cs-137	Larger confidence interval.
Te-131m/Te-132	I-131	Larger confidence interval.
I-132/I-133/ I-134/I-135	I-131	Almost the same physical/chemical properties. Assume same confidence interval.
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	No knowledge.
Ce-144	Cs-137 / Ru-106 / I-131 / Zr-95	Knowledge too poor to make useful contribution.

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m^2 of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.05	0.15	0.58
(ii) medium shielding building	0.024	0.074	0.32
(iii) high shielding building	0.012	0.045	0.2
(iv) basement family house	0.0055	0.035	0.17
(v) basement of multi-story block	0.0044	0.033	0.16
(vi) inside typical car	0.074	0.21	0.8
(vii) inside typical bus	0.056	0.17	0.65

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.05	0.15	0.58
(ii) medium shielding building	0.024	0.074	0.32
(iii) high shielding building	0.012	0.045	0.2
(iv) basement family house	0.0055	0.035	0.17
(v) basement of multi-story block	0.0044	0.033	0.16
(vi) inside typical car	0.074	0.21	0.8
(vii) inside typical bus	0.056	0.17	0.65

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.05	0.15	0.58
(ii) medium shielding building	0.024	0.074	0.32
(iii) high shielding building	0.012	0.045	0.2
(iv) basement family house	0.0055	0.035	0.17
(v) basement of multi-story block	0.0044	0.033	0.16
(vi) inside typical car	0.074	0.21	0.8
(vii) inside typical bus	0.056	0.17	0.65

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.05	0.15	0.58
(ii) medium shielding building	0.024	0.074	0.32
(iii) high shielding building	0.012	0.045	0.2
(iv) basement family house	0.0055	0.035	0.17
(v) basement of multi-story block	0.0044	0.033	0.16
(vi) inside typical car	0.074	0.21	0.8
(vii) inside typical bus	0.056	0.17	0.65

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.033	0.11	0.41
(ii) medium shielding building	0.02	0.059	0.26
(iii) high shielding building	0.0058	0.035	0.17
(iv) basement family house	0.0037	0.033	0.16
(v) basement of multi-story block	0.0037	0.033	0.16
(vi) inside typical car	0.054	0.18	0.68
(vii) inside typical bus	0.03	0.12	0.52

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.037	0.12	0.36	0.017	0.062	0.21
(ii) medium shielding building	0.017	0.059	0.18	0.0082	0.031	0.11
(iii) high shielding building	0.0075	0.035	0.12	0.004	0.02	0.072
(iv) basement family house	0.0035	0.028	0.1	0.0021	0.015	0.06
(v) basement of multi-story block	0.0029	0.027	0.097	0.0016	0.014	0.058
(vi) inside typical car	0.056	0.15	0.45	0.024	0.087	0.29
(vii) inside typical bus	0.04	0.12	0.39	0.02	0.068	0.22

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.037	0.12	0.36	0.017	0.062	0.21
(ii) medium shielding building	0.017	0.059	0.18	0.0082	0.031	0.11
(iii) high shielding building	0.0075	0.035	0.12	0.004	0.02	0.072
(iv) basement family house	0.0035	0.028	0.1	0.0021	0.015	0.06
(v) basement of multi-story block	0.0029	0.027	0.097	0.0016	0.014	0.058
(vi) inside typical car	0.056	0.15	0.45	0.024	0.087	0.29
(vii) inside typical bus	0.04	0.12	0.39	0.02	0.068	0.22

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.037	0.12	0.36	0.017	0.062	0.21
(ii) medium shielding building	0.017	0.059	0.18	0.0082	0.031	0.11
(iii) high shielding building	0.0075	0.035	0.12	0.004	0.02	0.072
(iv) basement family house	0.0035	0.028	0.1	0.0021	0.015	0.06
(v) basement of multi-story block	0.0029	0.027	0.097	0.0016	0.014	0.058
(vi) inside typical car	0.056	0.15	0.45	0.024	0.087	0.29
(vii) inside typical bus	0.04	0.12	0.39	0.02	0.068	0.22

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.037	0.12	0.36	0.017	0.062	0.21
(ii) medium shielding building	0.017	0.059	0.18	0.0082	0.031	0.11
(iii) high shielding building	0.0075	0.035	0.12	0.004	0.02	0.072
(iv) basement family house	0.0035	0.028	0.1	0.0021	0.015	0.06
(v) basement of multi-story block	0.0029	0.027	0.097	0.0016	0.014	0.058
(vi) inside typical car	0.056	0.15	0.45	0.024	0.087	0.29
(vii) inside typical bus	0.04	0.12	0.39	0.02	0.068	0.22

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.022	0.078	0.24	0.01	0.04	0.15
(ii) medium shielding building	0.014	0.048	0.15	0.0061	0.026	0.092
(iii) high shielding building	0.0036	0.028	0.1	0.0021	0.015	0.06
(iv) basement family house	0.0026	0.026	0.096	0.0015	0.014	0.057
(v) basement of multi-story block	0.0026	0.026	0.096	0.0015	0.014	0.057
(vi) inside typical car	0.037	0.13	0.42	0.018	0.072	0.25
(vii) inside typical bus	0.024	0.089	0.3	0.012	0.05	0.18

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.15	0.64
(ii) medium shielding building	0.026	0.076	0.3
(iii) high shielding building	0.015	0.049	0.21
(iv) basement family house	0.01	0.037	0.17
(v) basement of multi-story block	0.0098	0.036	0.16
(vi) inside typical car	0.074	0.21	0.76
(vii) inside typical bus	0.055	0.16	0.63

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.15	0.64
(ii) medium shielding building	0.026	0.076	0.3
(iii) high shielding building	0.015	0.049	0.21
(iv) basement family house	0.01	0.037	0.17
(v) basement of multi-story block	0.0098	0.036	0.16
(vi) inside typical car	0.074	0.21	0.76
(vii) inside typical bus	0.055	0.16	0.63

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.15	0.64
(ii) medium shielding building	0.026	0.076	0.3
(iii) high shielding building	0.015	0.049	0.21
(iv) basement family house	0.01	0.037	0.17
(v) basement of multi-story block	0.0098	0.036	0.16
(vi) inside typical car	0.074	0.21	0.76
(vii) inside typical bus	0.055	0.16	0.63

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.15	0.64
(ii) medium shielding building	0.026	0.076	0.3
(iii) high shielding building	0.015	0.049	0.21
(iv) basement family house	0.01	0.037	0.17
(v) basement of multi-story block	0.0098	0.036	0.16
(vi) inside typical car	0.074	0.21	0.76
(vii) inside typical bus	0.055	0.16	0.63

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.03	0.1	0.43
(ii) medium shielding building	0.022	0.061	0.25
(iii) high shielding building	0.01	0.037	0.17
(iv) basement family house	0.0093	0.035	0.16
(v) basement of multi-story block	0.0093	0.035	0.16
(vi) inside typical car	0.051	0.17	0.73
(vii) inside typical bus	0.035	0.12	0.47

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.13	0.3
(ii) medium shielding building	0.02	0.047	0.11
(iii) high shielding building	0.0073	0.017	0.04
(iv) basement family house	0.0025	0.0065	0.014
(v) basement of multi-story block	0.002	0.0052	0.012
(vi) inside typical car	0.088	0.19	0.4
(vii) inside typical bus	0.06	0.14	0.32

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.13	0.3
(ii) medium shielding building	0.02	0.047	0.11
(iii) high shielding building	0.0073	0.017	0.04
(iv) basement family house	0.0025	0.0065	0.014
(v) basement of multi-story block	0.002	0.0052	0.012
(vi) inside typical car	0.088	0.19	0.4
(vii) inside typical bus	0.06	0.14	0.32

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.13	0.3
(ii) medium shielding building	0.02	0.047	0.11
(iii) high shielding building	0.0073	0.017	0.04
(iv) basement family house	0.0025	0.0065	0.014
(v) basement of multi-story block	0.002	0.0052	0.012
(vi) inside typical car	0.088	0.19	0.4
(vii) inside typical bus	0.06	0.14	0.32

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.13	0.3
(ii) medium shielding building	0.02	0.047	0.11
(iii) high shielding building	0.0073	0.017	0.04
(iv) basement family house	0.0025	0.0065	0.014
(v) basement of multi-story block	0.002	0.0052	0.012
(vi) inside typical car	0.088	0.19	0.4
(vii) inside typical bus	0.06	0.14	0.32

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.028	0.077	0.18
(ii) medium shielding building	0.014	0.034	0.068
(iii) high shielding building	0.0024	0.0067	0.015
(iv) basement family house	0.0014	0.0044	0.011
(v) basement of multi-story block	0.0014	0.0044	0.011
(vi) inside typical car	0.053	0.15	0.37
(vii) inside typical bus	0.024	0.095	0.24

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 μm), Cs-137 (particulate, representative of ≈ 1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.03	0.07	0.2
Cs-137	0.2	0.33	0.48
I_2	0.19	0.34	0.51
CH_3I	0.84	0.9	0.95

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.01	0.02	0.07
Cs-137	0.04	0.11	0.25
I_2	0.04	0.11	0.27
CH_3I	0.57	0.79	0.9

Question 12

Ratio Tiac Indoors/Outdoors

Nuclide	Similar Ratio To (delete as appropriate)	Specific Comments
Ru-103/Ru-106	Cs-137	Larger confidence interval.
Te-129m/Te-132	I_2	Larger confidence interval.
Cs-134	Cs-137	Slightly larger confidence interval, since 134 is produced in different way from 137 in reactor; possibly different physical properties, but probably similar chemical ones.
Ba-140	Cs-137	Much larger confidence interval.
Ce-144	Cs-137 / Pu-240	Much larger confidence interval.
Pu-238/Pu-241	Pu-240	Only slightly larger confidence interval. Most Pu are physically/chemically the same.
Cm-242	Cs-137 / Pu-240	Much larger confidence interval.

Question 13. *Population Fractions.*

POPULATION FRACTION	5th Quantile	Median	95th Quantile
(i) agricultural and other outdoor workers	0.01	0.03	0.08
(ii) indoor workers	0.4	0.53	0.7
(iii) non-active adult population[a]	0.11	0.16	0.21
(ii) schoolchildren	0.08	0.13	0.18

a. All adults are considered to be in category i, ii, or iii. The non-active adult population are those that are not agricultural and outdoor workers or indoor workers. Activity here refers to employment not amount of energy expended.

People Working Outdoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.01	0.05	0.1
(ii) medium shielding, e.g., single brick family house	0.4	0.5	0.65
(iii) high shielding, e.g., multi-story office block	0.01	0.04	0.08
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.01	0.02	0.05
(vii) inside typical bus	0.001	0.01	0.02

People Working Indoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.01	0.03	0.05
(ii) medium shielding, e.g., single brick family house	0.4	0.65	0.85
(iii) high shielding, e.g., multi-story office block	0.1	0.25	0.35
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.01	0.03	0.05
(vii) inside typical bus	0.002	0.01	0.04

Non-Active Adult Population Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.01	0.03	0.05
(ii) medium shielding, e.g., single brick family house	0.75	0.85	0.97
(iii) high shielding, e.g., multi-story office block	0.01	0.03	0.05
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.0005	0.005	0.03
(vii) inside typical bus	0.0005	0.005	0.03

Schoolchildren Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.01	0.03	0.05
(ii) medium shielding, e.g., single brick family house	0.6	0.75	0.9
(iii) high shielding, e.g., multi-story office block	0.02	0.1	0.2
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.0005	0.005	0.03
(vii) inside typical bus	0.002	0.01	0.04

People Working Outdoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.02	0.1	0.15
(ii) medium shielding, e.g., single brick family house	0.3	0.4	0.6
(iii) high shielding, e.g., multi-story office block	0.0001	0.001	0.01
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.01	0.02	0.05
(vii) inside typical bus	0.001	0.01	0.02

People Working Indoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.02	0.1	0.15
(ii) medium shielding, e.g., single brick family house	0.7	0.8	0.95
(iii) high shielding, e.g., multi-story office block	0.0001	0.001	0.01
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.01	0.03	0.05
(vii) inside typical bus	0.002	0.01	0.04

Non-Active Adult Population Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.01	0.06	0.1
(ii) medium shielding, e.g., single brick family house	0.75	0.85	0.97
(iii) high shielding, e.g., multi-story office block	0.0001	0.001	0.01
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.0005	0.005	0.05
(vii) inside typical bus	0.0005	0.005	0.05

Schoolchildren Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.02	0.1	0.15
(ii) medium shielding, e.g., single brick family house	0.6	0.75	0.9
(iii) high shielding, e.g., multi-story office block	0.01	0.08	0.2
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.0005	0.005	0.05
(vii) inside typical bus	0.002	0.01	0.05

Estimated Dosages from Outdoor Exposure in Sample Countries

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.005	0.03	0.05
(ii) medium shielding, e.g., single brick family house	0.6	0.7	0.9
(iii) high shielding, e.g., multi-story office block	0.05	0.2	0.4
(iv) basement of single family house	0.00003	0.0001	0.0005
(v) basement multi-story office block	0.00003	0.0001	0.0005
(vi) inside typical car	0.003	0.03	0.07
(vii) inside typical bus	0.001	0.005	0.03

EXPERT D

Prologue

Uncertainty distributions of parameters depend on the range of application. This response for an Uncertainty Analysis of Consequence Assessment Programs assumes that uncertainty distributions of average parameters are needed. For example, the figures for the gamma dose-rate in air after a unit radionuclide activity deposition per unit area (Elicitation Questions 1 to 3) are intended to represent the uncertainty distribution of the average at many sites. The distributions of the gamma dose-rate in air after unit radionuclide activity depositions per unit area *a* at the single sites are wider. On the other hand, if the deposition mode is not specified, the distribution presents values of single deposition events, some of which are dry and others wet. Here, not the average about deposition events are presented, since it is assumed, that in Probabilistic Consequence Assessment Programs single points of distributions are calculated by simulated many release events, each of which has its own simulated meteorological condition and not average meteorological conditions. Other assumed conditions for deriving the parameter distributions are specified in the text.

Gamma dose-rates in air after wet depositions have been by far more extensively studied than gamma dose-rates after dry depositions. Therefore, the current study, is based on the experiences gained after wet depositions and adaptations to dry depositions are assumed in a second step. Correspondingly, in the chapters of this report first wet depositions are dealt with followed by a section on dry deposition, which is the opposite order of the Elicitation Questions.

1. Gamma dose-rates in air above open lawned areas

1.1 Wet depositions

Gamma dose-rates in air due to radionuclide distributions on and in the ground have been calculated by various authors (see e.g., Jacob et al., 1990 and references therein). After the reactor accident at Chernobyl, it has been found that the initial gamma dose rate in air after a wet deposition at a long distance from the release point is well described by a plane source in the ground below a soil slab with a mass per unit area of 0.5 g • cm^{-2} (Jacob and Meckbach, 1995). Average deviations of the observed gamma dose rates in air from this reference geometry have been calculated (see Table 1). The 5th and 95th quantile for the average value have been obtained by assuming a normal distribution of the measured values.

Table 1. Ratios of nuclide-specific gamma dose-rates in air measured during the fifth week after a wet deposition of radionuclides and calculated for the reference geometry of a plane source in the ground below a soil slab of 0.5 g • cm^{-2} (after Jacob and Meckbach, 1995).

Radionuclide	5th Quantile	Average	95th Quantile
^{103}Ru	0.88	0.96	1.04
^{131}I	0.94	1.07	1.19
^{134}Cs	0.97	1.01	1.05
^{140}La	0.78	0.88	0.99

Table 2. Average values of the conversion factors, D_F^M, relating gamma dose-rates in air and the activity per unit area for plane sources in the ground below a soil slab with a mass per unit area of 0.5 g • cm^{-2} (Jacob et al., 1990).

Radionuclide	D_F^M $Gy \cdot s^{-1}$ per $Bq \cdot m^{-2}$	Decay constant, λ (a^{-1})
^{95}Zr	6.14×10^{-16}	3.96
^{95}Nb	6.39×10^{-16}	7.19
^{106}Ru/^{106}Rh	1.73×10^{-16}	0.688
^{131}I	3.28×10^{-16}	31.5
^{137}Cs/^{137m}Ba	4.79×10^{-16}	0.0231

According to these results, the geometry of a plane source in the ground below a soil slab with a mass per unit area of 0.5 g • cm^{-2} has been chosen here as being representative for the gamma dose rate in air during the first few weeks after a wet deposition at a large distance from the release site. The corresponding factors are assumed to be normally distributed with average values as summarized in Table 2 and a relative standard deviation of 5%.

Radionuclides, for which the contribution of the progeny in the radioactive decay chain does not change significantly the relative time dependence of the gamma dose-rate, have been defined as radionuclides with simple time dependences (Jacob et al., 1988a). ^{106}Ru, ^{131}I and ^{137}Cs belong to this class of radionuclides, for which the average gamma dose-rate in air, $\dot{D}(t)$, at the time after a wet deposition may be approximated by

$$\dot{D}(t) = A \cdot D_F \cdot \exp(-\lambda t) \cdot r(t), \qquad (1)$$

where A (Bq • m^{-2}) is the activity deposited per unit area, λ the radioactive decay constant and $r(t)$ a function describing the attenuation due to the migration into the soil. The function $r(t)$ was derived by Jacob et al. (1994) from observations at large distances from the Chernobyl nuclear power plant and from data obtained for the weapons fallout in the form

$$r(t) = a \cdot \exp(-0.61 \cdot t) + b \cdot \exp(-0.015 \cdot t), \qquad (2)$$

where t is the time after deposition in years. After the reactor accident at Chernobyl it has been observed that at sites close to the release point, cesium migrated less into the soil than at larger distances (Balanov et al., 1996). The change of the relative amount of soluble cesium in the total Cesium deposit with the distance of the deposition site from the release point was considered to be the probable source of this difference in migration. In the Elicitation Questions no information has been given on the relative amount of soluble components in the deposit. This uncertainty contributes to the uncertainty in the parameters a and b. Average values of the distributions were chosen to be higher than the results of Jacob et al. (1994) (a=0.46, b=0.54), since that approximation is for the extreme case of large distances from the release point, i.e., for relatively large amounts of soluble components. The time dependence of the uncertainty distribution of a and b was based on the data on cesium depth distribution after the Chernobyl accident and after the atmospheric nuclear weapons tests, collected in ICRU 53 (1995).

For ^{106}Ru, ^{131}I and ^{137}Cs, the response to Elicitation Question 2 was based on log-normal distributions with a median value for a of 0.5 and for b of 0.6. The relative standard deviation immediately after the deposition ($t \leq 0.1$ y) was assumed to be 1.1 and for 10 years after deposition to be 1.3. For other times, interpolation and extrapolation was performed linearly in the relative standard deviation and logarithmically in time. The distribution of $\dot{D}(t)$ was calculated with the program Crystal Ball from the distributions of D_F, a, and b by rejecting values of $r(t)$ that are larger than 1.5, which corresponds to a plane source on a surface.

In the case of ^{95}Zr/^{95}Nb, the time dependence of the gamma dose-rate in air is non-trivial, due to the contribution of ^{95}Nb, produced by the deposited ^{95}Zr (Jacob et al., 1988b):

$$\dot{D}(t) = A_Z \cdot r(t), \left(\begin{array}{l} D_F^Z \cdot \exp(-\lambda_Z \cdot t) + D_F^N \\ \dfrac{\lambda_N}{\lambda_Z - \lambda_N} \left(\exp(-\lambda_N \cdot t) - \exp(-\lambda_Z \cdot t) \right) \end{array} \right) + A_N \cdot r(t) \cdot D_F^N \cdot \exp(-\lambda_Z \cdot t), \qquad (3)$$

where the index "Z" is used for ^{95}Zr and the index "N" for ^{95}Nb.

The Elicitation Questions do not specify whether the deposited activity of 1 Bq • m^{-2} is ^{95}Zr or the sum of ^{95}Zr and ^{95}Nb. It could also be assumed that an activity of 1 Bq • m^{-2} of each of the both radionuclides is deposited. In any case, an approximation of the right-hand side of Equation (3) by a single exponential function with the decay constant of ^{95}Zr and the sum of the two conversion factos D_F^Z and D_F^N leads for one of the time points specified in the Elicitation Questions to an error of more than 50%. For the response given here, the gamma dose-rate due to a deposition of ^{95}Zr was calculated (i.e., A_N was set to zero). In a second set of responses A_Z = A_N = 1 Bq • m^{-2} is assumed.

Zirconium, accidentally released by a nuclear power plant, has a potentially higher degree of insolubility than cesium. Results obtained after the Chernobyl accident (Balanov et al., 1996) indicate that such a case is best approximated by a higher value of b. Here, an average value of 0.8 was assumed for b. Again, in the simulation of the distribution, values of $r(t)$ larger than 1.5 were rejected. The assumed parameter distributions are summarized in Table 3.

1.2 Dry depositions

After a dry deposition on a lawned area, the radionuclides are attached to the grass and to the soil surface. The radiation is attenuated by the biomass of the grass and by the surface roughness. The attenuation due to migration into the soil is expected to be negligible before the first rain event after the deposition. Therefore, the average gamma dose-rate in air immediately after a dry deposition of ^{106}Ru, ^{131}I and ^{137}Cs is assumed here to be about 30% higher than for a wet deposition with the same activity per unit area. It is not known how this difference changes with time. It is assumed here that about half of the difference decreases with the short-term half-live in Equation (2).

Table 3. For a response to Elicitation Question 2, the parameters D_F, a, and b in Equations (1), (2), and (3) were assumed to be distributed as specified in the Table. The simulation was performed under the boundary condition $r(t) \leq 1.5$. For times not specified in the Table, relative standard deviations of the distributions were obtained by linear interpolation and extrapolation of the standard deviation and logarithmetic interpolation and extrapolation in time.

Parameter	Radionuclides	Time (a)	Distribution	Average	Relative Standard Deviation
D_F	^{95}Zr, ^{106}Ru, ^{131}I and ^{137}Cs	all	normal	Table 2	0.05
a	^{95}Zr, ^{106}Ru, ^{131}I and ^{137}Cs	≤0.1 10	log normal	0.5 0.5	1.1 1.3
b	^{106}Ru, ^{131}I and ^{137}Cs	≤0.1 10	log normal	0.6 0.6	1.1 1.3
b	^{95}Zr	≤0.1 10	log normal	0.8 0.8	1.1 1.3

Table 4. For a response to Elicitation Question 1, the parameters D_F, a and b in Equations (1), (2) and (3) were assumed to be distributed as specified in the Table. The simulation was performed under the boundary condition $r(t) \leq 1.5$. For times not specified in the Table, linear interpolation and extrapolation was applied to the relative standard deviations and logarithmetic interpolation and extrapolation in time.

Parameter	Radionuclides	Time (a)	Distribution	Average	Relative Standard Deviation
D_F	^{95}Zr, ^{106}Ru, ^{131}I and ^{137}Cs	all	normal	Table 2	0.05
a	^{106}Ru, ^{131}I and ^{137}Cs	≤0.1 10	log normal	0.7 0.7	1.1 1.3
b	^{106}Ru, ^{131}I and ^{137}Cs	≤0.1 10	log normal	0.7 0.7	1.1 1.3
a	^{95}Zr	≤0.1 10	log normal	0.55 0.55	1.1 1.3
b	^{95}Zr	≤0.1 10	log normal	0.85 0.85	1.1 1.3

In the case of ^{95}Zr, the same initial attenuation after a dry deposition is assumed as for the other radionuclides. Due to the potentially higher proportion of the insoluble components, the long term component *b* is chosen to be higher than for the other radionuclides.

For the simulation of the distribution of $\dot{D}(t)$ Equations (1), (2) and (3), and the parameter distributions in Table 4 were used. The simulation was performed under the boundary condition $r(t) \leq 1.5$.

1.3 Average deposition conditions

Precipitation data from a meteorological station close to Munich were used to assess average frequencies of wet and dry periods. Time intervals of 10 min were studied and treated as an interval with precipitation, if the precipitation rate averaged over the interval was larger than 0.3 mm h^{-1}. For four recent years, these data were recorded for more than 95% of the total year. Results in Table 5 show that precipitation occurs in about 10% of the intervals. This value was used in the simulation of the gamma dose-rate distribution to respond to Elicitation Question 3.

Table 5. Frequency of 10-min-intervals with precipitation rates larger than 0.3 mm h^{-1} at a meteorological station near Munich.

Year	1989	1992	1993	1994
Frequency (%)	9	9	15	7

2. Effective dose rates and effective doses

2.1 Wet depositions

The effective dose rate $\dot{E}_w$ after a wet deposition is given by

$$\dot{E}_w(t) = f_w(t) \cdot K_E \cdot \dot{D}(t), \tag{4}$$

where K_E (Sv • Gy^{-1}) is the conversion factor relating the gamma dose-rate in air to the average effective dose rate of adults, and $f_W(t)$ is the location factor after a wet deposition relating the gamma dose-rate in air above an open, lawned area to the gamma dose-rate at the location of interest. Values of K_E have been calculated by Petoussi et al., (1991), and the average K_E is assumed here to be normally distributed with an average value of 0.75 Sv • Gy^{-1} and a relative standard deviation of 0.05.

Measured location factors for the first three years after a wet deposition of cesium in rural and urban environments have been published by Likhtarev et al. (1995). The measured sites have been grouped into the four categories "lawns and parks," "predominantly unpaved," "predominantly paved," and "paved." It is clearly demonstrated that the contribution of paved surfaces to the gamma dose-rate at an average outdoor location decreases with time within several years down to a negligible amount. According to these results, location factors may be parameterized in the form,

$$f_w(t) = c + d \cdot \exp(-0.32 \cdot t), \tag{5}$$

where t is the time after the deposition in years. Location factors are here assumed to be log-normally distributed. The geometric mean of the results for the two site categories "predominantly paved" and "predominantly unpaved" is taken to be representative for the average value of $f_W(t)$ for outdoor locations in a typical urban area. Taking the category "predominantly paved" as representative for the 5th quantile and the category "predominantly unpaved" as representative for the 95th quantile, the values of the distribution parameters in Table 6 have been chosen.

For ^{131}I, after a wet deposition, the contribution of paved areas to the gamma dose-rate in air outdoors in an urban environment was reported to be negligible (Jacob et al., 1987). Therefore, the location factor for iodine in an urban environment is assumed here to be the constant term c in equation (5) for cesium, which describes the situation with negligible contributions from paved surfaces. Compared to cesium and iodine, ruthenium was reported to have an intermediate behavior (Jacob et al., 1987). Practically nothing is known about the behavior of zirconium in urban environments. For the distribution of the location factor, an average value has been assumed as for cesium; the standard deviation is assumed to be larger.

Effective doses $E_W(t)$ are obtained by integrating the effective dose-rates as given for ^{106}Ru, ^{131}I and ^{137}Cs in Equations (1), (2), (4), and (5):

$$E_W(t) = K_E \cdot A \cdot D_F \cdot I_W(\lambda, t), \tag{6}$$

where

$$\begin{aligned} I_W(\lambda,t) = &\frac{ac}{\lambda+0.61}\left(1-\exp(-(\lambda+0.61)t)\right) \\ &+\frac{ad}{\lambda+0.93}\left(1-\exp(-(\lambda+0.93)t)\right) \\ &+\frac{bc}{\lambda+0.015}\left(1-\exp(-(\lambda+0.015)t)\right) \\ &+\frac{bd}{\lambda+0.335}\left(1-\exp(-(\lambda+0.335)t)\right), \end{aligned} \tag{7}$$

and λ is the radioactive decay constant in (Ha^{-1}). In the case of ^{95}Zr, $H\dot{E}_w(t)$ is modeled by Equations (2), (3), (4) and (5), and the integration over the time yields

$$E_W(t) = K_E \cdot \left(\begin{aligned} &A_Z \cdot \Big(D_F^Z \cdot I_W(\lambda_Z,t) + D_F^N \cdot \\ &\qquad \frac{\lambda_N}{\lambda_Z - \lambda_N}\left(I_W(\lambda_N,t) - I_W(\lambda_Z,t)\right)\Big) \\ &\qquad + A_N \cdot D_F^N \cdot I(\lambda_N,t)\Big) \end{aligned} \right) \tag{8}$$

Again, in a first set of responses A_N is set equal to zero and in a second set $A_Z = A_N = 1$ Bq • m^{-2}.

The site category "predominately unpaved" in Likhtarev et al., 1995 is assumed here to be representative for typical outdoor locations in villages. Another typical location outdoors in rural environments are open fields. These may consist of meadows and fields. After wet deposition, gamma dose-rates in air over meadows and fields are comparable to dose-rates over open lawned areas, as long as no agricultural work on the fields has been performed. This kind of geometry has been treated in the responses to the Elicitation Questions 1, 2, and 3. For the responses to the Elicitation Questions 4, 5, and 6, it is assumed that the fields are plowed between the deposition and the first measurements. Gamma dose-rates in air over plowed fields have been measured to be about half of the gamma dose-rates in air over open lawned areas with the same activity per unit area (Balanov et al., 1996; Burson and Profio, 1977). For both kinds of outdoor rural locations, "predominantly unpaved" sites and a mixture over meadows and plowed fields, locations factors $f_W(t)$ were found to be relatively independent of time after deposition. Therefore, in Equations (5) and (7), the parameter d is set equal to zero for outdoor locations in a typical rural environment.

For responding to Elicitation Question 5, Equations (1) to (8) and the parameter distributions in Table 3 and in Table 6 were used.

2.2 Dry depositions

The effective dose rate $\dot{E}_D$ after a dry deposition may be calculated by:

$$\dot{E}_D = f_D(t) \cdot K_E \cdot \dot{D}(t), \quad (9)$$

where $f_D(t)$ is the location factor for a dry deposition, relating the gamma dose-rate in air over an open, lawned area to the gamma dose-rate in air at the location of interest.

Location factors $f_D(t)$ for dry depositions have been calculated with the help of photon transport simulations by Meckbach and Jacob (1988). According to the results, location factors immediately after dry depositions are higher than after wet depositions, at least in seasons where deciduous trees and bushes have leaves that potentially lead to high deposition rates (Jonas, 1984). About one year after the deposition and later, the location factors for dry and wet depositions are expected to be comparable, if it is assumed that the leaves are dropped in the autumn. This effect is parameterized here by

$$f_D(t) = f_W(t) + e \cdot \exp(-1.0 \cdot t), \quad (10)$$

where t in the time after deposition in years. The average values of the initial location factors after dry depositions are assumed here to be equal for the various radionuclides. However, iodine and ruthenium have be observed to be subject to a higher wash-off than cesium (Roed, 1987). These effects are modeled here by using higher values of e and lower values of d for ruthenium and iodine, as compared to cesium.

The effective dose E_D is obtained by integration of $\dot{E}_D$ over the time since deposition to

$$E_D(t) = E_W(t) + \Delta E(t), \quad (11)$$

for ^{106}Ru, ^{131}I and ^{137}Cs with

$$\Delta E(t) = K_E \cdot A \cdot D_F \cdot \Delta I(\lambda, t), \quad (12)$$

Table 6. Distributions of the parameters in Equations (4) to (8) for responding to Elicitation Question 5. The value of *d* was set equal to zero for iodine in urban environments and for rural environments. Distribution for times not specified in the Table were obtained by linear interpolation of the parameter value and logarithmetic interpolation in time.

Parameter	Radionuclides and Environment	Time (a)	Distribution	Average	Relative Standard Deviation
K_E	all	all	normal	0.75	0.05
c	^{106}Ru, ^{131}I and ^{137}Cs, urban	≤0.1 ≥3	log normal	0.3	1.15 1.25
c	^{95}Zr, urban	≤0.1 ≥3	log normal	0.3	1.2 1.3
d	^{137}Cs, urban	≤0.1 ≥3	log normal	0.25	1.15 1.25
d	^{106}Ru, urban	≤0.1 ≥3	log normal	0.125	1.15 1.25
d	^{95}Zr, urban	≤0.1 ≥3	log normal	0.25	1.2 1.3
c	^{137}Cs, rural	all	log normal	0.75	1.1

and

$$\Delta I(\lambda,t)=\frac{ae}{\lambda+1.61}\left(1-\exp\left(-(\lambda+1.61)t\right)\right)$$
$$+\frac{be}{\lambda+1.015}\left(1-\exp\left(-(\lambda+1.015)t\right)\right). \quad (13)$$

In the case of ^{95}Zr we obtain

$$\Delta E(t)=K_E\cdot\left(\begin{array}{l}A_Z\cdot\left(\begin{array}{l}D_F^Z\cdot\Delta I(\lambda_Z,t)+D_F^N\dfrac{\lambda_N}{\lambda_Z-\lambda_N}\\ \left(\Delta I(\lambda_N,t)-\Delta I(\lambda_Z,t)\right)\end{array}\right)\\ \quad+A_N\cdot D_F^N\cdot\Delta I(\lambda_N,t)\end{array}\right) \quad (14)$$

Again, in a first set of responses A_N is set equal to zero and in a second set $A_Z = A_N = 1\ \mathrm{Bq}\cdot\mathrm{m}^{-2}$.

For responding to Elicitation Question 4, Equations (1) to (14) and the parameter distributions in Tables 4, 6, and 7 were used.

Table 7. Distribution of the parameter e in Equations (10) and (13), for a response to Elicitation Question 4.

Radionuclides and Environment	Distribution	Average	Relative Standard Deviation
^{106}Ru, urban	log normal	0.375	1.15
^{131}I, urban	log normal	0.5	1.15
^{137}Cs, urban	log normal	0.25	1.15
^{95}Zr, urban	log normal	0.25	1.2
^{137}Cs, rural	log normal	0.25	1.1

2.3 Average deposition conditions

As in the case of gamma dose-rates in air over open lawned areas, for a response to Elicitation Question 6, 10% of wet deposition events and 90% of dry deposition events were sampled.

3. Radionuclides with similar behavior

Three sources of information may be used for reflecting on similarities of the environmental behavior of radionuclides.

The first source of information relates to similarities of chemical elements, i.e., radionuclides belonging to homologous elements can be assumed to behave similarly if they are released in a similar physico-chemical form.

The second source of information relates to the physio-chemical form of the radionuclides during release. If there is for example, an indication that ^{144}Ce and ^{95}Zr are both predominantly released in a insoluble form and on larger aerosols, they may be assumed to behave similarly.

The third source of information are experiments or measurements after radionuclide releases. It has been observed for example after the reactor accident of Chernobyl that cesium and barium behave similarly in processes that are relevant for external exposure calculations (Jacob et al., 1987; Roed, 1987).

As far as possible, these three sources of information were used to respond to Elicitation Questions 7 and 12.

4. Location factors

4.1 Wet depositions

Indoor location factors have been measured by Jacob and Meckbach (1994), during the second month after a wet deposition of Chernobyl radionuclides in southern Bavaria. The measurements support the results of previous calculations (Meckbach and Jacob, 1988) and emphasize that location factors for ^{131}I and ^{103}Ru are smaller than those for ^{134}Cs, ^{137}Cs, and ^{140}Ba. This is mainly due to the different environmental behavior of the radionuclides in urban environments (Jacob et al., 1987) and partly due to the lower energy of photons emitted by ^{131}I.

Location factors of vehicles have been measured in an experiment by Lauridsen and Hedeman Jensen (1983). Results are shown in Table 8. In a review of earlier experimental results, a range of shielding factors of 0.5 to 0.7 was reported for cars and buses (Burson and Profio, 1977). Taking into account outdoor location factors (Equation (5) and Table 6), a good consistency was observed between the two data sets, with the exception of passenger seats in buses showing a better shielding than a factor of 0.5 in the experiment of Lauridsen and Hedeman Jensen.

Table 8. Ranges of location factors for cars and buses as measured in an experiment by Lauridsen and Hedeman Jensen (1983).

Vehicle	Open area or close to a single house	Urban area
car	0.32 - 0.72	0.25 - 0.38
bus	0.11 - 0.51	0.16 - 0.30

Responses to Elicitation Question 10 (ii) are based on the referenced reports. For the responses it is assumed that high shielding buildings are located in urban environments, the other locations are assumed to be preferentially in suburban and rural environments. The responses refer to average locations and not extreme locations close to windows or in inner rooms without windows. Houses and environments typical for the central part of the European Union were assumed. Location factors for other areas as the southern part of the European Union have not been studied so intensively up to now. Since most of the measurements were performed for cesium, the response for cesium is used as a base for the other radionuclides.

The distributions of the location factors for ^{95}Zr and ^{144}Ce were derived by assuming the same average values as for cesium and by increasing the relative standard deviations by a factor of 1.2, to express the lower degree of knowledge.

To take into account the lower retention of ruthenium in urban environments, the location factors for categories (i), (ii) and (iv) were reduced by a factor of 1.15 compared to ^{137}Cs, and for categories (iii) and (v) by a factor of 1.3. For categories (vi) and (vii) intermediate values were used. Corresponding factors for ^{131}I were 1.4 and 1.8. Due to the low energy of photons emitted by ^{131}I and their diminished ability to penetrate building materials, an additional reduction factor of 1.1 was used for category (i) and of 1.2 for categories (iii), (iv) and (v).

4.2 Dry depositions

Due to the potentially high deposition on deciduous trees and bushes, location factors for dry depositions are expected to be higher than for wet depositions. In addition, indoor deposition may contribute significantly to indoor gamma exposures (Anderson, 1994). It is assumed here that the average deposition on indoor surfaces (floors, walls and ceilings) is 5% of the deposition on a lawn (IAEA, 1994; Roed and Cannell, 1987). Such an indoor deposition raises the location factor in a room of a multistory house block from 0.015 to 0.06 (Jacob and Meckbach, 1987). Finally, as already discussed in Chapter 2, average values of initial location factors for the radionuclides in the Elicitation Questions are assumed to be the same, since a process like the enhanced runoff of iodine or ruthenium is not expected. Also, the relative low energy of the photons emitted by ^{131}I results only in a negligible difference, since in well shielded locations the indoor deposition is assumed to dominate the external gamma exposure. The response to Elicitation Question 10 (i) is based on the calculations of Meckbach and Jacob (1988), by taking into account indoor depositions.

4.3 Average deposition conditions

As in the previous chapters, location factors for average deposition conditions (Elicitation Question 8), are obtained by sampling 10% from the parameter distributions for wet depositions (discussion in Section 4.1 and results in Elicitation Question 10 (ii) and 90% from the parameter distributions for dry depositions (discussion in Section 4.2 and results in Elicitation Question 10 (ii)).

The time dependence of the indoor location factors depends on the time dependence of the source strength of the various urban and rural surfaces and on change of the angular and energy distributions of the outdoor radiation field. Only one study has been published up to now on the time dependence of location factors (Meckbach and Jacob, 1988). In this study location factors immediately after the deposition and 1 year after the deposition have been compared. Since the time dependence of indoor location factors has not been studied in more detail up to now, it is assumed here, that the indoor location factors follow the time dependence of the outdoor location factors, and only a constant modifying factor R is calculated for response to Elicitation Question 9A:

$$R(t) = \frac{0.1 \cdot f_W(t) + 0.9 \cdot f_D(t)}{0.1 \cdot f_W(0) + 0.9 \cdot f_D(0)}. \tag{15}$$

According to Equations (5) and (10) we obtain

$$R(t) = \frac{c + d \cdot \exp(-0.32 \cdot t) + 0.9 \cdot e \cdot \exp(-1.0 \cdot t)}{c + d + 0.9 \cdot e}. \tag{16}$$

For a response to Elicitation Question 9A, the average values of the parameter distributions in Tables 6 and 7 have been used. For cerium the same values as for cesium have been used. In these tables, parameter values for rural environments are given only in the case of cesium. It is assumed here that these values also apply to the other radionuclides in rural environments. For location categories (i), (ii) and (iv) a rural environment, for the categories (iii) and (v) an urban environment and for (vi) and (vii) a mixture of both categories with equal weight have been assumed.

Table 9. Average values and relative standard deviations of log-normally distributed location factors for wet depositions.

Location	Average Value				
	^{95}Zr	^{106}Ru	^{131}I	^{137}Cs	^{144}Ce
(i) low shielding building	0.5	0.43	0.36	0.5	0.5
(ii) medium shielding building	0.07	0.06	0.045	0.07	0.07
(iii) high shielding building	0.01	0.008	0.005	0.01	0.01
(iv) basement family house	0.01	0.009	0.006	0.01	0.01
(v) basement multistory block	0.005	0.004	0.002	0.005	0.005
(vi) inside typical car	0.5	0.4	0.3	0.5	0.5
(vii) inside typical bus	0.3	0.25	0.2	0.3	0.3
Location	**Relative Standard Deviation**				
	^{95}Zr	^{106}Ru	^{131}I	^{137}Cs	^{144}Ce
(i) low shielding building	1.4	1.2	1.2	1.2	1.4
(ii) medium shielding building	1.4	1.2	1.2	1.2	1.4
(iii) high shielding building	1.7	1.4	1.4	1.4	1.7
(iv) basement family house	1.7	1.4	1.4	1.4	1.7
(v) basement multistory house	1.7	1.4	1.4	1.4	1.7
(vi) inside typical car	1.4	1.2	1.2	1.2	1.4
(vii) inside typical bus	1.4	1.2	1.2	1.2	1.4

5. Integrated air concentrations

The filtering effects of houses were discussed in the Second Report of the VAMP Urban Working Group (IAEA, 1995), earlier work was summarized in Brenk and de Witt (1987). More recent results have been described by Roed and Cannell (1987). The responses to Elicitation Question 11 for ^{137}Cs and ^{131}I in the forms of I_2 and CH_3I were based on the Second Report of the VAMP Urban Working Group. For ^{240}Pu a higher filter factor was assumed, compared to ^{137}Cs.

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Table 10. Average values and relative standard deviations of log-normally distributed location factors for all radionuclides after dry depositions.

Location	Average	Relative Standard Deviation
(i) low shielding building	0.7	1.2
(ii) medium shielding building	0.1	1.4
(iii) high shielding building	0.05	1.4
(iv) basement family house	0.05	1.4
(v) basement multistory block	0.05	1.4
(vi) inside typical car	0.6	1.2
(vii) inside typical bus	0.4	1.2

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Note: Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.

Question 1. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95 A_{Nb} = 0 Bq

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	7.41	8.57	9.88
10 days	7.96	9.12	10.4
30 days	8.18	9.34	10.6
100 days	5.31	6.38	7.68
1 year	0.326	0.423	0.554

Nuclide Zr-95 A_{Nb} = 1 Bq

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	15.3	17.5	20.0
10 days	14.3	16.4	18.7
30 days	12.4	14.2	16.2
100 days	6.31	7.55	9.05
1 year	0.332	0.429	0.556

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.09	2.42	2.78
30 days	1.93	2.23	2.56
100 days	1.53	1.84	2.21
1 year	0.715	0.919	1.18
3 years	0.119	0.168	0.243

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.92	4.56	5.3
1 day	3.66	4.21	4.85
3 days	3.04	3.52	4.05
10 days	1.67	1.91	2.21
30 days	0.289	0.336	0.38
100 days	0.000631	0.000752	0.000905

Nuclide Cs-137

Dose-Rate $(Gy \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	5.79	6.68	7.69
3 months	5.13	6.14	7.39
1 year	3.86	4.95	6.39
3 years	2.4	3.41	4.88
10 years	1.35	2.19	3.56
30 years	0.579	1.01	1.78
100 years	0.0362	0.0691	0.13

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95 A_{Nb} = 0 Bq

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	6.86	7.95	9.2
10 days	7.36	8.47	9.74
30 days	7.59	8.68	9.96
100 days	4.96	5.96	7.15
1 year	0.303	0.395	0.513

Nuclide Zr-95 A_{Nb} = 1 Bq

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	14.2	16.2	18.6
10 days	13.3	15.2	17.4
30 days	11.5	13.2	15.0
100 days	5.84	7.01	8.48
1 year	0.308	0.398	0.523

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.65	1.9	2.19
30 days	1.52	1.75	2.02
100 days	1.2	1.46	1.76
1 year	0.572	0.739	0.961
3 years	0.0974	0.14	0.202

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.12	3.6	4.15
1 day	2.85	3.29	3.8
3 days	2.4	2.77	3.19
10 days	1.31	1.51	1.74
30 days	0.229	0.265	0.305
100 days	0.000495	0.000598	0.000724

Nuclide Cs-137

Dose-Rate $(Gy \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.54	5.24	6.05
3 months	4.06	4.87	5.83
1 year	3.08	3.99	5.17
3 years	1.97	2.85	4.12
10 years	1.16	1.88	3.07
30 years	0.494	0.861	1.52
100 years	0.0315	0.0592	0.112

Question 3. *Gamma dose-rate ($Gy \bullet s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95 A_{Nb} = 0 Bq

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	7.3	8.51	9.84
10 days	7.85	9.08	10.5
30 days	8.05	9.28	10.6
100 days	5.24	6.34	7.66
1 year	0.323	0.42	0.549

Nuclide Zr-95 A_{Nb} = 1 Bq

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	15.1	17.4	19.9
10 days	14.2	16.3	18.6
30 days	12.2	14.1	16.1
100 days	6.23	7.5	9.02
1 year	0.328	0.426	0.553

Nuclide Ru-106

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.88	2.39	2.77
30 days	1.75	2.19	2.55
100 days	1.41	1.81	2.21
1 year	0.682	0.9	1.17
3 years	0.113	0.164	0.237

Nuclide I-131

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.57	4.52	5.25
1 day	3.29	4.14	4.82
3 days	2.75	3.48	4.04
10 days	1.5	1.89	2.2
30 days	0.263	0.332	0.385
100 days	0.000579	0.000744	0.000906

Nuclide Cs-137

Dose-Rate $(Gy \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	5.24	6.59	7.66
3 months	4.75	6.06	7.32
1 year	3.66	4.87	6.34
3 years	2.33	3.37	4.84
10 years	1.31	2.17	3.54
30 years	0.555	0.996	1.74
100 years	0.0347	0.068	0.126

Question 4. *Effective Dose Rate ($Sv \cdot s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95 A_{Nb} = 0 Bq, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.97	5.12	6.58
10 days	4.17	5.38	6.89
30 days	4.2	5.37	6.88
100 days	2.53	3.40	4.58
1 year	0.122	0.18	0.265

Nuclide Zr-95 A_{Nb} = 1 Bq, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	8.14	10.4	1.33
10 days	7.59	9.67	12.4
30 days	6.38	8.18	1.05
100 days	3.02	4.04	5.42
1 year	0.124	0.181	0.269

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3.52×10^{-10}	4.54×10^{-10}	5.84×10^{-10}
30 days	1.08×10^{-9}	1.39×10^{-9}	1.8×10^{-9}
100 days	3.19×10^{-9}	4.1×10^{-9}	5.24×10^{-9}
1 year	4.96×10^{-9}	6.73×10^{-9}	9.16×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.15	1.44	1.8
30 days	1.02	1.27	1.59
100 days	0.732	0.96	1.25
1 year	0.255	0.36	0.514
3 years	0.0277	0.045	0.0739

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	2.79×10^{-10}	3.51×10^{-10}	4.42×10^{-10}
100 days	8.14×10^{-10}	1.02×10^{-9}	1.28×10^{-9}
1 year	1.81×10^{-9}	2.4×10^{-9}	3.18×10^{-9}
3 years	2.35×10^{-9}	3.29×10^{-9}	4.66×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.14	2.73	3.48
1 day	1.95	2.49	3.2
3 days	1.64	2.09	2.66
10 days	0.884	1.12	1.43
30 days	0.149	0.19	0.243
100 days	0.000289	0.000382	0.000503

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	1.76×10^{-11}	2.25×10^{-11}	2.86×10^{-11}
3 days	4.84×10^{-11}	6.19×10^{-11}	7.86×10^{-11}
10 days	1.21×10^{-10}	1.56×10^{-10}	1.99×10^{-10}
30 days	1.93×10^{-10}	2.48×10^{-10}	3.15×10^{-10}
100 days	2.07×10^{-10}	2.66×10^{-10}	3.37×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.21	3.99	4.94
3 months	2.57	3.33	4.3
1 year	1.49	2.11	2.98
3 years	0.632	1.03	1.67
10 years	0.268	0.493	0.955
30 years	0.109	0.27	0.439
100 years	0.00710	0.0147	0.0324

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.31×10^{-9}	2.86×10^{-9}	3.56×10^{-9}
1 year	6.94×10^{-9}	9.13×10^{-9}	1.2×10^{-8}
3 years	1.29×10^{-8}	1.82×10^{-8}	2.58×10^{-8}
10 years	2.14×10^{-8}	3.28×10^{-8}	5.12×10^{-8}
30 years	3.18×10^{-8}	5.31×10^{-8}	9.21×10^{-8}
100 years	3.86×10^{-8}	7.05×10^{-8}	1.3×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.03	4.99	6.16
3 months	3.41	4.33	5.5
1 year	2.28	3.11	4.21
3 years	1.3	1.94	2.89
10 years	0.73	1.23	2.08
30 years	0.313	0.563	1.02
100 years	0.0196	0.0387	0.0749

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.94×10^{-9}	3.66×10^{-9}	4.54×10^{-9}
1 year	9.54×10^{-9}	1.23×10^{-8}	1.59×10^{-8}
3 years	2.01×10^{-8}	2.74×10^{-8}	3.71×10^{-8}
10 years	4×10^{-8}	6×10^{-8}	8.97×10^{-8}
30 years	7.05×10^{-8}	1.13×10^{-7}	1.85×10^{-7}
100 years	8.95×10^{-8}	1.55×10^{-7}	2.72×10^{-7}

Question 5. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95 A_{Nb} = 0 Bq, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.43	3.24	4.32
10 days	2.58	3.45	4.58
30 days	2.64	3.5	4.64
100 days	0.861	1.61	5.78
1 year	0.0924	0.14	0.215

Nuclide Zr-95 A_{Nb} = 1 Bq, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	5.01	6.63	8.74
10 days	4.69	6.18	8.22
30 days	4.02	5.32	7.07
100 days	1.02	1.92	7.42
1 year	0.0928	0.141	0.217

Nuclide Zr-95 A_{Nb} = 0 Bq, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.17×10^{-10}	2.9×10^{-10}	3.88×10^{-10}
30 days	6.71×10^{-10}	8.92×10^{-10}	1.2×10^{-9}
100 days	2.05×10^{-9}	2.7×10^{-9}	3.55×10^{-9}
1 year	3.2×10^{-9}	4.57×10^{-9}	6.53×10^{-9}

Nuclide Zr-95 A_{Nb} = 1 Bq, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	4.19×10^{-10}	5.56×10^{-10}	7.28×10^{-10}
30 days	1.17×10^{-9}	1.55×10^{-9}	2.05×10^{-9}
100 days	2.98×10^{-9}	3.92×10^{-9}	5.23×10^{-9}
1 year	4.18×10^{-9}	5.96×10^{-9}	8.52×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.468	0.6	0.771
30 days	0.425	0.549	0.703
100 days	0.329	0.447	0.606
1 year	0.144	0.214	0.319
3 years	0.0212	0.0356	0.0591

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.16×10^{-10}	1.49×10^{-10}	1.9×10^{-10}
100 days	3.48×10^{-10}	4.51×10^{-10}	5.78×10^{-10}
1 year	8.53×10^{-10}	1.17×10^{-9}	1.6×10^{-9}
3 years	1.21×10^{-9}	1.78×10^{-9}	2.64×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.595	0.799	1.07
1 day	0.546	0.731	0.989
3 days	0.457	0.616	0.825
10 days	0.249	0.335	0.447
30 days	0.0438	0.0589	0.0793
100 days	9.28E-05	0.000132	0.00019

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	4.9×10^{-12}	6.57×10^{-12}	8.94×10^{-12}
3 days	1.35×10^{-11}	1.83×10^{-11}	2.43×10^{-11}
10 days	3.42×10^{-11}	4.62×10^{-11}	6.21×10^{-11}
30 days	5.48×10^{-11}	7.38×10^{-11}	9.88×10^{-11}
100 days	5.89×10^{-11}	7.9×10^{-11}	1.07×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.69	2.16	2.74
3 months	1.43	1.91	2.55
1 year	0.971	1.42	2.07
3 years	0.506	0.828	1.37
10 years	0.227	0.424	0.816
30 years	0.0942	0.182	0.373
100 years	0.00599	0.0125	0.0275

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.26×10^{-9}	1.61×10^{-9}	2.04×10^{-9}
1 year	3.99×10^{-9}	5.52×10^{-9}	7.5×10^{-9}
3 years	8.27×10^{-9}	1.22×10^{-8}	1.81×10^{-8}
10 years	1.51×10^{-8}	2.45×10^{-8}	4.03×10^{-8}
30 years	2.47×10^{-8}	4.25×10^{-8}	7.56×10^{-8}
100 years	3.05×10^{-8}	5.61×10^{-8}	1.09×10^{-7}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.31	2.95	3.7
3 months	2.09	2.72	3.53
1 year	1.61	2.23	3.05
3 years	1.06	1.60	2.42
10 years	0.619	1.05	1.79
30 years	0.267	0.485	0.878
100 years	0.0169	0.0327	0.0645

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.75×10^{-9}	2.24×10^{-9}	2.81×10^{-9}
1 year	6.07×10^{-9}	8.08×10^{-9}	1.06×10^{-8}
3 years	1.42×10^{-8}	1.97×10^{-8}	2.73×10^{-8}
10 years	3.14×10^{-8}	4.74×10^{-8}	7.27×10^{-8}
30 years	5.73×10^{-8}	9.38×10^{-8}	1.55×10^{-7}
100 years	7.27×10^{-8}	1.29×10^{-7}	2.3×10^{-7}

Question 6. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m² of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95 A_{Nb} = 0 Bq, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.22	4.97	6.51
10 days	3.44	5.26	6.87
30 days	3.46	5.27	6.83
100 days	1.45	2.61	7.42
1 year	0.116	0.176	0.263

Nuclide Zr-95 A_{Nb} = 1 Bq, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	6.56	10.2	13.2
10 days	6.15	9.49	12.3
30 days	5.27	8.01	10.4
100 days	2.63	3.94	5.40
1 year	0.117	0.178	0.265

Nuclide Zr-95 A_{Nb} = 0 Bq, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3.52×10^{-10}	4.55×10^{-10}	5.78×10^{-10}
30 days	1.1×10^{-9}	1.39×10^{-9}	1.78×10^{-9}
100 days	3.19×10^{-9}	4.1×10^{-9}	5.25×10^{-9}
1 year	4.93×10^{-9}	6.7×10^{-9}	9.13×10^{-9}

Nuclide Zr-95 A_{Nb} = 1 Bq, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	6.81×10^{-10}	8.65×10^{-10}	1.11×10^{-9}
30 days	1.88×10^{-9}	2.40×10^{-9}	3.09×10^{-9}
100 days	4.69×10^{-9}	5.98×10^{-9}	7.7×10^{-9}
1 year	6.52×10^{-9}	8.93×10^{-9}	1.22×10^{-8}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.607	1.42	1.79
30 days	0.547	1.25	1.58
100 days	0.448	0.933	1.23
1 year	0.206	0.35	0.509
3 years	0.0263	0.0437	0.0734

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	2.81×10^{-10}	3.51×10^{-10}	4.38×10^{-10}
100 days	8.17×10^{-10}	1.02×10^{-9}	1.28×10^{-9}
1 year	1.81×10^{-9}	2.39×10^{-9}	3.14×10^{-9}
3 years	2.37×10^{-9}	3.32×10^{-9}	4.66×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.789	2.67	3.45
1 day	0.729	2.45	3.15
3 days	0.614	2.05	2.63
10 days	0.333	1.1	1.41
30 days	0.0585	0.186	0.24
100 days	0.000133	0.000375	0.000499

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	1.77×10^{-11}	2.26×10^{-11}	2.87×10^{-11}
3 days	4.86×10^{-11}	6.21×10^{-11}	7.9×10^{-11}
10 days	1.22×10^{-10}	1.56×10^{-10}	2.01×10^{-10}
30 days	1.93×10^{-10}	2.47×10^{-10}	3.12×10^{-10}
100 days	2.09×10^{-10}	2.66×10^{-10}	3.38×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.14	3.92	4.9
3 months	1.94	3.25	4.29
1 year	1.33	2.05	2.95
3 years	0.613	1.01	1.64
10 years	0.259	0.488	0.929
30 years	0.107	0.217	0.438
100 years	0.00698	0.0143	0.0318

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.32×10^{-9}	2.87×10^{-9}	3.56×10^{-9}
1 year	6.94×10^{-9}	9.15×10^{-9}	1.2×10^{-8}
3 years	1.28×10^{-8}	1.82×10^{-8}	2.59×10^{-8}
10 years	2.12×10^{-8}	3.28×10^{-8}	5.22×10^{-8}
30 years	3.20×10^{-8}	5.31×10^{-8}	9.23×10^{-8}
100 years	3.85×10^{-8}	7.07×10^{-8}	1.32×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.93	4.9	6.13
3 months	2.73	4.26	5.48
1 year	2.07	3.02	4.18
3 years	1.26	1.9	2.86
10 years	0.714	1.22	2.04
30 years	0.311	0.56	1.01
100 years	0.0196	0.0382	0.0745

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.96×10^{-9}	3.65×10^{-9}	4.51×10^{-9}
1 year	9.54×10^{-9}	1.23×10^{-8}	1.59×10^{-8}
3 years	2×10^{-8}	2.74×10^{-8}	3.77×10^{-8}
10 years	3.98×10^{-8}	6.03×10^{-8}	9.17×10^{-8}
30 years	7.04×10^{-8}	1.13×10^{-7}	1.87×10^{-7}
100 years	8.78×10^{-8}	1.55×10^{-7}	2.78×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140	Cs-137	
Te-131m/Te-132	Cs-137 / I-131 / Zr-95	No answer
I-132/I-133/ I-134/I-135	I-131	
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	No answer
Ce-144	Zr-95	

Urban Environment

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140	Cs-137	
Te-131m/Te-132	Cs-137 / Ru-106 / I-131 / Zr-95	No answer
I-132/I-133/ I-134/I-135	I-131	
Mo-99	Cs-137 / Ru-106 / I-131 / Zr-95	No answer
Ce-144	Zr-95	

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m² of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.432	0.673	0.944
(ii) medium shielding building	0.0464	0.0895	0.175
(iii) high shielding building	0.00862	0.0442	0.0853
(iv) basement family house	0.00827	0.0439	0.0853
(v) basement of multi-story block	0.0042	0.0444	0.0859
(vi) inside typical car	0.395	0.582	0.816
(vii) inside typical bus	0.249	0.386	0.545

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.412	0.667	0.939
(ii) medium shielding building	0.0474	0.0879	0.175
(iii) high shielding building	0.00758	0.0442	0.0853
(iv) basement family house	0.0087	0.0439	0.0852
(v) basement of multi-story block	0.00383	0.0444	0.0859
(vi) inside typical car	0.376	0.574	0.806
(vii) inside typical bus	0.238	0.382	0.542

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.359	0.666	0.939
(ii) medium shielding building	0.0411	0.0877	0.175
(iii) high shielding building	0.00483	0.0442	0.0853
(iv) basement family house	0.00555	0.0439	0.0852
(v) basement of multi-story block	0.00195	0.0444	0.0859
(vi) inside typical car	0.296	0.573	0.806
(vii) inside typical bus	0.196	0.382	0.541

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.455	0.669	0.94
(ii) medium shielding building	0.0494	0.0885	0.175
(iii) high shielding building	0.00947	0.0442	0.0853
(iv) basement family house	0.00942	0.0439	0.0853
(v) basement of multi-story block	0.00473	0.0444	0.0859
(vi) inside typical car	0.412	0.579	0.807
(vii) inside typical bus	0.264	0.384	0.541

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.432	0.674	0.946
(ii) medium shielding building	0.0465	0.0894	0.175
(iii) high shielding building	0.00854	0.0442	0.0853
(iv) basement family house	0.00825	0.0439	0.0852
(v) basement of multi-story block	0.00418	0.0444	0.0859
(vi) inside typical car	0.391	0.582	0.816
(vii) inside typical bus	0.251	0.386	0.545

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.369	0.575	0.806	0.332	0.518	0.726
(ii) medium shielding building	0.0396	0.0764	0.149	0.0357	0.0688	0.135
(iii) high shielding building	0.00628	0.0322	0.0621	0.0033	0.0177	0.0341
(iv) basement family house	0.00706	0.0375	0.0728	0.00636	0.0338	0.0656
(v) basement of multi-story block	0.00306	0.0323	0.0625	0.00168	0.0178	0.0344
(vi) inside typical car	0.312	0.46	0.645	0.231	0.34	0.477
(vii) inside typical bus	0.197	0.305	0.431	0.146	0.226	0.319

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.351	0.57	0.802	0.317	0.513	0.722
(ii) medium shielding building	0.0405	0.0751	0.149	0.0365	0.0676	0.135
(iii) high shielding building	0.00512	0.0298	0.0576	0.00303	0.0177	0.0341
(iv) basement family house	0.00743	0.0375	0.0728	0.00669	0.0338	0.0655
(v) basement of multi-story block	0.00259	0.0299	0.058	0.00153	0.0178	0.0344
(vi) inside typical car	0.288	0.44	0.617	0.22	0.336	0.472
(vii) inside typical bus	0.182	0.292	0.415	0.14	0.22	0.317

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.307	0.569	0.8	0.276	0.512	0.722
(ii) medium shielding building	0.0351	0.0749	0.149	0.0316	0.0674	0.135
(iii) high shielding building	0.003	0.0274	0.053	0.00193	0.0177	0.0341
(iv) basement family house	0.00474	0.0375	0.0728	0.00427	0.0338	0.0655
(v) basement of multi-story block	0.00121	0.0276	0.0533	0.00078	0.0176	0.0344
(vi) inside typical car	0.218	0.422	0.594	0.173	0.335	0.472
(vii) inside typical bus	0.144	0.282	0.399	0.115	0.223	0.316

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.389	0.571	0.803	0.35	0.514	0.744
(ii) medium shielding building	0.0422	0.0756	0.149	0.038	0.0681	0.135
(iii) high shielding building	0.00689	0.0322	0.0621	0.00379	0.0177	0.0341
(iv) basement family house	0.00804	0.0375	0.0728	0.00724	0.0338	0.0656
(v) basement of multi-story block	0.00344	0.0323	0.0625	0.00189	0.0178	0.0344
(vi) inside typical car	0.326	0.458	0.638	0.241	0.339	0.472
(vii) inside typical bus	0.209	0.304	0.428	0.154	0.225	0.316

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.37	0.576	0.808	0.332	0.518	0.727
(ii) medium shielding building	0.0397	0.0763	0.149	0.0358	0.0687	0.135
(iii) high shielding building	0.00621	0.0322	0.0621	0.00342	0.0177	0.0341
(iv) basement family house	0.00705	0.0375	0.0728	0.00634	0.03338	0.0655
(v) basement of multi-story block	0.00304	0.0323	0.0625	0.00167	0.0177	0.0344
(vi) inside typical car	0.31	0.46	0.645	0.229	0.34	0.477
(vii) inside typical bus	0.199	0.305	0.431	0.147	0.226	0.319

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.495	0.685	0.949
(ii) medium shielding building	0.0494	0.0925	0.178
(iii) high shielding building	0.0249	0.0465	0.087
(iv) basement family house	0.0246	0.0462	0.0869
(v) basement of multi-story block	0.0248	0.0468	0.0872
(vi) inside typical car	0.425	0.588	0.814
(vii) inside typical bus	0.282	0.392	0.546

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.495	0.685	0.949
(ii) medium shielding building	0.0494	0.0925	0.178
(iii) high shielding building	0.0249	0.0465	0.087
(iv) basement family house	0.0246	0.0462	0.0869
(v) basement of multi-story block	0.0248	0.0468	0.0872
(vi) inside typical car	0.425	0.588	0.814
(vii) inside typical bus	0.282	0.392	0.546

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.495	0.685	0.949
(ii) medium shielding building	0.0494	0.0925	0.178
(iii) high shielding building	0.0249	0.0465	0.087
(iv) basement family house	0.0246	0.0462	0.0869
(v) basement of multi-story block	0.0248	0.0468	0.0872
(vi) inside typical car	0.425	0.588	0.814
(vii) inside typical bus	0.282	0.392	0.546

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.495	0.685	0.949
(ii) medium shielding building	0.0494	0.0925	0.178
(iii) high shielding building	0.0249	0.0465	0.087
(iv) basement family house	0.0246	0.0462	0.0869
(v) basement of multi-story block	0.0248	0.0468	0.0872
(vi) inside typical car	0.425	0.588	0.814
(vii) inside typical bus	0.282	0.392	0.546

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.495	0.685	0.949
(ii) medium shielding building	0.0494	0.0925	0.178
(iii) high shielding building	0.0249	0.0465	0.087
(iv) basement family house	0.0246	0.0462	0.0869
(v) basement of multi-story block	0.0248	0.0468	0.0872
(vi) inside typical car	0.425	0.588	0.814
(vii) inside typical bus	0.282	0.392	0.546

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.247	0.464	0.861
(ii) medium shielding building	0.0348	0.065	0.122
(iii) high shielding building	0.00286	0.00825	0.023
(iv) basement family house	0.00293	0.00817	0.0236
(v) basement of multi-story block	0.00145	0.00411	0.0115
(vi) inside typical car	0.247	0.468	0.873
(vii) inside typical bus	0.146	0.278	0.522

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.304	0.421	0.583
(ii) medium shielding building	0.0426	0.059	0.0817
(iii) high shielding building	0.00393	0.00735	0.014
(iv) basement family house	0.00436	0.00832	0.0159
(v) basement of multi-story block	0.00197	0.00373	0.00702
(vi) inside typical car	0.281	0.391	0.54
(vii) inside typical bus	0.178	0.246	0.341

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.254	0.354	0.487
(ii) medium shielding building	0.0318	0.0439	0.0609
(iii) high shielding building	0.00246	0.00463	0.00879
(iv) basement family house	0.00294	0.00551	0.0104
(v) basement of multi-story block	0.000997	0.00187	0.0035
(vi) inside typical car	0.212	0.294	0.409
(vii) inside typical bus	0.142	0.196	0.271

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.355	0.492	0.682
(ii) medium shielding building	0.0496	0.0687	0.095
(iii) high shielding building	0.00487	0.00929	0.0176
(iv) basement family house	0.00495	0.00935	0.0175
(v) basement of multi-story block	0.00248	0.00465	0.00874
(vi) inside typical car	0.355	0.492	0.684
(vii) inside typical bus	0.213	0.293	0.408

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.245	0.463	0.88
(ii) medium shielding building	0.0348	0.0655	0.122
(iii) high shielding building	0.0029	0.00823	0.0229
(iv) basement family house	0.00291	0.00811	0.0235
(v) basement of multi-story block	0.00144	0.0041	0.0117
(vi) inside typical car	0.245	0.463	0.878
(vii) inside typical bus	0.147	0.278	0.524

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 μm), Cs-137 (particulate, representative of ≈ 1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.9	1	1.1
Cs-137	0.9	1	1.1
I_2	0.9	1	1.1
CH_3I	0.9	1	1.1

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.4	0.6	0.8
Cs-137	0.6	0.75	0.9
I_2	0.3	0.5	0.7
CH_3I	0.9	1	1.1

Question 12

Nuclide	Similar Ratio To (delete as appropriate)	Specific Comments
Ru-103/Ru-106	Cs-137	
Te-129m/Te-132	Cs-137 / Pu-240 / I_2 / CH_3I	No idea
Cs-134	Cs-137	
Ba-140	Cs-137	
Ce-144	Pu-240	
Pu-238/Pu-241	Pu-240	
Cm-242	Pu-240	

Question 13 was not addressed.

EXPERT E

The elaboration of the answers to the first Questions (1-6 and 8-10) was based on the use of the URBAPAT code, developed in the UPM (described in Martín and Gallego, 1991, Gallego and Martín, 1994, and with more detail in Martín, Gallego and Alonso, 1992).

URBAPAT (URBAn PAThway) is a computer model, written in FORTRAN 77, for the evaluation of gamma external exposure and adequate countermeasures after a radiological accident involving dispersion and deposition of radioactive material on different urban surfaces.

The code estimates the evolution of radioactive material in the urban environment using a dynamic model consisting of 21 compartments that simulate five different urban surfaces with their particular retention properties. For the assessment of the gamma external exposure in urban areas, the model considers the contribution of each surface to the dose rate delivered by several radionuclides in different locations outside and inside three types of built environments (rural, with semi-detached houses; residential, with rows of terrace houses; and house blocks, with multi-story buildings). The population is classified in various groups, according to their stay time in each location.

Most of the parameters involved in the calculation are known with varying degrees of uncertainty. The variability of some of them, and their assumed distributions, has been taken into account by running the code with different samples of values generated by Latin Hypercube Sampling.

Below are collected the parameters whose variation has been considered, as well as the distributions assigned to them and their limit values (in normal distributions, percentiles 0.1% and 99.9%). One hundred (100) independent samples of all these parameters have been generated by Latin Hypercube Sampling, and the code has been run for each one of them. The resulting collection of outputs allows an estimation of the statistics (average, percentiles) of the desired results.

Spatial and temporal evolution of the radioactive materials in URBAPAT

URBAPAT adopts a dynamic model in order to simulate the behavior and evolution of radionuclides in the urban environment. Such a model is based on the linear multicompartmental model theory, where the transfer rate of radionuclides is set up from one compartment to another. The dynamic model comprises 21 compartments which simulate the evolution of the radionuclides in five urban surfaces: roofs, walls, lawns/soil, paved areas and trees (see Figure 1). These surfaces can be described as permeable or impermeable based on whether water penetrates or runs off the surface.

For the estimation of the absorbed dose-rate in air at 1 m above a uniform, flat and open lawned area at several times following initial deposition of 1 Bq/m^2 of ^{95}Zr/^{95}Nb, ^{106}Ru/^{106}Rh, ^{131}I and ^{137}Cs/^{137m}Ba to the ground (Questions 1 to 3), only the four compartments representing the soil have been used. The variations of the corresponding transfer rates are shown in the Table 1. Table 1 also shows the variations considered in other parameters that control the transfer of nuclides from one compartment to another which are used to answer the following questions. Only those parameters which appear as significant in previous sensitivity analyses have been considered.

For this exercise, the radionuclide library of the code has been completed with ^{106}Ru, ^{144}Ce and ^{95}Zr, which were not previously included.

Questions 1 to 3 (Gamma dose in air)

The gamma dose in air has been calculated from the concentrations in the four compartments that represent the soil; surface soil (0-1 cm), soil (1-25 cm) with Cs in labile form or in fixed form, and deep soil. The equation used is:

$$\dot{D}(t) = \sum_n A_n(t) \cdot SF_n \sum_j y_j \cdot K_j\left(E_j\right)$$

where

$K_j(E_j)$ = The kerma in air 1 m above an infinite smooth air-ground interface per γ mm^{-2} for a source of energy E_j (interpolated from tables in Meckbach et al.).

y_j = Yield of photons with energy E_j per decay.

$A_n(t)$ = Activity in the compartment n at time t (Bq m^{-2}).

SF_n = Adjusted shielding factor, dose rate from the compartment n with reference to dose rate from an infinite smooth air-ground interface.

Wet deposition has been simulated by an initial transfer of activity deposited from top soil to labile form in deeper soil

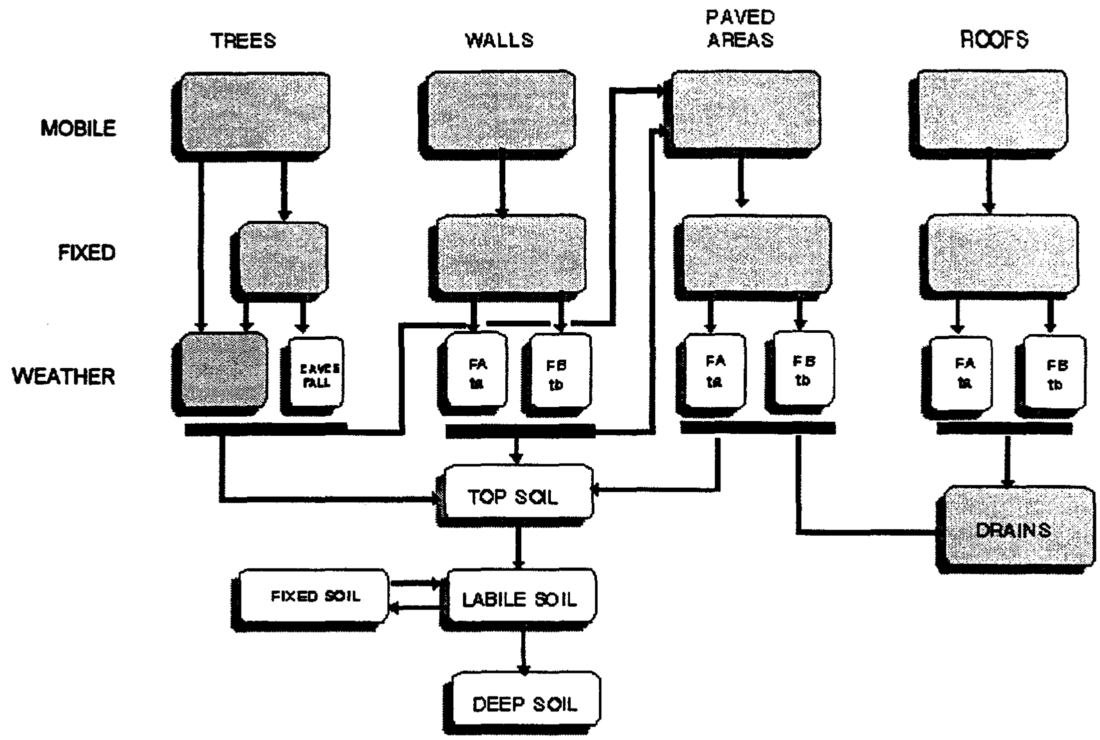

Figure 1. Schematic diagram of the compartment model in URBAPAT.

Table 1. Variable Transfer Rates (Martín and Gallego, 1991; Martín, 1993)

Parameter	Distribution	Values	
FTMOFI	Uniform	0.3, 0.9	Fraction of activity in trees which passes from mobile to fixed form
RTMOFI	Normal	0.1, 0.5	Transfer rate from mobile to fixed form in trees
FTWETS	Uniform	0.3, 0.8	Fraction of activity in trees which passes from weathered form to top soil
FTWEPAM	Uniform	0.2, 0.7	Fraction of activity in trees which passes from weathered form to paved areas
FPFIWE1	Normal	0.2, 0.35	Fraction of fixed activity in walls which passes to weathered form
FPWETS	Uniform	0.1, 0.35	Fraction of activity in paved areas which passes from weathered form to top soil
FPWEDRA	Uniform	0.5, 0.9	Fraction of activity of paved areas which passes from weathered form to drains
FWWETS	Uniform	0.1, 0.35	Fraction of activity in walls which passes from weathered form to top soil
FTMOFR	Uniform	0.2, 0.7	Fraction of activity in trees which is washed off by the first heavy rain
FWMOFR	Uniform	0.1, 0.6	Fraction of activity in walls which is washed off by the first heavy rain
FPMOFR	Uniform	0.2, 0.7	Fraction of activity in paved areas which is washed off by the first heavy rain
RTMOWE	Normal	0.1, 0.5	Transfer rate from mobile to weathered form in trees
RTSLS	Triangular	1.E-4, 6.65E-4, 8.E-4	Migration rate from top soil to labile soil
RLSFS	Triangular	8.E-4, 1.9 E-3, 4.E-3	Migration rate from labile soil to fixed soil
RFSLS	Triangular	7.E-5, 2.1E-4, 6.E-4	Migration rate from fixed soil to labile soil
RLSDS	Normal	6.6E-6, 8.E-5	Migration rate from labile soil to deep soil

(1-25 cm). The variations considered in this initial transfer together with those in the shielding factors are shown in Table 2.

After running the model under these assumptions, the variation factors observed in the dose rate were not very large, since they correspond, in any case, to adjustments made to post-Chernobyl measurements for ^{137}Cs up to a few years after deposition. In the problem, the dose rate is asked for different radionuclides, soil types and weather conditions. Therefore, the calculations made have been taken as a reference for the median values of best estimates. But since it is recognized that several other phenomena are not included in the model, adjustment factors to the median have been applied for the estimation of the 5th and 95th quantiles for time periods longer than 1 year, based on the experience from our participation in the VAMP Urban Working Group (answers to Question 3).

For Question 3, regarding deposition in average conditions, a weighted average of the results for Questions 1 and 2 was obtained by assuming a probability for rain conditions varying between 0.04 for the 95th percentile and 0.14 for the 5th percentile respectively, with a probability 0.09 for the median. These rain probabilities were thought to be representative of the warm climate in northwest Europe.

Questions 4 to 6

For these questions, concerning the assessment of effective dose-rate and effective dose to an adult outdoors in "typical" urban and rural (open field) environments, at several times following initial deposition of 1 Bq/m^2 of ^{95}Zr/^{95}Nb, ^{106}Ru/^{106}Rh, ^{131}I and ^{137}Cs/^{137m}Ba to the lawned areas of the ground, deposition in other surfaces is given relative to the deposition over soil (lawn with clipped grass). The central values for the relative depositions were taken from the first report of the VAMP Urban Working Group (IAEA, 1994, Tables II and VI). For dry deposition, values are given for all the radionuclides of the question but for wet deposition, only ^{137}Cs and ^{131}I are quoted in that report. Therefore ^{137}Cs was taken as representative for all the radionuclides except ^{131}I. To consider variations in these relative depositions, a 40% variation above and below the central values was considered.

The studies performed by Meckbach et al. (1988), with calculations of kerma in air for several locations in the urban environment, are taken as a reference in URBAPAT for the assessment of the external gamma dose. Meckbach et al. (1988) considered four types of urban environments differentiated by the types of buildings, their dimensions and the building materials. The kerma was calculated using the Monte-Carlo method for monoenergetic sources of 0.3, 0.662 and 3.0 MeV, at a large number of locations.

Since the problem specified neither the type and proximity of buildings, nor the type of surfaces or soil to be considered, as a reference for the best estimate, the URBAPAT code has been run for a "typical urban environment" equivalent to that described in Meckbach et al. (1988) as residential area with rows of terrace houses (see Figure 3 in the quoted reference). The relative proportions of the different surfaces were varied, but since the kerma reference values were always the same, only small variations were observed. As a conclusion, the URBAPAT results are included for the median values but for the quantiles, adjustment factors were used, with larger variations for dry deposition than for wet deposition to consider the larger uncertainties in the former case (Jacob and Meckbach., 1991).

Table 2. Wet Deposition Transfer Parameters

Parameter	Distribution	Values	
FWETSO	Triangular	0.5, 0.75, 0.8	Fraction of activity which penetrates the soil in the initial instant in the case of wet deposition
SFTOSO	Uniform	1.0, 1.11	Inverse of the shielding factor for activity in top soil (0-1 cm)
SFLASO	Uniform	1.75, 2.75	Inverse of the shielding factor for labile and fixed forms of activity in soil (1-25 cm)

The effective dose rate, D_{ni}, to an adult standing in a certain location, including outdoors locations, after deposition of a radionuclide, with an activity in soil, A(Bq•m^{-2}), is calculated as follows:

$$\dot{D}_j = A \cdot k \sum_k r_k(t) \cdot f_{jk}$$

where

k the unit dose effective-rate conversion factor (pSv•s^{-1} per Bq•m^{-2}) per unit activity deposited in soil of the radionuclide (from Jacob et al., 1988);

f_{jk} location factor, a dimensional, which relates the kerma at location j produced by the radionuclide deposited on surface k, relative to that over a lawn (interpolated from data in Meckbach et al., 1988).

$r_k(t)$ time dependent effective source strength of the radionuclide on surface k, relative to a soil or lawn with a fresh dry unit deposition, evaluated by the URBAPAT compartmental model;

For the answer to Question 6, the same probabilities for rain conditions were assumed as for the answer in Question 3.

In the case of the open "rural" environment, the results from the Questions 1 to 3 were converted from dose rate in air to effective dose rate by using the appropriate conversion factor (0.543 Sv/Gy for ^{137}Cs).

Question 7

In our opinion, the processes that affect the behavior of a radionuclide deposited on a given surface will be strongly affected by their chemical nature. In this sense, it is reasonable to think that, for different isotopes of the same element, similar behavior can be expected, and that the only characteristic which will be different is the decay constant. Therefore, if we consider the same uncertainties in other physical properties, such as particle sizes, weather conditions, soil types, building characteristics, etc., we will find the same uncertainty in the final behavior of the radionuclide.

As a consequence, we have obviously decided to assign a similar behavior to isotopes of the same element. For radionuclides not being isotopes of any of the radionuclides previously analyzed, the preference criterion has been the chemical similarity. In this way, ^{144}Ce has been related to ^{95}Zr, since both are tetravalent, and are treated similarly in source term analysis (for instance, in the MELCOR code, Boucheron et al., 1994). ^{99}Mo has been grouped with ^{106}Ru since they normally appear in the same chemical group in the source term, because of their similar volatility and solubility. With regard to ^{131m}Te/^{132}Te and ^{140}Ba, there are no clear chemical similarities, although we have found that ^{140}Ba is normally very soluble and can appear as aerosol, as is normally the case for ^{137}Cs; therefore a weak correlation could be attributed to both radionuclides, which are close together in the periodic table. Finally, tellurium, because of its proximity to iodine in the periodic table, should show similar behavior, and therefore some correlation should exist between ^{131m}Te/^{132}Te and ^{131}I.

The same answer is given for the two environments considered in the question. Since the rationale is based in chemical similarities between elements, we can not find reasons to distinguish between their behavior in an open lawned area and an urban environment.

Questions 8-10

In URBAPAT, the locations are grouped in three different types of urban environments: rural, with semi-detached houses; residential, with rows of terrace houses; and house blocks with multi-story buildings. For the rural and residential environment, the model considers the following locations: (1) cellar and base floor; (2) first and second floor or garret; and (3) outdoors. For multi-story buildings, four locations are considered: (1) cellar and first floor; (2) intermediate floors; (3) the two last floors; and (4) outdoors.

To answer to these questions, the low shielding buildings have been assimilated into the so-called location (2) in the semi-detached houses environment; medium shielding building into location (2) in the environment of row-terrace houses; high shielding building into location (2) in multi-story buildings. For the basement in family houses, neither were considered appropriate, so direct assessment was made as well as for the case of basements in multi-story blocks. Finally, for cars and buses, the effective dose outdoors in a residential environment has been corrected with shielding factors taken from Burson (1974).

When applicable, the median values have been based on URBAPAT calculations, relating the dose at every location to that over an open field (smooth infinite lawn). For the quantiles, adjustment factors considered reasonable have been applied.

For average deposition conditions, the same assumptions concerning rain probabilities have been made.

Question 11

To estimate the ingress of airborne radionuclides into buildings, we have used a simple single compartment model, similar to that proposed by Roed (1988). In such a model, the differential equation governing indoor concentration would be

$$dC_i/dt = \lambda_r \, f \, C_o - (\lambda_r + \lambda_d) \cdot C_i \, ,$$

where C_i and C_o are the indoor and outdoor air concentrations respectively (Bq/m^3), λ_r is the rate coefficient for ventilation (h^{-1}), f is the filtering factor (fraction not retained) in cracks and pores through which the material will ingress into the building, and λ_d is the rate coefficient of deposition on internal surfaces (h^{-1}).

Integrating the equation, assuming a constant outdoor concentration during a certain time period and a nul initial contamination indoor, a very simple expression is reached to relate the integrated indoor concentration $(\hat{C}_i)$ to the integrated outdoor concentration $(\hat{C}_o)$ (the ratio asked in the question), usually called transfer factor:

$$D = \hat{C}_i / \hat{C}_o = (\lambda_r \cdot f) / (\lambda_r + \lambda_d) .$$

The parameters governing this model have been varied for the four radionuclide types and the two situations assumed in the problem, as is shown in Table 3. The quoted values are the maximum, minimum and central value used to estimate the median and 5% and 95% percentiles of the best estimate. The values chosen are based on the literature review (Roed and Cannel, 1987; Roed, 1988; Brenk and De Witt, 1987; Roed and Goddard, 1991, mainly). To obtain the median value for the transfer factor, the central values have been used for all the parameters. To obtain 5th quantiles, minimum λ_r and f together with maximum λ_d were used, and for the 95th quantiles, the opposite combination of parameters were used.

As can be seen in the table, ventilation rates are independent of the radionuclide; the quoted values are based upon those presented by the different authors consulted, and are considered quite high when doors and windows are open. In that case, obviously, the filtering factor is set always to 1. The deposition rate is considered not dependent on the opening or closing of doors and windows. With regard to isotope dependent parameters, no correlations have been assumed between the different species, since they all present different characteristics. For ^{240}Pu, higher deposition rates and lower filtering factors have been assumed, based on results of Roed and Cannel (1987) for similar radionuclides. The filtering factor is considered to be lower because of the large particle size for Pu. For ^{137}Cs, the deposition rate is larger than that reported in Roed and Cannel (1987) because these values were obtained without furniture in the dwelling, and it is observed (Roed and Goddard, 1991) that furniture significantly enhances the deposition rate. The filtering factor is more or less based on Roed and Cannel (1987). For methyl iodide, since it is a relatively inert gaseous form, the deposition rate is always assumed to be zero, and the filtering factor very close to unit. Since the model would give no uncertainty for the situation with doors and windows closed, a small uncertainty has been quite arbitrarily assumed to take account of other phenomena not considered (weather conditions, for instance). Finally, for molecular iodine, which can be very reactive, the deposition rate is assumed high (larger than for cesium) but since it is a gas, the filtering factor is considered close to unit.

Table 3.

		Pu-240	Cs-137	CH_3I	I_2
Open doors and windows	λ_r (h$_{-1}$)	5, 10, 30	5, 10, 30	5, 10, 30	5, 10, 30
	λ_d (h$_{-1}$)	1, 4, 6	0.2, 0.6, 1	0, 0, 0	0.6, 1, 1.5
	f	1, 1, 1	1, 1, 1	1, 1, 1	1, 1, 1
Closed doors and windows	λ_r (h$_{-1}$)	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6	0.2, 0.4, 0.6
	λ_d (h$_{-1}$)	1, 4, 6	0.2, 0.6, 1	0, 0, 0	0.6, 1, 1.5
	f	0.25, .05, 0.8	0.4, 0.6, 1	0.8, 0.9, 1	0.7, 0.9, 1

Note: The indicated numbers give the minimum-central-maximum values of the parameters.

Question 12

The ingress of radionuclides into buildings should be significantly influenced by the volatility of the radionuclides, which will be high for the gaseous forms of iodine and for cesium or ruthenium, and by the chemical similarities. Uncertainties such as the physical characteristics of the buildings, weather conditions, etc., will be the same for all the radionuclides. Following the reasoning used in the rationale for Question 7, we have as far as reasonable assigned a similar behavior to isotopes of the same element. For the other radionuclides, the preference criterion has been mainly chemical similarity, as well as the volatility and solubility. Observations after the Chernobyl accident have been also taken into account (Devell, 1988).

Therefore, according to its chemical nature, ^{140}Ba is associated with ^{137}Cs, but the correlation cannot be assumed very strong, since we do not have detailed information for supporting that assumption.

Tellurium, because of its proximity to iodine in the periodic table, should show a similar behavior, and therefore some correlation should exist between $^{131m}Te/^{132}Te$ and ^{131}I. Since there exists a possibility of creation of dimethyl telluride, $(CH_3)_2Te$, in the containment of a nuclear power plant, which has a high volatility as methyl iodide, it seems appropriate to assign a weak correlation with CH_3I. On the other hand, Chernobyl releases contained Te mainly in particulate form, and so it could be also correlated with I in particulate form (not considered in the question). Since I particulate is not included, a weak correlation could be assumed with Cs.

For ruthenium, high deposition rates indoors have been observed (Roed and Cannel, 1987), and deposition was observed in two different forms: in hot particles, frequently monoelemental, and in oxidized form as an aerosol. Therefore, there could exist some similarities with Pu in the first case, and with I in particulate forms (which is not included in the question).

Finally, ^{144}Ce and ^{242}Cm can show a similar behavior to Pu particulate, since their volatility is also very low, and well as their chemical reactivity. Post-Chernobyl observations seem to confirm this.

Question 13

For the first table, the median values have been obtained directly from statistical information (BBV, 1992; INE, 1994). Therefore, for agricultural and other outdoor workers we have included all the agricultural plus forestry plus construction workers, with respect to the total population of Spain for 1989. The remaining (both employees and autonomous) are considered as indoor workers. Schoolchildren are considered as the fraction of the population younger than 16 in 1989. Non-active adults comprise the rest of the population of Spain.

To give deviations in the previous figures, the same calculations have been made for all the regions (17) into which the country is subdivided, taking the highest as a representation of the 95th quantile, and the lowest as 5th quantile.

The rest of the information in this question, concerning times spent in every location by different type of persons is directly based in personal judgement, since no surveys or objective information on which to base the assessment is available. Therefore, in our minds, the type of person representative for each situation has been (as a first approximation):

- For people working outdoors, and living in an urban environment, a construction worker.
- For people working indoors, and living in an urban environment, a service worker (office or commerce).
- For non-active population, a housekeeper or retired person.
- For people working outdoors, and living in an rural environment, an agricultural worker.
- For people working indoors, and living in an rural environment, a service worker (commerce).

The differences in the time spent indoors/outdoors would come mainly from seasonal and geographical differences, since climate is more severe inland in the high flat lands, and more moderate in the coast.

For the final table, a weighted mean of the previous fractions has been considered, taking into account that approximately 40% of the population live in cities and 60% in smaller towns or villages, with living habits which could be considered as "rural".

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Note: **Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.**

Question 1. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	8.4	8.8	9.25
10 days	7.95	8.36	8.8
30 days	6.5	6.82	7.2
100 days	1.7	1.84	2
1 year	0.00595	0.00897	0.0115

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.25	2.37	2.5
30 days	2.1	2.22	2.35
100 days	1.8	1.9	2
1 year	0.7	1.05	1.35
3 years	0.12	0.216	0.28

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.25	4.48	4.71
1 day	3.9	4.11	4.35
3 days	3.25	3.46	3.65
10 days	1.75	1.89	2
30 days	0.315	0.333	0.355
100 days	0.000715	0.000752	0.00079

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	6.35	6.67	7
3 months	6.2	6.51	6.85
1 year	4.05	6.11	6.75
3 years	2.9	5.19	6.3
10 years	1.65	3.32	5
30 years	0.75	1.5	2.25
100 years	0.0795	0.239	0.358

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	6.05	6.36	6.75
10 days	5.75	6.05	6.45
30 days	4.75	5.05	5.35
100 days	1.25	1.35	1.5
1 year	0.0045	0.00675	0.0088

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.6	1.71	1.8
30 days	1.5	1.61	1.7
100 days	1.3	1.39	1.5
1 year	0.525	0.792	1
3 years	0.0965	0.174	0.225

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.1	3.24	3.45
1 day	2.8	2.97	3.15
3 days	2.35	2.5	2.65
10 days	1.25	1.36	1.45
30 days	0.23	0.242	0.265
100 days	0.000475	0.000505	0.000535

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.55	4.82	5.1
3 months	4.4	4.71	5
1 year	2.9	4.37	4.85
3 years	2.05	3.66	4.75
10 years	1.25	2.52	3.8
30 years	0.725	1.43	2.15
100 years	0.081	0.241	0.36

Question 3. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	8.05	8.58	9.15
10 days	7.65	8.15	8.75
30 days	6.25	6.66	7.15
100 days	1.65	1.8	1.95
1 year	0.00575	0.00877	0.0115

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.15	2.31	2.5
30 days	2	2.16	2.35
100 days	1.75	1.85	2
1 year	0.675	1.03	1.35
3 years	0.115	0.212	0.28

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.1	4.37	4.65
1 day	3.75	4.01	4.2
3 days	3.1	3.37	3.6
10 days	1.7	1.84	2
30 days	0.305	0.325	0.35
100 days	0.00068	0.00073	0.00078

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	6.3	6.5	6.95
3 months	5.95	6.35	6.75
1 year	3.9	5.95	6.65
3 years	2.75	5.05	6.25
10 years	1.6	3.25	4.95
30 years	0.745	1.49	2.25
100 years	0.0795	0.239	0.36

Question 4. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.45	5.58	13
10 days	1.95	4.55	10.5
30 days	1.55	3.51	8.1
100 days	0.385	0.894	2.05
1 year	0.175	0.406	0.935

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.9×10^{-10}	4.3×10^{-10}	9.8×10^{-10}
30 days	4.9×10^{-10}	1.12×10^{-9}	2.58×10^{-9}
100 days	1.03×10^{-9}	2.36×10^{-9}	5.42×10^{-9}
1 year	1.17×10^{-9}	2.7×10^{-9}	6.21×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.54	1.23	2.85
30 days	0.41	0.951	2.2
100 days	0.345	0.791	1.85
1 year	0.18	0.417	0.96
3 years	0.036	0.0828	0.19

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.2×10^{-10}	2.7×10^{-10}	6.2×10^{-10}
100 days	3.5×10^{-10}	7.9×10^{-10}	1.82×10^{-9}
1 year	9.2×10^{-10}	2.12×10^{-9}	4.88×10^{-9}
3 years	1.49×10^{-9}	3.41×10^{-9}	7.84×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.61	1.4	3.25
1 day	0.555	1.28	2.95
3 days	0.47	1.08	2.5
10 days	0.255	0.588	1.35
30 days	0.045	0.104	0.24
100 days	0.000105	0.00024	0.000555

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	5.1×10^{-12}	1.17×10^{-11}	2.7×10^{-11}
3 days	1.4×10^{-11}	3.2×10^{-11}	7.35×10^{-11}
10 days	3.55×10^{-11}	8.18×10^{-11}	1.9×10^{-10}
30 days	5.65×10^{-11}	1.3×10^{-10}	3×10^{-10}
100 days	6.1×10^{-11}	1.4×10^{-10}	3.2×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.15	2.64	6.1
3 months	1	2.35	5.4
1 year	0.895	2.06	4.75
3 years	0.685	1.58	3.65
10 years	0.395	0.911	2.1
30 years	0.215	0.494	1.15
100 years	0.0375	0.0863	0.2

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	8.2×10^{-10}	1.89×10^{-9}	4.35×10^{-9}
1 year	3.1×10^{-9}	7.1×10^{-9}	1.6×10^{-8}
3 years	7.9×10^{-9}	1.82×10^{-8}	4.2×10^{-8}
10 years	1.9×10^{-8}	4.46×10^{-8}	1.05×10^{-7}
30 years	3.8×10^{-8}	8.62×10^{-8}	1.95×10^{-7}
100 years	6×10^{-8}	1.38×10^{-7}	3.15×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.45	3.62	3.8
3 months	3.4	3.53	3.7
1 year	2.2	3.32	3.65
3 years	1.55	2.82	3.4
10 years	0.9	1.8	2.7
30 years	0.405	0.814	1.2
100 years	0.043	0.13	0.195

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.65×10^{-9}	2.75×10^{-9}	2.95×10^{-9}
1 year	9.05×10^{-9}	1.08×10^{-8}	1.2×10^{-8}
3 years	2.05×10^{-8}	3×10^{-8}	3.4×10^{-8}
10 years	4.7×10^{-8}	7.97×10^{-8}	1.01×10^{-7}
30 years	8.75×10^{-8}	1.58×10^{-7}	2.32×10^{-7}
100 years	1.25×10^{-7}	2.62×10^{-7}	4.95×10^{-7}

Question 5. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.5	2.66	4.8
10 days	1.4	2.51	4.5
30 days	0.99	1.78	3.2
100 days	0.25	0.446	0.805
1 year	0.00095	0.00171	0.0031

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.2×10^{-10}	2.2×10^{-10}	3.9×10^{-10}
30 days	3.1×10^{-10}	5.6×10^{-10}	1×10^{-9}
100 days	6.6×10^{-10}	1.18×10^{-9}	2.1×10^{-9}
1 year	7.5×10^{-10}	1.36×10^{-9}	2.45×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.405	0.73	1.3
30 days	0.36	0.645	1.15
100 days	0.285	0.517	0.93
1 year	0.145	0.263	0.475
3 years	0.033	0.0594	0.105

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1×10^{-10}	1.8×10^{-10}	3.2×10^{-10}
100 days	2.9×10^{-10}	5.2×10^{-10}	9.4×10^{-10}
1 year	7.5×10^{-10}	1.38×10^{-9}	2.5×10^{-9}
3 years	1.25×10^{-9}	2.23×10^{-9}	4×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.51	0.918	1.65
1 day	0.47	0.841	1.5
3 days	0.395	0.708	1.25
10 days	0.215	0.385	0.695
30 days	0.0375	0.0672	0.12
100 days	8.55E-05	0.000154	0.000275

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	4.2×10^{-12}	7.52×10^{-12}	1.35×10^{-11}
3 days	1.15×10^{-11}	2.1×10^{-11}	3.8×10^{-11}
10 days	2.95×10^{-11}	5.3×10^{-11}	9.55×10^{-11}
30 days	4.7×10^{-11}	8.42×10^{-11}	1.5×10^{-10}
100 days	5.15×10^{-11}	9.27×10^{-11}	1.65×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.1	2.01	3.65
3 months	0.97	1.75	3.15
1 year	0.79	1.43	2.55
3 years	0.67	1.21	2.2
10 years	0.495	0.889	1.6
30 years	0.27	0.487	0.875
100 years	0.0495	0.0891	0.16

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	8.05×10^{-10}	1.45×10^{-9}	2.6×10^{-9}
1 year	2.85×10^{-9}	5.16×10^{-9}	9.3×10^{-9}
3 years	7.39×10^{-9}	1.33×10^{-8}	2.4×10^{-8}
10 years	2×10^{-8}	3.62×10^{-8}	6.5×10^{-8}
30 years	4.3×10^{-8}	7.78×10^{-8}	1.4×10^{-7}
100 years	7.2×10^{-8}	1.3×10^{-7}	2.3×10^{-7}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.45	2.61	2.8
3 months	2.4	2.56	2.7
1 year	1.6	2.37	2.65
3 years	1.1	1.99	2.6
10 years	0.69	1.37	2.05
30 years	0.39	0.776	1.15
100 years	0.044	0.131	0.195

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.9×10^{-9}	2.01×10^{-9}	2.15×10^{-9}
1 year	6.3×10^{-9}	7.85×10^{-9}	8.45×10^{-9}
3 years	1.45×10^{-8}	2.14×10^{-8}	2.5×10^{-8}
10 years	3.45×10^{-8}	5.82×10^{-8}	7.55×10^{-8}
30 years	6.6×10^{-8}	1.24×10^{-7}	1.75×10^{-7}
100 years	1.05×10^{-7}	2.21×10^{-7}	3.15×10^{-7}

Question 6. *Effective Dose Rate ($Sv \cdot s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.3	5.29	12.5
10 days	1.9	4.35	10
30 days	1.45	3.34	7.85
100 days	0.37	0.849	2
1 year	0.00165	0.00382	0.0091

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.8×10^{-10}	4.1×10^{-10}	9.6×10^{-10}
30 days	4.6×10^{-10}	1.06×10^{-9}	2.5×10^{-9}
100 days	9.8×10^{-10}	2.24×10^{-9}	5.3×10^{-9}
1 year	1.1×10^{-9}	2.56×10^{-9}	6.05×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.521	1.18	2.75
30 days	0.405	0.92	2.15
100 days	0.335	0.763	1.8
1 year	0.175	0.402	0.94
3 years	0.0355	0.0805	0.185

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.8×10^{-10}	4.1×10^{-10}	9.6×10^{-10}
100 days	4.6×10^{-10}	1.06×10^{-9}	2.5×10^{-9}
1 year	9.8×10^{-10}	2.24×10^{-9}	5.3×10^{-9}
3 years	1.1×10^{-9}	2.56×10^{-9}	6.05×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.595	1.35	3.15
1 day	0.545	1.23	2.9
3 days	0.46	1.04	2.45
10 days	0.25	0.568	1.3
30 days	0.044	0.1	0.235
100 days	0.0001	0.000231	0.00054

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	4.95×10^{-12}	1.13×10^{-11}	2.65×10^{-11}
3 days	1.35×10^{-11}	3.09×10^{-11}	7.2E-11
10 days	3.45×10^{-11}	7.89×10^{-11}	1.85×10^{-10}
30 days	5.51×10^{-11}	1.2×10^{-10}	2.9×10^{-10}
100 days	5.95×10^{-11}	1.3×10^{-10}	3.1×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.15	2.57	5.95
3 months	1	2.29	5.3
1 year	0.88	1.99	4.65
3 years	0.685	1.54	3.55
10 years	0.41	0.909	2.05
30 years	0.22	0.493	1.15
100 years	0.039	0.0865	0.195

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	8.1×10^{-10}	1.84×10^{-9}	4.3×10^{-9}
1 year	3.05×10^{-9}	6.91×10^{-9}	1.6×10^{-8}
3 years	7.85×10^{-9}	1.77×10^{-8}	4.1×10^{-8}
10 years	1.95×10^{-8}	4.38×10^{-8}	1×10^{-7}
30 years	3.85×10^{-8}	8.54×10^{-8}	1.95×10^{-7}
100 years	6.15×10^{-8}	1.37×10^{-7}	3.15×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.3	3.53	3.75
3 months	3.25	3.43	3.7
1 year	2.1	3.22	3.6
3 years	1.5	2.74	3.4
10 years	0.87	1.76	2.65
30 years	0.405	0.81	1.2
100 years	0.0435	0.13	0.195

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.55×10^{-9}	2.68×10^{-9}	2.9×10^{-9}
1 year	8.65×10^{-9}	1.05×10^{-8}	1.15×10^{-8}
3 years	2×10^{-8}	2.99×10^{-8}	3.35×10^{-8}
10 years	4.55×10^{-8}	7.75×10^{-8}	1×10^{-7}
30 years	8.45×10^{-8}	1.55×10^{-7}	2.3×10^{-7}
100 years	1.2×10^{-7}	2.58×10^{-7}	4.9×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	strong correlation
Cs-134/Cs-136	Cs-137	strong correlation
Ba-140	Cs-137	weak correlation
Te-131m/Te-132	I-131	medium correlation
I-132/I-133/ I-134/I-135	I-131	strong correlation
Mo-99	Ru-106	medium correlation
Ce-144	Zr-95	medium correlation

Urban Environment

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	strong correlation
Cs-134/Cs-136	Cs-137	strong correlation
Ba-140	Cs-137	weak correlation
Te-131m/Te-132	I-131	medium correlation
I-132/I-133/ I-134/I-135	I-131	strong correlation
Mo-99	Ru-106	medium correlation
Ce-144	Zr-95	medium correlation

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m² of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.11	0.17	0.34
(ii) medium shielding building	0.063	0.095	0.19
(iii) high shielding building	0.014	0.022	0.044
(iv) basement family house	0.0065	0.013	0.023
(v) basement of multi-story block	0.0011	0.0022	0.0044
(vi) inside typical car	0.26	0.52	0.78
(vii) inside typical bus	0.24	0.48	0.72

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.15	0.3
(ii) medium shielding building	0.064	0.097	0.19
(iii) high shielding building	0.0046	0.007	0.014
(iv) basement family house	0.007	0.014	0.028
(v) basement of multi-story block	0.00046	0.0007	0.0014
(vi) inside typical car	0.29	0.59	0.85
(vii) inside typical bus	0.27	0.55	0.81

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.15	0.3
(ii) medium shielding building	0.048	0.072	0.14
(iii) high shielding building	0.0047	0.0071	0.014
(iv) basement family house	0.005	0.01	0.02
(v) basement of multi-story block	0.00035	0.00071	0.0014
(vi) inside typical car	0.19	0.38	0.57
(vii) inside typical bus	0.18	0.35	0.52

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.16	0.32
(ii) medium shielding building	0.063	0.094	0.19
(iii) high shielding building	0.0043	0.0064	0.013
(iv) basement family house	0.0065	0.013	0.026
(v) basement of multi-story block	0.00032	0.00064	0.0013
(vi) inside typical car	0.35	0.71	0.96
(vii) inside typical bus	0.33	0.66	0.93

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.16	0.25	0.5
(ii) medium shielding building	0.093	0.14	0.28
(iii) high shielding building	0.014	0.021	0.042
(iv) basement family house	0.01	0.02	0.04
(v) basement of multi-story block	0.001	0.0021	0.0041
(vi) inside typical car	0.35	0.71	0.96
(vii) inside typical bus	0.32	0.65	0.93

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.061	0.092	0.14	NR	NR	NR
(ii) medium shielding building	0.031	0.049	0.073	NR	NR	NR
(iii) high shielding building	0.0037	0.0056	0.037	NR	NR	NR
(iv) basement family house	0.006	0.009	0.013	NR	NR	NR
(v) basement of multi-story block	0.0013	0.002	0.003	NR	NR	NR
(vi) inside typical car	0.31	0.47	0.72	NR	NR	NR
(vii) inside typical bus	0.29	0.43	0.7	NR	NR	NR

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.13	0.2	0.3	0.04	0.061	0.09
(ii) medium shielding building	0.038	0.057	0.085	0.02	0.031	0.046
(iii) high shielding building	0.003	0.0046	0.0069	0.0025	0.0038	0.0057
(iv) basement family house	0.01	0.019	0.029	0.0067	0.01	0.015
(v) basement of multi-story block	0.00046	0.0007	0.0011	0.00043	0.00065	0.00097
(vi) inside typical car	0.28	0.42	0.65	0.24	0.36	0.54
(vii) inside typical bus	0.26	0.39	0.62	0.22	0.33	0.49

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.073	0.11	0.16	0.033	0.05	0.075
(ii) medium shielding building	0.037	0.055	0.082	0.02	0.03	0.045
(iii) high shielding building	0.0031	0.0047	0.007	0.0025	0.0038	0.0057
(iv) basement family house	0.011	0.016	0.024	0.008	0.012	0.018
(v) basement of multi-story block	0.0004	0.0006	0.0009	0.0004	0.0006	0.0009
(vi) inside typical car	0.28	0.43	0.64	0.25	0.37	0.55
(vii) inside typical bus	0.26	0.39	0.58	0.23	0.34	0.51

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.15	0.23	0.061	0.092	0.14
(ii) medium shielding building	0.08	0.12	0.18	0.037	0.055	0.082
(iii) high shielding building	0.005	0.0075	0.011	0.0027	0.004	0.006
(iv) basement family house	0.0067	0.01	0.015	0.0033	0.005	0.0075
(v) basement of multi-story block	0.00067	0.001	0.0015	0.00067	0.001	0.0015
(vi) inside typical car	0.35	0.52	0.78	0.19	0.29	0.43
(vii) inside typical bus	0.32	0.48	0.72	0.18	0.27	0.4

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.11	0.17	0.34
(ii) medium shielding building	0.065	0.098	0.19
(iii) high shielding building	0.016	0.024	0.048
(iv) basement family house	0.007	0.014	0.028
(v) basement of multi-story block	0.0016	0.0024	0.0048
(vi) inside typical car	0.26	0.52	0.78
(vii) inside typical bus	0.24	0.48	0.72

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.15	0.3
(ii) medium shielding building	0.067	0.1	0.2
(iii) high shielding building	0.0048	0.0072	0.014
(iv) basement family house	0.007	0.014	0.028
(v) basement of multi-story block	0.00036	0.00072	0.0014
(vi) inside typical car	0.29	0.59	0.88
(vii) inside typical bus	0.27	0.55	0.82

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.11	0.16	0.32
(ii) medium shielding building	0.051	0.077	0.15
(iii) high shielding building	0.0058	0.0087	0.017
(iv) basement family house	0.005	0.017	0.022
(v) basement of multi-story block	0.00043	0.00087	0.0017
(vi) inside typical car	0.18	0.37	0.55
(vii) inside typical bus	0.17	0.34	0.51

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.16	0.32
(ii) medium shielding building	0.067	0.1	0.2
(iii) high shielding building	0.0043	0.0065	0.013
(iv) basement family house	0.007	0.014	0.028
(v) basement of multi-story block	0.00032	0.00065	0.0013
(vi) inside typical car	0.38	0.78	0.98
(vii) inside typical bus	0.36	0.72	0.96

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.19	0.28	0.55
(ii) medium shielding building	0.1	0.15	0.3
(iii) high shielding building	0.015	0.023	0.046
(iv) basement family house	0.015	0.03	0.06
(v) basement of multi-story block	0.0011	0.0023	0.0046
(vi) inside typical car	0.39	0.78	0.98
(vii) inside typical bus	0.36	0.72	0.96

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.15	0.3
(ii) medium shielding building	0.045	0.068	0.14
(iii) high shielding building	0.0036	0.0054	0.011
(iv) basement family house	0.005	0.01	0.02
(v) basement of multi-story block	0.0005	0.001	0.002
(vi) inside typical car	0.25	0.49	0.73
(vii) inside typical bus	0.22	0.45	0.67

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.099	0.14	0.28
(ii) medium shielding building	0.042	0.063	0.13
(iii) high shielding building	0.0067	0.01	0.02
(iv) basement family house	0.049	0.099	0.19
(v) basement of multi-story block	0.0005	0.001	0.002
(vi) inside typical car	0.27	0.55	0.82
(vii) inside typical bus	0.25	0.51	0.76

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.057	0.085	0.17
(ii) medium shielding building	0.022	0.033	0.066
(iii) high shielding building	0.0027	0.0041	0.0082
(iv) basement family house	0.0025	0.005	0.01
(v) basement of multi-story block	0.0002	0.00041	0.00082
(vi) inside typical car	0.21	0.42	0.63
(vii) inside typical bus	0.19	0.39	0.58

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.15	0.3
(ii) medium shielding building	0.043	0.065	0.13
(iii) high shielding building	0.0037	0.0055	0.011
(iv) basement family house	0.0045	0.0091	0.018
(v) basement of multi-story block	0.00027	0.00055	0.0011
(vi) inside typical car	0.21	0.43	0.64
(vii) inside typical bus	0.2	0.4	0.6

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1	0.15	0.3
(ii) medium shielding building	0.043	0.065	0.13
(iii) high shielding building	0.0037	0.0055	0.011
(iv) basement family house	0.0045	0.0091	0.018
(v) basement of multi-story block	0.00027	0.00055	0.0011
(vi) inside typical car	0.26	0.52	0.75
(vii) inside typical bus	0.24	0.48	0.73

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 µm), Cs-137 (particulate, representative of ≈ 1 µm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.45	0.71	0.97
Cs-137	0.83	0.94	0.99
I_2	0.77	0.91	0.98
CH_3I	0.9	0.95	1

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.008	0.05	0.3
Cs-137	0.07	0.24	0.75
I_2	0.08	0.26	0.5
CH_3I	0.8	0.9	1

Question 12

Nuclide	Similar Ratio To (delete as appropriate)	Specific Comments
Ru-103/Ru-106	Cs-137 / Pu-240	medium correlation with Pu-240 weak correlation with Cs-137
Te-129m/Te-132	Cs-137 / CH_3I	weak correlation with CH_3I weak correlation with Cs-137
Cs-134	Cs-137	strong correlation
Ba-140	Cs-137	weak correlation
Ce-144	Pu-240	medium correlation
Pu-238/Pu-241	Pu-240	strong correlation
Cm-242	Pu-240	medium correlation

Question 13. *Population Fractions.*

POPULATION FRACTION	5th Quantile	Median	95th Quantile
(i) agricultural and other outdoor workers	0.031	0.073	0.167
(ii) indoor workers	0.232	0.244	0.334
(iii) non-active adult population[a]	0.44	0.463	0.554
(ii) schoolchildren	0.173	0.22	0.262

a. All adults are considered to be in category i, ii, or iii. The non-active adult population are those that are not agricultural and outdoor workers or indoor workers. Activity here refers to employment not amount of energy expended.

People Working Outdoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.009	0.01	0.012
(ii) medium shielding, e.g., single brick family house	0.072	0.08	0.09
(iii) high shielding, e.g., multi-story office block	0.45	0.5	0.55
(iv) basement of single family house	0.0025	0.003	0.0035
(v) basement multi-story office block	0.0025	0.003	0.0035
(vi) inside typical car	0.025	0.03	0.035
(vii) inside typical bus	0.013	0.015	0.017

People Working Indoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.009	0.01	0.012
(ii) medium shielding, e.g., single brick family house	0.09	0.11	0.12
(iii) high shielding, e.g., multi-story office block	0.675	0.75	0.82
(iv) basement of single family house	0.0025	0.003	0.0035
(v) basement multi-story office block	0.009	0.01	0.011
(vi) inside typical car	0.03	0.035	0.04
(vii) inside typical bus	0.013	0.015	0.017

Non-Active Adult Population Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.009	0.01	0.011
(ii) medium shielding, e.g., single brick family house	0.18	0.2	0.22
(iii) high shielding, e.g., multi-story office block	0.603	0.67	0.74
(iv) basement of single family house	0.009	0.01	0.011
(v) basement multi-story office block	0.009	0.01	0.011
(vi) inside typical car	0.009	0.01	0.011
(vii) inside typical bus	0.009	0.01	0.011

Schoolchildren Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.009	0.01	0.011
(ii) medium shielding, e.g., single brick family house	0.12	0.13	0.14
(iii) high shielding, e.g., multi-story office block	0.59	0.65	0.72
(iv) basement of single family house	0.0001	0.0005	0.005
(v) basement multi-story office block	0.0001	0.0005	0.005
(vi) inside typical car	0.009	0.01	0.011
(vii) inside typical bus	0.0001	0.015	0.017

People Working Outdoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.014	0.015	0.0165
(ii) medium shielding, e.g., single brick family house	0.29	0.32	0.352
(iii) high shielding, e.g., multi-story office block	0.29	0.32	0.352
(iv) basement of single family house	0.009	0.01	0.011
(v) basement multi-story office block	0.0018	0.002	0.003
(vi) inside typical car	0.063	0.07	0.08
(vii) inside typical bus	0.0018	0.002	0.003

People Working Indoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.014	0.015	0.0165
(ii) medium shielding, e.g., single brick family house	0.37	0.41	0.451
(iii) high shielding, e.g., multi-story office block	0.37	0.41	0.451
(iv) basement of single family house	0.018	0.02	0.022
(v) basement multi-story office block	0.0036	0.004	0.0044
(vi) inside typical car	0.018	0.02	0.022
(vii) inside typical bus	0.0001	0.0002	0.001

Non-Active Adult Population Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.014	0.015	0.0165
(ii) medium shielding, e.g., single brick family house	0.34	0.375	0.4125
(iii) high shielding, e.g., multi-story office block	0.34	0.375	0.4125
(iv) basement of single family house	0.018	0.02	0.022
(v) basement multi-story office block	0.0036	0.004	0.0044
(vi) inside typical car	0.012	0.013	0.014
(vii) inside typical bus	0.0001	0.0002	0.001

Schoolchildren Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.014	0.015	0.0165
(ii) medium shielding, e.g., single brick family house	0.284	0.315	0.346
(iii) high shielding, e.g., multi-story office block	0.441	0.49	0.54
(iv) basement of single family house	0.0001	0.0005	0.005
(v) basement multi-story office block	0.0001	0.0005	0.005
(vi) inside typical car	0.01	0.012	0.013
(vii) inside typical bus	0.0001	0.015	0.017

Estimated Dosages from Outdoor Exposure in Sample Countries

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.0105	0.013	0.019
(ii) medium shielding, e.g., single brick family house	0.2246	0.2813	0.4026
(iii) high shielding, e.g., multi-story office block	0.4076	0.512	0.7334
(iv) basement of single family house	0.0093	0.0111	0.0173
(v) basement multi-story office block	0.0039	0.0047	0.0081
(vi) inside typical car	0.0132	0.0182	0.0304
(vii) inside typical bus	0.003	0.0071	0.0111

EXPERT F

Question 1-3

Models

These questions address the quantities, i.e., the dose-rates over a flat, infinite lawn, which serve as a reference values in the definition of location factors in Question 4-6 and 8-10.

There are least five main uncertainties to be discussed for each nuclide;

- the uncertainty of the dose-rate from an ideal source
- the influence of surface roughness,
- the initial migration,
- the speed of migration
- uncertainties in radiometric data.

The first three uncertainties have been thoroughly studied after the Chernobyl accident and are quite well known. I have used Beck's (Beck et al., 1972) calculation of dose-rates over an ideal source and assumed a dose-rate 1 cm relaxation length (page 51, Table 9, 0.625 cm^2/g) to compensate for surface roughness. These results are in good agreement with later calculations.

The speed of migration after 10 years is not known, but will probably not influence the long-term doses to any large extent. I have used the formula proposed by Jacob (Jacob and Meckbach, 1990) (1.87 years half-life of 54% of the dose) for all nuclides, which is in good agreement with Swedish measurements.

Of course, the different nuclides will have a different behavior in the long-term perspective, especially iodine. However, I have not seen any measurements indicating any substantial differences between the actual nuclides with respect to initial migration and speed of migration. In Karlberg (1987), soil profiles were collected shortly after the Chernobyl accident. There were no significant differences between ^{131}I and ^{137}Cs even though the deposition was a wet one. For dry deposition, the difference should be even less. This might be due to the special chemical form of the Chernobyl fallout, where the activity was bound to carrier particles, and therefore the behavior relates to the particles rather than to the radioactive substances. In any case, for ^{131}I the short half life supersedes the effects of a different migration speed, and this is probably also valid for other nuclides besides ^{137}Cs.

Figure 1 shows the dose-rate as a function of time for the different nuclides.

Basically, there is no significant difference between a dry and wet deposition with respect to the long-term effects. As soon as rainfall occurs, the cases will be similar. For the wet deposition case, Question 2, a initial factor of 0.8 (Jacob and Meckbach, 1990) has been used for all nuclides to account for the larger initial migration.

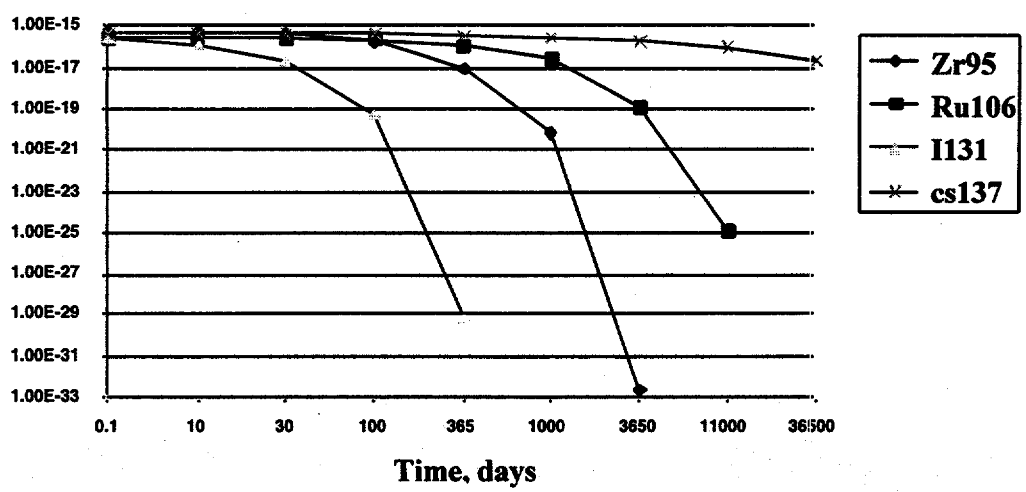

Figure 1. Dose-rate as a function of time for selected radionuclides.

As indicated above, the difference is small between dry and wet deposition, and since rain occurs only around 10% of time, the numbers for the independent-of-deposition case, question 3, were set identical to the numbers for dry deposition.

Uncertainty

A quite simple and unexpected source of uncertainty is the different radiometric data that exist in the literature.

The assigned confidence interval increases from a factor 1.7 immediately after deposition to a factor 6 at 100 years (Question 1), which seems reasonable when dealing with uncertainty of average values. The intervals were constructed with an arithmetic expression as a function of time and are based on "feeling" rather than facts.

Correlations

A 100% correlation between the nuclides, disregarding the effect of decay, is assumed.

Question 4-6

The values given to this question are similar to the location factors in Questions 8-10, but for outdoors. The uncertainties are much larger here than in Questions 1-3 and the uncertainties related to the following factors must be addressed;

- the relative distribution of activity on different surfaces;
- the subsequent weathering and migration;
- the average time spent on different surfaces.

The first problem was studied by many after the Chernobyl accident, and I have used the relative source distributions for dry deposition found in Roed and Jacob (1990) and for wet deposition in Karlberg (1992). I have divided the types of surfaces into two categories; "hard," and permeable (like lawns). The initial source distributions are summarized below.

The distribution for wet deposition will depend strongly on the amount of runoff and consequently on the intensity and the total amount of rainfall. Since the question were independent of these factors, I have used "average numbers" and increased the uncertainty interval.

	^{95}Zr	^{106}Ru	^{131}I	^{137}Cs
Dry deposition, hard surfaces	1	1	0.2	0.2
Dry deposition, permeable surfaces	1	1	1	1
Wet deposition, hard surfaces	0.4	0.4	0.1	0.4
Wet deposition, permeable surfaces	0.8	0.8	0.8	0.8

The hard surfaces differ to a large extent with respect to weathering, and I have used a double exponential approximation (30% with a half-life of 200 days and 70% with 1000 days) to represent an average hard surface and assumed 80% of the time is spent on such a surface. For the permeable surface, I have used the same as for Question 1-3 and assumes 20% of the time is spent on this surface. These assumptions lead to an average exposure of 4% relative to time spent on the reference surface at all times for Cs, which seems reasonable. For the rural situation, I have reversed the time spent on the different surfaces.

Figure 2 shows the dose-rate for ^{137}Cs for the different questions. As one can see it is the influence from the permeable surfaces that dominates the dose-rate in the long run. Consequently the time spent on such surfaces is an important parameter.

The differences due to the deposition processes are small. Dry conditions exists 90% of time and generally give rise to higher doses; thus the influence of the wet deposition would be very small, and consequently the "dry" numbers have been used for question 6.

Uncertainty

The confidence interval starts with a factor 5 and ends with a factor 15 at 100 years for Cs. The main factor contributing to the uncertainty for integrated doses is, as discussed above, the behavior on permeable surfaces and the average time spent on such surfaces.

Correlations

There is a strong correlation with the results of questions 1-3. Correlations between nuclides are 100%, disregarding the effect of decay.

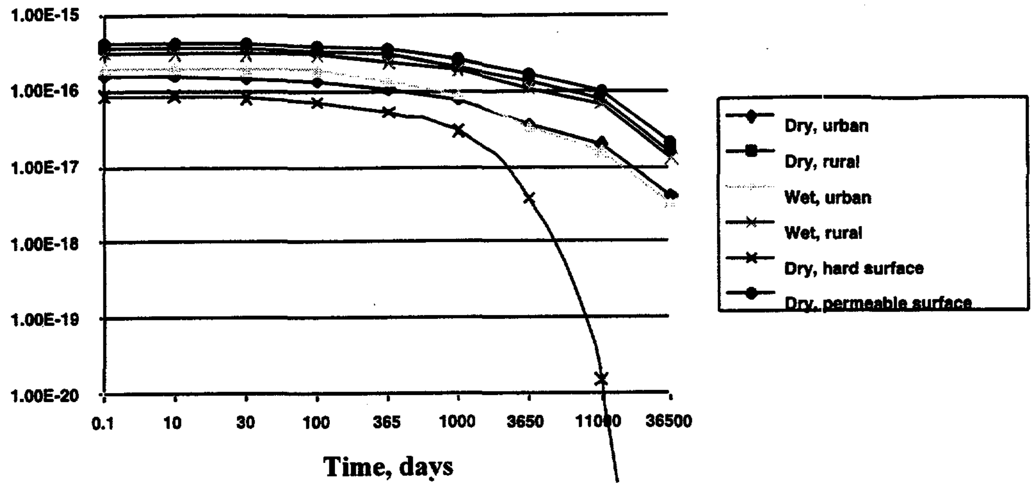

Figure 2. Dose-rate as a function of time for Cs-137 for selected conditions.

Question 7

This is dependent to a high degree on the accident conditions and the formation of chemical properties of particles and other chemical substances.

Question 8-10

Questions 8-10 is similar to Questions 4-6, i.e., location factors, but here the locations are indoors. Similar uncertainties exist as in Questions 4-6 with respect to initial source distribution, but in addition to that, one has to assign shielding factors (location factors but related to the actual deposition around the location) to the respective indoor locations and consider the properties of the surrounding areas.

Many studies have been made for shielding factors, in particular some extensive ones in Sweden for typical Swedish buildings including one family houses as well as multi-story houses. The consensus from these studies (FAO, date unspecified) and international studies like Jacob and Meckbach (1990) have been used for the shielding factors, which are shown in Table 1.

The distribution of areas surrounding each location has been treated in the following way: only two types of surfaces have been considered, "hard" ones and permeable ones (lawns) as in Question 4-6; the low and medium shielding houses including the basement (i,ii,iv) are situated close to the permeable surfaces; and the rest are situated close to the hard surfaces. The same relative distributions for the nuclides have been used as in Questions 4-6. Since the deposition mechanisms were not specified in the questions, the values for dry deposition have been used. Compensation for the low energy of ^{144}Ce was made with a factor 2.

Table 1. Shielding Factors

	Surrounding surface	5th quantile	Median	95th quantile
low shielding building	Permeable	3.00E-01	5.00E-01	7.00E-01
medium shielding building	Permeable	5.00E-02	1.00E-01	2.00E-01
high shielding building	Hard	2.00E-02	4.00E-02	7.00E-02
basement of family house	Permeable	3.00E-03	1.00E-02	5.00E-02
basement of multi-story block	Hard	2.00E-03	1.00E-02	5.00E-02
inside car	Hard	5.00E-01	7.00E-01	8.00E-01
inside bus	Hard	3.00E-01	5.00E-01	7.00E-01

It is quite obvious that the location factors are time-dependent, since they relate to the dose on a reference point, a lawn. The results for Question 9 were obtained with the same formula as in Question 4-6, i.e., the factor for modification of the location factors was given by the quotient between the dose-rate on the surrounding surface relative to the reference surface, a lawn shortly after the deposition.

In Question 10, the results are the same as in Question 8 for the case with dry deposition. For wet deposition, the corresponding initial distribution according to Questions 4-6 has been used.

Uncertainty

The main uncertainty factors in question 8 are the variation of house types and interpretation of the meaning of a "medium shielding house " etc. The variation is large but since the question asks for average conditions the uncertainty could be reduced.

Correlations

There is a strong correlation with the results of Questions 1-3 and 4-6 regarding the initial distributions and the dose-rates on different surfaces. Correlations between nuclides are 100%, disregarding the effect of decay.

Question 11

I am not an expert in this field and I have just used the best available figures, i.e., from the VAMP study.

Question 12

I have not answered this question for the reasons above.

Question 13

I have spent a lot of time on this question! The Swedish TV company (SVT, dates unspecified) carried out comprehensive studies of the behavior of Swedish people. The studies were made for different age groups, but only to some extent were urban and rural conditions separated. Behavior does not seem to differ much in this sense, however.

The number of people living in different types of houses was found from a special study by the Swedish Defense Research Establishment (FAO, dates unspecified), mainly for estimation of shielding in a nuclear war situation. The classification of people into the different groups was made using data from Swedish official statistics, and the number of outdoor workers was found by summing of employees in different working areas, also from official Swedish statistics.

References

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Jacob, P. and Meckbach, R. 1990. External exposure from deposited radionuclides, Proceedings from "Seminar on methods and codes for assessing the off-site consequences of nuclear accidents" Athens, 1-11 May 1990. EUR 13013.

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Karlberg, O. 1992. *The environmental behavior of Chernobyl fallout in a high fallout region of Sweden.* STUDSVIK/NS-91/1.

Roed, J. and Jacob, P. 1990. Deposition on urban surfaces and subsequent weathering, Proceedings from "Seminar on methods and codes for assessing the off-site consequences of nuclear accidents" Athens, 1-11 May 1990. EUR 13013.

SVT (Swedish Radio and Television Company). Several reports in Swedish.

Note: **Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.**

Question 1. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.3	5.6	7.3
10 days	2.9	5	8.5
30 days	2.2	4	7.2
100 days	0.95	1.8	3.4
1 year	0.045	0.091	0.18

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.1	2.7	3.6
30 days	1.4	2.6	4.6
100 days	1.1	2.2	4.1
1 year	0.57	1.2	2.3
3 years	0.13	0.27	0.58

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.3	3	3.9
1 day	2.1	2.7	3.5
3 days	1.9	2.4	3.1
10 days	0.74	1.3	2.2
30 days	0.13	0.23	0.41
100 days	0.00028	0.00054	0.001

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.4	4.4	5.7
3 months	2.2	4.1	7.9
1 year	1.8	3.6	7.2
3 years	1.3	2.7	5.7
10 years	0.75	1.7	3.7
30 years	0.44	1	2.3
100 years	0.085	0.21	0.49

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.4	4.5	5.8
10 days	2.4	4	6.8
30 days	1.8	3.2	5.7
100 days	0.76	1.4	2.7
1 year	0.036	0.073	0.15

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.7	2.2	2.9
30 days	1.1	2	3.7
100 days	0.91	1.7	3.3
1 year	0.46	0.92	1.9
3 years	0.1	0.22	0.46

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.8	2.4	3.1
1 day	1.6	2.2	2.8
3 days	1.4	1.9	2.5
10 days	0.6	1	1.7
30 days	0.1	0.18	0.32
100 days	0.00023	0.00043	0.00082

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.7	3.5	4.6
3 months	1.7	3.3	6.3
1 year	1.4	2.9	5.8
3 years	1	2.2	4.6
10 years	0.6	1.3	2.9
30 years	0.35	0.81	1.9
100 years	0.068	0.16	0.4

Question 3. *Gamma dose-rate ($Gy \bullet s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \bullet s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.3	5.6	7.3
10 days	2.9	5	8.5
30 days	2.2	4	7.2
100 days	0.95	1.8	3.4
1 year	0.045	0.091	0.18

Nuclide Ru-106

Dose-Rate ($Gy \bullet s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.1	2.7	3.6
30 days	1.4	2.6	4.6
100 days	1.1	2.2	4.1
1 year	0.57	1.2	2.3
3 years	0.13	0.27	0.58

Nuclide I-131

Dose-Rate ($Gy \bullet s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.3	3	3.9
1 day	2.1	2.7	3.5
3 days	1.9	2.4	3.1
10 days	0.74	1.3	2.2
30 days	0.13	0.23	0.41
100 days	0.00028	0.00054	0.001

Nuclide Cs-137

Dose-Rate ($Gy \bullet s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.4	4.4	5.7
3 months	2.2	4.1	7.9
1 year	1.8	3.6	7.2
3 years	1.3	2.7	5.7
10 years	0.75	1.7	3.7
30 years	0.44	1	2.3
100 years	0.085	0.21	0.49

Question 4. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors .. a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	5.6	16
10 days	1.8	5	14
30 days	1.3	3.9	12
100 days	0.53	1.7	5.3
1 year	0.022	0.073	0.25

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.6×10^{-10}	4.6×10^{-10}	1.3×10^{-9}
30 days	4.1×10^{-10}	1.2×10^{-9}	3.6×10^{-9}
100 days	8.9×10^{-10}	2.8×10^{-9}	8.9×10^{-9}
1 year	1.2×10^{-9}	4×10^{-9}	1.3×10^{-8}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.3	2.7	8
30 days	0.84	2.5	7.5
100 days	0.63	2	6.4
1 year	0.28	0.93	3.1
3 years	0.05	0.18	0.61

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	2.3×10^{-10}	6.8×10^{-10}	2×10^{-9}
100 days	6.4×10^{-10}	2×10^{-9}	6.5×10^{-9}
1 year	1.6×10^{-9}	5.2×10^{-9}	1.8×10^{-8}
3 years	2.2×10^{-9}	7.7×10^{-9}	2.7×10^{-8}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.49	1.1	2.3
1 day	0.44	1	2.1
3 days	0.4	0.9	2
10 days	0.16	0.45	1.3
30 days	0.027	0.08	0.24
100 days	0.000059	0.00019	0.00059

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	4.3×10^{-12}	9.3×10^{-12}	2×10^{-11}
3 days	6.7×10^{-12}	2×10^{-11}	6×10^{-11}
10 days	2.2×10^{-11}	6.2×10^{-11}	1.8×10^{-10}
30 days	3.3×10^{-11}	1×10^{-10}	3×10^{-10}
100 days	3.4×10^{-11}	1.1×10^{-10}	3.4×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.73	1.6	4.7
3 months	0.45	1.4	4.5
1 year	0.34	1.1	3.9
3 years	0.22	0.78	2.7
10 years	0.098	0.36	1.3
30 years	0.053	0.2	0.78
100 years	0.01	0.041	0.16

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	4.1×10^{-10}	1.3×10^{-9}	4.1×10^{-9}
1 year	1.3×10^{-9}	4.2×10^{-9}	1.4×10^{-8}
3 years	2.7×10^{-9}	9.4×10^{-9}	3.3×10^{-8}
10 years	5.7×10^{-9}	2.1×10^{-8}	7.7×10^{-8}
30 years	9.8×10^{-9}	3.8×10^{-8}	1.5×10^{-7}
100 years	1.5×10^{-8}	6×10^{-8}	2.4×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.7	3.7	12
3 months	1.1	3.5	11
1 year	0.89	3	10
3 years	0.64	2.2	7.8
10 years	0.36	1.3	4.9
30 years	0.21	0.81	3.1
100 years	0.041	0.16	0.66

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	9.8×10^{-10}	3.1×10^{-9}	9.8×10^{-9}
1 year	3.1×10^{-9}	1×10^{-8}	3.5×10^{-8}
3 years	7×10^{-9}	2.4×10^{-8}	8.6×10^{-8}
10 years	1.7×10^{-8}	6.2×10^{-8}	2.3×10^{-7}
30 years	3.3×10^{-8}	1.3×10^{-7}	4.9×10^{-7}
100 years	5.4×10^{-8}	2.2×10^{-7}	8.7×10^{-7}

Question 5. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.2	2.7	7
10 days	0.84	2.4	6.8
30 days	0.63	1.9	5.6
100 days	0.26	0.82	2.6
1 year	0.011	0.037	0.12

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	7.7×10^{-11}	2.2×10^{-10}	6.2×10^{-10}
30 days	2×10^{-10}	5.9×10^{-10}	1.8×10^{-9}
100 days	4.3×10^{-10}	1.4×10^{-9}	4.3×10^{-9}
1 year	5.7×10^{-10}	1.9×10^{-9}	6.5×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.61	1.3	3.7
30 days	0.4	1.2	3.6
100 days	0.31	0.98	3.1
1 year	0.14	0.46	1.6
3 years	0.026	0.092	0.32

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.1×10^{-10}	3.3×10^{-10}	9.8×10^{-10}
100 days	3.1×10^{-10}	9.8×10^{-10}	3.1×10^{-9}
1 year	7.6×10^{-10}	2.5×10^{-9}	8.6×10^{-9}
3 years	1.1×10^{-9}	3.8×10^{-9}	1.3×10^{-8}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.33	0.71	1.5
1 day	0.3	0.62	1.4
3 days	0.27	0.58	1.2
10 days	0.11	0.3	0.86
30 days	0.018	0.054	0.16
100 days	0.00004	0.00013	0.0004

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	2.9×10^{-12}	6.2×10^{-12}	1.3×10^{-11}
3 days	9×10^{-12}	1.8×10^{-11}	3.9×10^{-11}
10 days	1.5×10^{-11}	4.2×10^{-11}	1.2×10^{-10}
30 days	2.2×10^{-11}	6.7×10^{-11}	2×10^{-10}
100 days	2.3×10^{-11}	7.2×10^{-11}	2.3×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.97	2.1	6
3 months	0.59	1.9	5.9
1 year	0.43	1.4	4.8
3 years	0.26	0.91	3.2
10 years	0.089	0.33	1.2
30 years	0.042	0.16	0.63
100 years	0.0082	0.033	0.13

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	5.4×10^{-10}	1.7×10^{-9}	5.4×10^{-9}
1 year	1.6×10^{-9}	5.5×10^{-9}	1.8×10^{-8}
3 years	3.3×10^{-9}	1.2×10^{-8}	4.1×10^{-8}
10 years	6.4×10^{-9}	2.4×10^{-8}	8.8×10^{-8}
30 years	9.8×10^{-9}	3.8×10^{-8}	1.4×10^{-7}
100 years	1.4×10^{-8}	5.5×10^{-8}	2.2×10^{-7}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.5	3.2	9.5
3 months	0.93	3	9.4
1 year	0.75	2.5	8.4
3 years	0.53	1.9	6.5
10 years	0.29	1.1	4
30 years	0.17	0.65	2.5
100 years	0.033	0.13	0.53

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	8.3×10^{-10}	2.6×10^{-9}	8.4×10^{-9}
1 year	2.6×10^{-9}	8.9×10^{-9}	3×10^{-8}
3 years	5.9×10^{-9}	2.1×10^{-8}	7.2×10^{-8}
10 years	1.4×10^{-8}	5.1×10^{-8}	1.9×10^{-7}
30 years	2.7×10^{-8}	1×10^{-7}	4×10^{-7}
100 years	4.4×10^{-8}	1.8×10^{-7}	7.1×10^{-7}

Question 6. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	5.6	15
10 days	1.8	5	14
30 days	1.3	3.9	12
100 days	0.53	1.7	5.3
1 year	0.022	0.073	0.25

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	1.6×10^{-10}	4.6×10^{-10}	1.3×10^{-9}
30 days	4.1×10^{-10}	1.2×10^{-9}	3.6×10^{-9}
100 days	8.9×10^{-10}	2.8×10^{-9}	8.9×10^{-9}
1 year	1.2×10^{-9}	4×10^{-9}	1.3×10^{-8}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.3	2.7	7.7
30 days	0.84	2.5	7.5
100 days	0.63	2	6.4
1 year	0.28	0.93	3.1
3 years	0.05	0.18	0.61

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	2.3×10^{-10}	6.8×10^{-10}	2×10^{-9}
100 days	6.4×10^{-10}	2×10^{-9}	6.5×10^{-9}
1 year	1.6×10^{-9}	5.2×10^{-9}	1.8×10^{-8}
3 years	2.2×10^{-9}	7.7×10^{-9}	2.7×10^{-8}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.49	1.1	2.3
1 day	0.44	1	2.1
3 days	0.4	0.9	2
10 days	0.16	0.45	1.3
30 days	0.027	0.08	0.24
100 days	0.000059	0.00019	0.00059

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	4.3×10^{-12}	9.3×10^{-12}	2×10^{-11}
3 days	6.7×10^{-12}	2×10^{-11}	6×10^{-11}
10 days	2.2×10^{-11}	6.2×10^{-11}	1.8×10^{-10}
30 days	3.3×10^{-11}	1×10^{-10}	3×10^{-10}
100 days	3.4×10^{-11}	1.1×10^{-10}	3.4×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.73	1.6	4.7
3 months	0.45	1.4	4.5
1 year	0.34	1.1	3.9
3 years	0.22	0.78	2.7
10 years	0.098	0.36	1.3
30 years	0.053	0.2	0.78
100 years	0.01	0.041	0.16

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	4.1×10^{-10}	1.3×10^{-9}	4.1×10^{-9}
1 year	1.3×10^{-9}	4.2×10^{-9}	1.4×10^{-8}
3 years	2.7×10^{-9}	9.4×10^{-9}	3.3×10^{-8}
10 years	5.7×10^{-9}	2.1×10^{-8}	7.7×10^{-8}
30 years	9.8×10^{-9}	3.8×10^{-8}	1.5×10^{-7}
100 years	1.5×10^{-8}	6×10^{-8}	2.4×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.7	3.7	12
3 months	1.1	3.5	11
1 year	0.89	3	10
3 years	0.64	2.2	7.8
10 years	0.36	1.3	4.9
30 years	0.21	0.81	3.1
100 years	0.041	0.16	0.66

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	9.8×10^{-10}	3.1×10^{-9}	9.8×10^{-9}
1 year	3.1×10^{-9}	1×10^{-8}	3.5×10^{-8}
3 years	7×10^{-9}	2.4×10^{-8}	8.6×10^{-8}
10 years	1.7×10^{-8}	6.2×10^{-8}	2.3×10^{-7}
30 years	3.3×10^{-8}	1.3×10^{-7}	4.9×10^{-7}
100 years	5.4×10^{-8}	2.2×10^{-7}	8.7×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106 / Zr-95	Not chemically the same behavior (Zr), but Ru and Zr seem to adhere to the same type of particles.
Cs-134/Cs-136	Cs-137	Chemically identical
Ba-140	Ru-106 / Zr-95	Not chemically the same behavior, but Ru, Ba, and Zr seem to adhere to the same type of particles.
Te-131m/Te-132	Ru-106 / Zr-95	Not chemically the same behavior, but Ru, Te, and Zr seem to adhere to the same type of particles.
I-132/I-133/ I-134/I-135	I-131	Chemically identical
Mo-99	Ru-106	Both belong to the so-called "transition group"
Ce-144	Zr-95	Both belong to the so-called "Lanthanide group"

Urban Environment

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106 / Zr-95	Not chemically the same behavior (Zr), but Ru and Zr seem to adhere to the same type of particles.
Cs-134/Cs-136	Cs-137	Chemically identical
Ba-140	Ru-106 / Zr-95	Not chemically the same behavior, but Ru, Ba, and Zr seem to adhere to the same type of particles.
Te-131m/Te-132	Ru-106 / Zr-95	Not chemically the same behavior, but Ru, Te, and Zr seem to adhere to the same type of particles.
I-132/I-133/ I-134/I-135	I-131	Chemically identical
Mo-99	Ru-106	Both belong to the so-called "transition group"
Ce-144	Zr-95	Both belong to the so-called "Lanthanide group"

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m^2 of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.21	0.5	0.91
(ii) medium shielding building	0.035	0.1	0.26
(iii) high shielding building	0.014	0.04	0.091
(iv) basement family house	0.0021	0.01	0.065
(v) basement of multi-story block	0.0014	0.01	0.065
(vi) inside typical car	0.35	0.7	1.04
(vii) inside typical bus	0.21	0.5	0.91

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.21	0.5	0.91
(ii) medium shielding building	0.035	0.1	0.26
(iii) high shielding building	0.014	0.04	0.091
(iv) basement family house	0.0021	0.01	0.065
(v) basement of multi-story block	0.0014	0.01	0.065
(vi) inside typical car	0.35	0.7	1.04
(vii) inside typical bus	0.21	0.5	0.91

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.168	0.4	0.728
(ii) medium shielding building	0.035	0.1	0.26
(iii) high shielding building	0.0028	0.008	0.0182
(iv) basement family house	0.0021	0.01	0.065
(v) basement of multi-story block	0.0028	0.02	0.013
(vi) inside typical car	0.07	0.14	0.208
(vii) inside typical bus	0.042	0.1	0.182

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.21	0.5	0.91
(ii) medium shielding building	0.035	0.1	0.26
(iii) high shielding building	0.0028	0.008	0.0182
(iv) basement family house	0.0021	0.01	0.065
(v) basement of multi-story block	0.00028	0.002	0.013
(vi) inside typical car	0.07	0.14	0.208
(vii) inside typical bus	0.042	0.1	0.182

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.105	0.25	0.455
(ii) medium shielding building	0.0175	0.05	0.13
(iii) high shielding building	0.007	0.02	0.0455
(iv) basement family house	0.00105	0.005	0.0325
(v) basement of multi-story block	0.0007	0.005	0.0325
(vi) inside typical car	0.175	0.35	0.52
(vii) inside typical bus	0.105	0.25	0.455

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.168	0.4	0.728	0.105	0.25	0.455
(ii) medium shielding building	0.028	0.08	0.208	0.0175	0.05	0.13
(iii) high shielding building	0.0028	0.008	0.0182	0.0007	0.002	0.00455
(iv) basement family house	0.00168	0.008	0.052	0.00105	0.005	0.0325
(v) basement of multi-story block	0.00028	0.002	0.013	0.00007	0.0005	0.00325
(vi) inside typical car	0.035	0.07	0.104	0.0035	0.007	0.0104
(vii) inside typical bus	0.021	0.05	0.091	0.0021	0.005	0.0091

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.168	0.4	0.728	0.105	0.25	0.455
(ii) medium shielding building	0.028	0.08	0.208	0.0175	0.05	0.13
(iii) high shielding building	0.0028	0.008	0.0182	0.0007	0.002	0.00455
(iv) basement family house	0.00168	0.008	0.052	0.00105	0.005	0.0325
(v) basement of multi-story block	0.00028	0.002	0.013	0.00007	0.0005	0.00325
(vi) inside typical car	0.035	0.07	0.104	0.0035	0.007	0.0104
(vii) inside typical bus	0.021	0.05	0.091	0.0021	0.005	0.0091

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.134	0.32	0.58	0.084	0.2	0.364
(ii) medium shielding building	0.028	0.08	0.21	0.0175	0.05	0.13
(iii) high shielding building	0.00028	0.0008	0.00182	0.000028	0.00008	0.000182
(iv) basement family house	0.00168	0.008	0.052	0.00105	0.005	0.0325
(v) basement of multi-story block	0.000028	0.0002	0.0013	2.8E-06	0.00002	0.00013
(vi) inside typical car	0.0035	0.007	0.0104	0.00007	0.00014	0.000208
(vii) inside typical bus	0.0021	0.005	0.0091	0.000042	0.0001	0.000182

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.168	0.4	0.728	0.105	0.25	0.455
(ii) medium shielding building	0.028	0.08	0.208	0.0175	0.05	0.13
(iii) high shielding building	0.00056	0.0016	0.00364	0.00014	0.0004	0.00091
(iv) basement family house	0.00168	0.008	0.052	0.00105	0.005	0.0325
(v) basement of multi-story block	0.000056	0.0004	0.0026	0.000014	0.0001	0.00065
(vi) inside typical car	0.007	0.014	0.0208	0.0007	0.0014	0.00208
(vii) inside typical bus	0.0042	0.01	0.0182	0.00042	0.001	0.00182

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.084	0.2	0.364	0.0525	0.125	0.2275
(ii) medium shielding building	0.014	0.04	0.104	0.00875	0.025	0.065
(iii) high shielding building	0.0014	0.004	0.0091	0.00035	0.001	0.00228
(iv) basement family house	0.00084	0.004	0.026	0.000525	0.0025	0.0163
(v) basement of multi-story block	0.00014	0.001	0.0065	0.000035	0.00025	0.00163
(vi) inside typical car	0.0175	0.035	0.052	0.00175	0.0035	0.0052
(vii) inside typical bus	0.0105	0.025	0.0455	0.00105	0.0025	0.00455

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.21	0.5	0.91
(ii) medium shielding building	0.035	0.1	0.26
(iii) high shielding building	0.014	0.04	0.091
(iv) basement family house	0.0021	0.01	0.065
(v) basement of multi-story block	0.0014	0.01	0.065
(vi) inside typical car	0.35	0.7	1.04
(vii) inside typical bus	0.21	0.5	0.91

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.21	0.5	0.91
(ii) medium shielding building	0.035	0.1	0.26
(iii) high shielding building	0.014	0.04	0.091
(iv) basement family house	0.0021	0.01	0.065
(v) basement of multi-story block	0.0014	0.01	0.065
(vi) inside typical car	0.35	0.7	1.04
(vii) inside typical bus	0.21	0.5	0.91

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.168	0.4	0.728
(ii) medium shielding building	0.035	0.1	0.26
(iii) high shielding building	0.0028	0.008	0.0182
(iv) basement family house	0.0021	0.01	0.065
(v) basement of multi-story block	0.00028	0.002	0.013
(vi) inside typical car	0.07	0.14	0.208
(vii) inside typical bus	0.042	0.1	0.182

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.21	0.5	0.91
(ii) medium shielding building	0.035	0.1	0.26
(iii) high shielding building	0.0028	0.008	0.0182
(iv) basement family house	0.0021	0.01	0.065
(v) basement of multi-story block	0.00028	0.002	0.013
(vi) inside typical car	0.07	0.114	0.208
(vii) inside typical bus	0.042	0.1	0.182

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.105	0.25	0.455
(ii) medium shielding building	0.0175	0.05	0.13
(iii) high shielding building	0.007	0.02	0.0455
(iv) basement family house	0.00105	0.005	0.0325
(v) basement of multi-story block	0.0007	0.005	0.0325
(vi) inside typical car	0.175	0.35	0.52
(vii) inside typical bus	0.105	0.25	0.455

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.168	0.4	0.728
(ii) medium shielding building	0.028	0.08	0.208
(iii) high shielding building	0.0056	0.016	0.0364
(iv) basement family house	0.00168	0.008	0.052
(v) basement of multi-story block	0.00056	0.004	0.026
(vi) inside typical car	0.14	0.28	0.416
(vii) inside typical bus	0.084	0.2	0.364

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.168	0.4	0.728
(ii) medium shielding building	0.028	0.08	0.208
(iii) high shielding building	0.0056	0.016	0.0364
(iv) basement family house	0.00168	0.008	0.052
(v) basement of multi-story block	0.00056	0.004	0.026
(vi) inside typical car	0.14	0.28	0.416
(vii) inside typical bus	0.084	0.2	0.364

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.1344	0.32	0.5824
(ii) medium shielding building	0.028	0.08	0.208
(iii) high shielding building	0.0014	0.004	0.0091
(iv) basement family house	0.00168	0.008	0.052
(v) basement of multi-story block	0.00014	0.001	0.0065
(vi) inside typical car	0.035	0.07	0.104
(vii) inside typical bus	0.021	0.05	0.091

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.168	0.4	0.728
(ii) medium shielding building	0.0228	0.08	0.208
(iii) high shielding building	0.0056	0.016	0.0364
(iv) basement family house	0.00168	0.008	0.052
(v) basement of multi-story block	0.00056	0.004	0.026
(vi) inside typical car	0.14	0.28	0.416
(vii) inside typical bus	0.084	0.2	0.364

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.084	0.2	0.364
(ii) medium shielding building	0.014	0.04	0.104
(iii) high shielding building	0.0028	0.008	0.0182
(iv) basement family house	0.00084	0.004	0.026
(v) basement of multi-story block	0.000228	0.002	0.013
(vi) inside typical car	0.07	0.14	0.208
(vii) inside typical bus	0.042	0.1	0.182

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 μm), Cs-137 (particulate, representative of ≈ 1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.2	0.8	0.9
Cs-137	0.4	0.8	0.9
I_2	0.3	0.7	0.8
CH_3I	0.9	0.99	1

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.2	0.5	0.9
Cs-137	0.4	0.7	0.9
I_2	0.3	0.6	0.8
CH_3I	0.9	0.99	1

Question 12 was not addressed.

Question 13. *Population Fractions.*

POPULATION FRACTION	5th Quantile	Median	95th Quantile
(i) agricultural and other outdoor workers	0.03	0.05	0.1
(ii) indoor workers	0.3	0.35	0.4
(iii) non-active adult population[a]	0.4	0.45	0.5
(ii) schoolchildren	0.13	0.15	0.15

a. All adults are considered to be in category i, ii, or iii. The non-active adult population are those that are not agricultural and outdoor workers or indoor workers. Activity here refers to employment not amount of energy expended.

People Working Outdoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.005	0.01	0.03
(ii) medium shielding, e.g., single brick family house	0.01	0.03	0.05
(iii) high shielding, e.g., multi-story office block	0.3	0.6	0.7
(iv) basement of single family house	0.0005	0.001	0.01
(v) basement multi-story office block	0.001	0.02	0.04
(vi) inside typical car	0.02	0.04	0.06
(vii) inside typical bus	0.02	0.04	0.06

People Working Indoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.001	0.01	0.03
(ii) medium shielding, e.g., single brick family house	0.001	0.03	0.05
(iii) high shielding, e.g., multi-story office block	0.6	0.8	0.9
(iv) basement of single family house	0.001	0.01	0.1
(v) basement multi-story office block	0.01	0.02	0.04
(vi) inside typical car	0.005	0.03	0.05
(vii) inside typical bus	0.01	0.04	0.06

Non-Active Adult Population Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.001	0.02	0.04
(ii) medium shielding, e.g., single brick family house	0.001	0.02	0.05
(iii) high shielding, e.g., multi-story office block	0.6	0.8	0.9
(iv) basement of single family house	0.0001	0.001	0.01
(v) basement multi-story office block	0.001	0.01	0.03
(vi) inside typical car	0.005	0.01	0.03
(vii) inside typical bus	0.01	0.03	0.05

Schoolchildren Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.01	0.03	0.06
(ii) medium shielding, e.g., single brick family house	0.02	0.12	0.2
(iii) high shielding, e.g., multi-story office block	0.5	0.7	0.8
(iv) basement of single family house	0.005	0.01	0.03
(v) basement multi-story office block	0.01	0.02	0.04
(vi) inside typical car	0.005	0.01	0.03
(vii) inside typical bus	0.005	0.01	0.03

People Working Outdoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.08	0.12	0.2
(ii) medium shielding, e.g., single brick family house	0.05	0.1	0.2
(iii) high shielding, e.g., multi-story office block	0.2	0.3	0.5
(iv) basement of single family house	0.01	0.04	0.1
(v) basement multi-story office block	0.001	0.01	0.05
(vi) inside typical car	0.01	0.03	0.05
(vii) inside typical bus	0.005	0.01	0.03

People Working Indoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.14	0.18
(ii) medium shielding, e.g., single brick family house	0.08	0.12	0.16
(iii) high shielding, e.g., multi-story office block	0.4	0.5	0.6
(iv) basement of single family house	0.01	0.04	0.07
(v) basement multi-story office block	0.005	0.01	0.03
(vi) inside typical car	0.01	0.03	0.05
(vii) inside typical bus	0.005	0.01	0.03

Non-Active Adult Population Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.22	0.3
(ii) medium shielding, e.g., single brick family house	0.1	0.2	0.3
(iii) high shielding, e.g., multi-story office block	0.2	0.4	0.6
(iv) basement of single family house	0.01	0.04	0.08
(v) basement multi-story office block	0.002	0.01	0.02
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.005	0.02	0.04

Schoolchildren Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.18	0.3
(ii) medium shielding, e.g., single brick family house	0.1	0.18	0.3
(iii) high shielding, e.g., multi-story office block	0.2	0.45	0.6
(iv) basement of single family house	0.01	0.06	0.1
(v) basement multi-story office block	0.005	0.01	0.03
(vi) inside typical car	0.005	0.01	0.03
(vii) inside typical bus	0.005	0.01	0.03

Estimated Dosages from Outdoor Exposure in Sample Countries

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.07	0.1	0.15
(ii) medium shielding, e.g., single brick family house	0.07	0.1	0.15
(iii) high shielding, e.g., multi-story office block	0.5	0.61	0.7
(iv) basement of single family house	0.01	0.02	0.04
(v) basement multi-story office block	0.005	0.01	0.02
(vi) inside typical car	0.01	0.02	0.04
(vii) inside typical bus	0.01	0.02	0.04

EXPERT G

Question 1

Most of the data on the gamma dose rate in air above a flat and open lawned area are related to the measurement of radiocesium after the Chernobyl accident (see, for example, Jacob et al., 1994). The long-term behavior of radiocesium can also be derived from measurements made more than 20 years after fallout from nuclear weapons testing (Miller et al., 1990).

The median values of the gamma dose rates in air, K_a in Gy s^{-1} per Bq m^{-2}, at time *t* after deposition, for the various radionuclides, *RN*, have been calculated as:

$$K_a(t, RN) = DREF(RN) \times DF(t, RN) \times AF(t) \times CF \quad (1)$$

where:

DREF(RN) is the reference air dose coefficient for radionuclide *RN* at time *t*=0 for plane surface contamination. These dose coefficients were taken from Beck (1980).

DF(t,RN) is the temporal variation of the activity deposited on the ground.

- For ^{95}Zr, ^{131}I, ^{106}Ru, ^{131}I, and $^{137}Cs/^{137m}Ba$:

  $DF(t,RN) = \exp(-\lambda(RN) \times t)$,

  where $\lambda(RN)$ is the radioactive decay constant of radionuclide *RN*.

- For ^{95}Nb, which is the decay product of ^{95}Zr and has a relatively long physical half-life:

  $DF(t,Nb) = (\lambda(Nb) / (\lambda(Nb) - \lambda(Zr))) \times (\exp(-\lambda(Zr) \times t) - \exp(-\lambda(Nb) \times t))$

AF(t) is a function that represents the decrease in the gamma dose rate due to runoff or to penetration of the radionuclide into the ground. For ^{137}Cs and wet deposition, Jacob et al. (1994) proposed the following relationship:

$$AF(t) = p1 \times \exp(-p2 \times t) + p3 \times \exp(-p4 \times t)$$

where: $p1 = 0.31$
$p2 = 0.61\ a^{-1}$
$p3 = 0.37$
$p4 = 0.015\ a^{-1}$

This relationship has been used for wet deposition and for all radionuclides considered in this exercise.

CF is a factor that takes into account the fact that the value of *AF(t)* seems to underestimate the behavior of ^{137}Cs following dry deposition. The value of *CF* is taken to be equal to 1.2 for all radionuclides considered in this exercise.

The values of λ(*RN*) and of *DREF(RN)* are presented in Table 1, while the values of *DF(RN*,t) and of *AF(t)* are presented in Table 2.

Table 1. Values of radioactive decay constants, λ, and of reference air dose coefficients, *DREF*, used for the radionuclides considered in this exercise.

Radionuclide, *RN*	$\lambda(RN)$ [a^{-1}]	*DREF(RN)* [Gy • s^{-1} per Bq m^{-2}]
^{95}Zr	3.9543	9.1×10^{-16}
^{95}Nb	7.1977	9.4×10^{-16}
$^{106}Ru/^{106m}Rh$	0.6871	2.5×10^{-16}
^{131}I	31.4675	4.8×10^{-16}
$^{137}Cs/^{137m}Ba$	0.0231	7.0×10^{-16}

Table 2. Values of reduction factors due to radioactive decay [*DF(t,RN)*] and to run-off or penetration into the ground *AF(t)* used for the radionuclides considered in this exercise.

Time, *t*, after deposition	*AF(t)*	*DF(t,RN)*				
		^{95}Zr	^{95}Nb	$^{106}Ru/^{106m}Rh$	^{131}I	$^{137}Cs/^{137m}Ba$
0	0.68	1	0	1	1	1
1 d	0.68				0.9174	
3 d	0.68				0.7721	
10 d	0.67	0.8973	0.1693	0.9814	0.4223	
30 d	0.66	0.7225	0.3752	0.9451	0.0753	
100 d	0.63	0.3384	0.4422	0.8284	0.0002	0.9937
1 a	0.53	0.0192	0.0409	0.5030		0.9772
3 a	0.40			0.1273		0.9330
10 a	0.32					0.7937
30 a	0.24					0.5
100 a	0.083					0.0992

Discussion

The values of *DREF(RN)* and of *DF(t,RN)* are based on well-understood physical processes and are known with good accuracy. The most important uncertainties lie in:

- the values of *AF(t)*;
- the assumption that *AF(t)* is valid for radionuclides other than ^{137}Cs that are considered in this exercise; and
- the values of *CF*.

Figure 1 illustrates the data used to derive the values of *AF(t)* and of *CF*. Most of the sites for which data are available were contaminated with Chernobyl fallout associated with rain (data denoted with upper-case letters). It seems clear that the value of 1, which corresponds to a plane, infinite source of ^{137}Cs, is never achieved, even at very short times after deposition. This may be due to a ground roughness effect (OCD, 1968) or to very rapid penetration of ^{137}Cs into the soil through fissures. The value of AF decrease relatively slowly with time, at least over a few years following deposition. With respect to longer times after deposition, Jacob et al. (1994) found that the global fallout data for the New York area, reported over more than 20 years (Miller et al., 1990) agree fairly well with the Chernobyl data. It is to be noted that global fallout in the New York area occurred also mainly with precipitation.

Jacob et al. (1994) measured radionuclides other than radiocesium and found that, for the first half year after deposition, the attenuation of iodine and ruthenium radiation was of the same order as for cesium; information on zirconium or niobium has not been found. It is assumed that the function *AF(t)*, which was derived from cesium data, also fits well the data for iodine, ruthenium, zirconium, and niobium.

The value of *CF* is derived from data in Figure 1, which show that Ukrainian values (represented with lower-case letters) are about 40% higher than the German values. It is not known with certainty why the two sets of data are different; possible reasons are different physico-chemical binding of the deposit or different behavior of activities deposited according to wet and dry processes (Chernobyl fallout in Ukraine was mainly due to dry processes). In a somewhat arbitrary manner, it is assumed that half of the difference between German and Ukrainian values (that is, 20%) is due to a more superficial distribution of a dry deposit, when compared with wet.

The variation with time of the selected median values of $AF(t) \times CF$ is presented as curve labelled "Dry" in Figure 1.

The 5th and 95th percentile values are derived from Figure 1. Since there is very little error on *DREF* and *DF*, the variability results from the product $AF(t) \times CF$, which lies in the range from 0 to 1 (0 for a highly permeable soil, in which the radionuclides would percolate very rapidly; 1 for

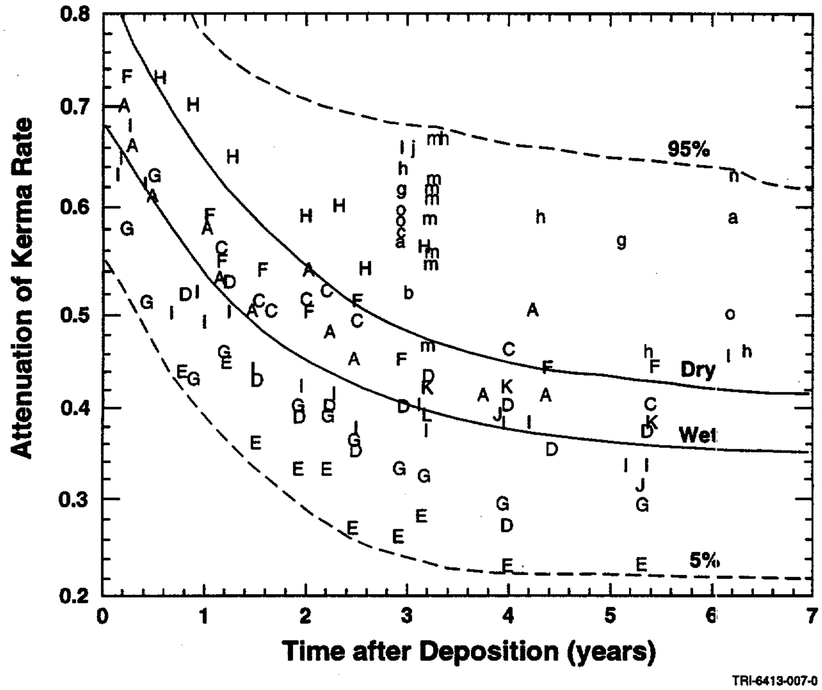

Figure 1. Attenuation of kerma rates as a function of time after deposition of ^{137}Cs. The upper case letters represent sites where deposition was mainly due to wet processes, whereas the lower case letters represent sites where deposition was mainly dry.

a totally impermeable soil). The 5th and 95th percentiles are assumed to be represented by the highest and lowest values presented in Figure 1. The corresponding envelopes are shown on Figure 1. Table 3 presents the 5th, 50th, and 95th percentile values adopted for the product $AF(t) \times CF$ for all times after deposition for which gamma dose rates in air have to be estimated.

Question 2

The manner in which the gamma dose rates in air were calculated is described in the rationale for Question 1. The median values are calculated using equation (1), the only change being that the value of *CF* is taken to be equal to 1.

Because of the possibility that the Ukrainian data for wet deposition would be similar to those obtained for dry deposition, the 5th and 95th percentile values for AF(t) are taken to be the same for wet and for dry deposition.

Question 3

Because periods of precipitation are relatively rare in the eastern United States (5 to 10% of the time), and because the differences in the gamma dose rates per unit deposition for dry and wet deposition are estimated to be small, the median values of the gamma dose rates in air for average weather conditions are taken to be the same as those calculated for dry deposits.

The 5th and 95th percentile values for average weather conditions are assumed to be the same as those provided for either dry or wet deposition.

Question 4

The effective dose rate to an adult outdoors in a typical "urban" environment is calculated as:

$$HRE(t, RN) = K_a(t, RN) \times LF \times FE \qquad (2)$$

where:

FE is a conversion coefficient from dose rate in air to effective dose rate for the radiation field considered. *FE* varies little with gamma energy; a representative value is 0.8 Sv Gy^{-1}.

Table 3.

Time, t, after deposition	$AF(t) \times CF$		
	5th percentile	median	95th percentile
0	0.55	0.82	0.95
1 d	0.55	0.82	0.95
3 d	0.55	0.82	0.95
10 d	0.54	0.80	0.94
30 d	0.53	0.79	0.93
100 d	0.51	0.76	0.90
1 a	0.39	0.64	0.78
3 a	0.24	0.48	0.68
10 a	0.19	0.38	0.60
30 a	0.14	0.29	0.58
100 a	0.05	0.10	0.20

LF is a location factor that takes into account that an open lawned area is not representative of a typical "urban" environment and that the adult will spend a substantial fraction of his/her time over paved areas or near buildings. Data on *LF* are relatively rare and highly uncertain. In a suburban environment, dry deposition per unit area is likely to be higher on trees and bushes, and lower on pavements and tiles, than on lawns (Jacob and Meckbach, 1990; Roed, 1990; Tveten, 1990). Jacob and Meckbach (1990) suggested that, at the time of dry deposition, a representative value of *LF* might be 1.0 for either a suburban or a rural environment. In this document, the median value of *LF* is taken to be 1.0 for the "urban" environment (which is defined as being in fact suburban) as well as for the rural environment. The 5th and 95th quantiles of *LF* are estimated to be 0.4 and 1.2, respectively; the lower value (0.4) is equal to the representative value used by Jacob and Meckbach (1990) for an urban environment, while the upper value of 1.2 is subjectively estimated to be appropriate for an area with many trees and bushes. Although it is acknowledged that the values of *LF* are likely to vary according to the radionuclide considered and as a function of time after deposition, these variations have not been taken into account in this exercise.

The 5th and 95th percentiles attached to the distribution of *HRE* have been calculated using the 5th and 95th percentiles of the distribution of K_a; given the additional uncertainties on *LF*, the 5th to 95th percentile range for *HRE* is somewhat expanded. Monte-Carlo calculations would be required to properly estimate the 5th and 95th quantiles of *HRE*. In this document, this range was approximately and subjectively obtained, usually by rounding down the 5th percentile and rounding up the 95th percentile.

There are very strong correlations between the estimates given for each time and each radionuclide. The median values of the effective dose, *HE*, were obtained by integrating analytically the median values of *HRE*:

$$HE(T, RN) = \int_0^T HRE(t, RN).dt = DREF(RN) \times CF \times LF \times FE \int_0^T DF(t, RN).AF(t).dt \quad (3)$$

The 5th and 95th percentiles of *HE(T,RN)* have been derived from the values obtained for *HRE(t,RN)* by using the same ratios of the median to 5th percentile and of the 95th percentile to the median.

Question 5

The procedure followed to estimate *HRE* and *HE* is described in the rationale given for question 4. In the case of wet deposition, the characteristics of the surface upon which the activity is deposited (lawns, trees, bushes, pavement, etc.) do not play an important role with respect to the initial value of *LF* (Tveten, 1990). Following the suggestion of Jacob and Meckbach (1990), the median values of the location factors for wet deposition have been taken to be 0.7 for both the urban environment (which is defined as being in fact suburban) and for the rural environment. The 5th and 95th quantiles are subjectively estimated to be 0.4 and 0.9, respectively. Compared with the answers given for Question 4, the median values of the dose rates are multiplied by 0.7 and divided by 1.2 (overall factor of 0.58) while the 5th and 95th percentiles are multiplied by 0.7.

Question 6

The values used for dry deposition (see question 4) have been assumed to represent the average weather conditions as well. The answers to Question 6 are identical to those for Question 4.

Question 7

Three groups of radionuclides have been considered, mainly on the basis of volatility:

- I, Te, and Cs are highly volatile;
- Ba, Ce, Zr-Nb are refractory; and
- Ru and Mo are in an intermediate class.

However, it is not clear to me whether these radionuclides behave differently in the environment as far as external irradiation from deposited materials is concerned.

Question 8

Estimates of location factors have been published for Cs-137 (Burson and Profio, 1977; Jacob and Meckbach, 1990). These estimates are reproduced in Table 4.

Values are generally higher for dry deposition than for wet deposition, mainly because trees and bushes intercept and retain much more activity under dry deposition conditions than under wet deposition conditions.

Because the occurrence of wet deposition is fairly rare, the median values selected for average weather conditions are those associated with dry deposition.

It is recognized that the location factors are radionuclide-dependent, if only because of differences in their gamma energy spectra. On these grounds, location factors should be higher for ^{95}Zr, and lower for ^{106}Ru, ^{131}I, and ^{144}Ce. These differences have not been quantified in this document.

The 5th and 95th percentiles of the location factors have been assessed subjectively. The variability is likely to be less for relatively high values of the location factor (0.1 and greater) than for low values (less than 0.1). A ratio of 3 has been assigned to the ratios of the median to 5th percentile and of the 95th percentile to median when the estimated values were less than 0.1. When the estimated values were equal to 0.1 or greater than 0.1, the ratios of the median to 5th percentile and of the 95th percentile to the median were taken to be less than, or equal to, 2.

Question 9

The location factors are time dependent because radionuclides will be eliminated at different rates from different surfaces (lawns, plowed fields, roofs, streets, paved areas, etc.). However, literature data are insufficient to predict with reasonable accuracy the variation with time of the location factor for the radionuclides considered. Subjective estimates have been given using the simple assumption that the same scaling factor can be used to modify initial location factors (Part A).

Table 4. Estimates of location factors for ^{137}Cs (Burson and Profio 1977; Jacob and Meckbach 1990).

Location	Location factor for	
	dry deposition	wet deposition
Wooden framed house	0.7	0.5
Brick family house	0.1	0.07
Tall multi-story building	0.03	0.01
Basement in a single-family house	0.01	0.005
Basement in a multi-story building	0.001	0.001
Typical car in a suburban street	0.7	0.7
Typical bus in a suburban street	0.5	0.5

The scaling factors are tentatively estimated to be 0.6 for 1 year after deposition and 0.4 for 10 years after deposition.

Question 10

The procedure followed to derive estimates of initial location factors for dry and wet deposition is provided in the rationale related to Question 8.

Question 11

The indoor-to-outdoor TIAC ratios depend on the physico-chemical characteristics of the radionuclide and on the ventilation rate in the building.

For an inert gas, like CH_3I, the indoor-to-outdoor TIAC ratio should be equal to 1, irrespective of the ventilation rate in the building. For particulate materials, the indoor-to-outdoor ratios will be less than 1 as they will be depleted by deposition on internal surfaces. Additional depletion will be caused by deposition in fissures that allow outdoor air to enter into the building. The fraction deposited will be higher for reactive products like I_2 and for large Pu particles than for small Cs particles.

Roed et al. (1990) suggested median estimates of 0.2 for tight houses and of 0.5 for drafty houses with a variation with ventilation rates *VR*, in h^{-1}, according to: TIAC = $(0.24 \times VR) + 0.21$.

For the purposes of this exercise, median estimates for aerosols are assumed to be in the range from 0.3 to 0.5 for drafty houses and 0.2 to 0.3 for tight houses.

Question 12

Similarities in the indoor-to-outdoor TIAC ratios are expected to be associated with the aerosol size. The following elements are grouped together:

Cs, Ru, and Te (small particle sizes), and
Ba, Ce, Cm, and Pu (large particle sizes).

Question 13

Not answered.

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Note: **Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.**

Question 1. *Gamma dose-rate ($Gy \bullet s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	5	7.5	8.6
10 days	5.3	7.8	9.1
30 days	5.4	8	9.4
100 days	3.7	5.5	6.5
1 year	0.22	0.36	0.44

Nuclide Ru-106

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.4	2	2.4
30 days	1.3	1.9	2.2
100 days	1.1	1.6	1.9
1 year	0.49	0.8	1
3 years	0.076	0.15	0.22

Nuclide I-131

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	3.9	4.6
1 day	2.4	3.6	4.2
3 days	2	3	3.5
10 days	1.1	1.6	1.9
30 days	0.19	0.29	0.34
100 days	0.00049	0.00076	0.00089

Nuclide Cs-137

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.8	5.7	6.7
3 months	3.5	5.3	6.3
1 year	2.7	4.4	5.3
3 years	1.6	3.1	4.4
10 years	1	2.1	3.3
30 years	0.49	1	2
100 years	0.021	0.069	0.21

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	5	6.2	8.6
10 days	5.3	6.5	9.1
30 days	5.4	6.7	9.4
100 days	3.7	4.6	6.5
1 year	0.22	0.3	0.44

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.4	1.7	2.4
30 days	1.3	1.6	2.2
100 days	1.1	1.3	1.9
1 year	0.49	0.67	1
3 years	0.076	0.13	0.22

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	3.2	4.6
1 day	2.4	3	4.2
3 days	2	2.5	3.5
10 days	1.1	1.3	1.9
30 days	0.19	0.24	0.34
100 days	0.00049	0.00063	0.00089

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.5	4.8	6.7
3 months	3.5	4.4	6.3
1 year	2.7	3.7	5.3
3 years	1.6	2.6	4.4
10 years	1	1.8	3.3
30 years	0.49	0.84	2
100 years	0.021	0.058	0.21

Question 3. *Gamma dose-rate ($Gy \bullet s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	5	7.5	8.6
10 days	5.3	7.8	9.1
30 days	5.4	8	9.4
100 days	3.7	5.5	6.5
1 year	0.22	0.36	0.44

Nuclide Ru-106

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.4	2	2.4
30 days	1.3	1.9	2.2
100 days	1.1	1.6	1.9
1 year	0.49	0.8	1
3 years	0.076	0.15	0.22

Nuclide I-131

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	3.9	4.6
1 day	2.4	3.6	4.2
3 days	2	3	3.5
10 days	1.1	1.6	1.9
30 days	0.19	0.29	0.34
100 days	0.00049	0.00076	0.00089

Nuclide Cs-137

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.8	5.7	6.7
3 months	3.5	5.3	6.3
1 year	2.7	4.4	5.3
3 years	1.6	3.1	4.4
10 years	1	2.1	3.3
30 years	0.49	1	2
100 years	0.021	0.069	0.21

Question 4. *Effective Dose Rate (Sv • s⁻¹) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m² of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.5	6	7.5
10 days	4	6.2	8
30 days	4	6.4	8
100 days	3	4.4	6
1 year	0.1	0.29	0.4

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3.4×10^{-10}	5.3×10^{-10}	6.8×10^{-10}
30 days	1×10^{-9}	1.6×10^{-9}	2×10^{-9}
100 days	3.4×10^{-9}	5×10^{-9}	6.8×10^{-9}
1 year	5×10^{-9}	8.7×10^{-9}	1.2×10^{-8}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.6	2
30 days	1	1.5	2
100 days	0.8	1.3	2
1 year	0.3	0.64	1
3 years	0.05	0.12	0.2

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	2.7×10^{-10}	4.1×10^{-10}	5.5×10^{-10}
100 days	7.4×10^{-10}	1.2×10^{-9}	1.8×10^{-9}
1 year	1.5×10^{-9}	3.3×10^{-9}	5.2×10^{-9}
3 years	2.2×10^{-9}	5.3×10^{-9}	8.8×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2	3.1	4
1 day	1.5	2.9	4
3 days	1	2.4	3.5
10 days	0.7	1.3	2
30 days	0.1	0.23	0.4
100 days	0.0003	0.00061	0.001

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	1.4×10^{-11}	2.7×10^{-11}	3.7×10^{-11}
3 days	3.1×10^{-11}	7.5×10^{-11}	1.1×10^{-10}
10 days	1×10^{-10}	$1. \times 10^{-10}$	2.9×10^{-10}
30 days	1.3×10^{-10}	3×10^{-10}	5.2×10^{-10}
100 days	1.6×10^{-10}	3.2×10^{-10}	5.2×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3	4.6	5.4
3 months	2.5	4.2	5
1 year	2	3.5	4.5
3 years	1	2.5	4
10 years	0.5	1.7	3
30 years	0.3	0..8	2
100 years	0.015	0.055	0.2

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.4×10^{-9}	4×10^{-9}	4.8×10^{-9}
1 year	7.4×10^{-9}	1.3×10^{-8}	1.7×10^{-8}
3 years	1.3×10^{-8}	3.2×10^{-8}	5.1×10^{-8}
10 years	2.3×10^{-8}	7.9×10^{-8}	1.4×10^{-7}
30 years	4×10^{-8}	1.6×10^{-7}	4×10^{-7}
100 years	4×10^{-8}	2.2×10^{-7}	8×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3	4.6	5.4
3 months	2.5	4.2	5
1 year	2	3.5	4.5
3 years	1	2.5	4
10 years	0.5	1.7	3
30 years	0.3	0.8	2
100 years	0.015	0.055	0.2

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.4×10^{-9}	4×10^{-9}	4.8×10^{-9}
1 year	7.4×10^{-9}	1.3×10^{-8}	1.7×10^{-8}
3 years	1.3×10^{-8}	3.2×10^{-8}	5.1×10^{-8}
10 years	2.3×10^{-8}	7.9×10^{-8}	1.4×10^{-7}
30 years	4×10^{-8}	1.6×10^{-7}	4×10^{-7}
100 years	6×10^{-8}	2.2×10^{-7}	8×10^{-7}

Question 5. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.5	3.5	5.3
10 days	2.8	3.6	4.8
30 days	2.8	3.7	4.8
100 days	2.1	2.6	4.2
1 year	0.075	0.17	0.28

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.4×10^{-10}	3.1×10^{-10}	4.1×10^{-10}
30 days	7×10^{-10}	9.3×10^{-10}	1.2×10^{-9}
100 days	2.3×10^{-9}	2.9×10^{-9}	4.7×10^{-9}
1 year	2.3×10^{-9}	5.1×10^{-9}	8.4×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.7	0.93	1.4
30 days	0.7	0.88	1.4
100 days	0.56	0.76	1.4
1 year	0.21	0.37	0.7
3 years	0.035	0.07	0.14

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.9×10^{-10}	2.4×10^{-10}	3.8×10^{-10}
100 days	5.2×10^{-10}	7×10^{-10}	1.3×10^{-9}
1 year	1.1×10^{-9}	1.9×10^{-9}	3.6×10^{-9}
3 years	1.5×10^{-9}	3.1×10^{-9}	6.2×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.4	1.8	2.8
1 day	1	1.7	2.1
3 days	0.7	1.4	2.5
10 days	0.49	0.76	1.4
30 days	0.07	0.13	0.28
100 days	0.00021	0.00036	0.0007

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	9.4×10^{-12}	1.6×10^{-11}	2×10^{-11}
3 days	2.2×10^{-11}	4.4×10^{-11}	7.9×10^{-11}
10 days	7.1×10^{-11}	1.1×10^{-10}	2×10^{-10}
30 days	9.2×10^{-11}	1.7×10^{-10}	3.7×10^{-10}
100 days	1.1×10^{-10}	1.9×10^{-10}	3.7×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.1	2.7	3.8
3 months	1.7	2.4	3.5
1 year	1.4	2	3.2
3 years	0.7	1.5	2.8
10 years	0.35	1	2.1
30 years	0.2	0.47	1.4
100 years	0.01	0.032	0.14

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.6×10^{-9}	2.3×10^{-9}	3.5×10^{-9}
1 year	5.3×10^{-9}	7.6×10^{-9}	1.2×10^{-8}
3 years	8.9×10^{-9}	1.9×10^{-8}	3.5×10^{-8}
10 years	1.6×10^{-8}	4.6×10^{-8}	9.7×10^{-8}
30 years	4×10^{-8}	9.3×10^{-8}	2.8×10^{-7}
100 years	4.1×10^{-8}	1.3×10^{-7}	5.7×10^{-7}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.1	2.7	3.8
3 months	1.7	2.4	3.5
1 year	1.4	2	3.2
3 years	0.7	1.5	2.8
10 years	0.35	1	2.1
30 years	0.2	0.47	1.4
100 years	0.01	0.032	0.14

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.6×10^{-9}	2.3×10^{-9}	3.5×10^{-9}
1 year	5.3×10^{-9}	7.6×10^{-9}	$1. \times 10^{-8}$
3 years	8.9×10^{-9}	1.9×10^{-8}	3.5×10^{-8}
10 years	1.6×10^{-8}	4.6×10^{-8}	9.7×10^{-8}
30 years	4×10^{-8}	9.3×10^{-8}	2.8×10^{-7}
100 years	4.1×10^{-8}	1.3×10^{-7}	5.7×10^{-7}

Question 6. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.5	6	7.5
10 days	4	6.2	8
30 days	4	6.4	8
100 days	3	4.4	6
1 year	0.1	0.29	0.4

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3.4×10^{-10}	5.3×10^{-10}	6.8×10^{-10}
30 days	1×10^{-9}	1.6×10^{-9}	2×10^{-9}
100 days	3.4×10^{-9}	5×10^{-9}	6.8×10^{-9}
1 year	5×10^{-9}	8.7×10^{-9}	1.2×10^{-8}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.6	2
30 days	1	1.5	2
100 days	0.8	1.3	2
1 year	0.3	0.64	1
3 years	0.05	0.12	0.2

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	2.7×10^{-10}	4.1×10^{-10}	5.5×10^{-10}
100 days	7.4×10^{-10}	1.2×10^{-9}	1.8×10^{-9}
1 year	1.5×10^{-9}	3.3×10^{-9}	5.2×10^{-9}
3 years	2.2×10^{-9}	5.3×10^{-9}	8.8×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2	3.1	4
1 day	1.5	2.9	4
3 days	1	2.4	3.5
10 days	0.7	1.3	2
30 days	0.1	0.23	0.4
100 days	0.0003	0.00061	0.001

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	1.4×10^{-11}	2.7×10^{-11}	3.7×10^{-11}
3 days	3.1×10^{-11}	7.5×10^{-11}	1.1×10^{-10}
10 days	1×10^{-10}	1.9×10^{-10}	2.9×10^{-10}
30 days	1.3×10^{-10}	3×10^{-10}	5.2×10^{-10}
100 days	1.6×10^{-10}	3.2×10^{-10}	5.2×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3	4.6	5.4
3 months	2.5	4.2	5
1 year	2	3.5	4.5
3 years	1	2.5	4
10 years	0.5	1.7	3
30 years	0.3	0.8	2
100 years	0.015	0.055	0.2

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.4×10^{-9}	4×10^{-9}	4.8×10^{-9}
1 year	7.4×10^{-9}	1.3×10^{-8}	1.7×10^{-8}
3 years	1.3×10^{-8}	3.2×10^{-8}	5.1×10^{-8}
10 years	2.3×10^{-8}	7.9×10^{-8}	1.4×10^{-7}
30 years	4×10^{-8}	1.6×10^{-7}	4×10^{-7}
100 years	4×10^{-8}	2.2×10^{-7}	8×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3	4.6	5.4
3 months	2.5	4.2	5
1 year	2	3.5	4.5
3 years	1	2.5	4
10 years	0.5	1.7	3
30 years	0.3	0.8	2
100 years	0.015	0.055	0.2

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.4×10^{-9}	4×10^{-9}	4.8×10^{-9}
1 year	7.4×10^{-9}	1.3×10^{-8}	1.7×10^{-8}
3 years	1.3×10^{-8}	3.2×10^{-8}	5.1×10^{-8}
10 years	2.3×10^{-8}	7.9×10^{-8}	1.4×10^{-7}
30 years	4×10^{-8}	1.6×10^{-7}	4×10^{-7}
100 years	6×10^{-8}	2.2×10^{-7}	8×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137 / I-131	
Ba-140	Zr-95	
Te-131m/Te-132	Cs-137 / I-131	
I-132/I-133/ I-134/I-135	Cs-137 / I-131	
Mo-99	Ru-106	
Ce-144	Zr-95	

Urban Environment

Nuclide	Similar Behavior To	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137 / I-131	
Ba-140	Zr-95	
Te-131m/Te-132	Cs-137 / I-131	
I-132/I-133/ I-134/I-135	Cs-137 / I-131	
Mo-99	Ru-106	
Ce-144	Zr-95	

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m² of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.5	0.7	1
(ii) medium shielding building	0.05	0.1	0.2
(iii) high shielding building	0.01	0.03	0.09
(iv) basement family house	0.003	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.25	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.5	0.7	1
(ii) medium shielding building	0.05	0.1	0.2
(iii) high shielding building	0.01	0.03	0.09
(iv) basement family house	0.003	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.25	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.5	0.7	1
(ii) medium shielding building	0.05	0.1	0.2
(iii) high shielding building	0.01	0.03	0.09
(iv) basement family house	0.003	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.25	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.5	0.7	1
(ii) medium shielding building	0.05	0.1	0.2
(iii) high shielding building	0.01	0.03	0.09
(iv) basement family house	0.003	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.25	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.5	0.7	1
(ii) medium shielding building	0.05	0.1	0.2
(iii) high shielding building	0.01	0.03	0.09
(iv) basement family house	0.003	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.25	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.35	0.49	0.7	0.25	0.35	0.5
(ii) medium shielding building	0.035	0.07	0.14	0.025	0.05	0.1
(iii) high shielding building	0.007	0.021	0.063	0.005	0.015	0.045
(iv) basement family house	0.0021	0.007	0.021	0.0015	0.005	0.015
(v) basement of multi-story block	0.00021	0.0007	0.0021	0.00015	0.0005	0.0015
(vi) inside typical car	0.125	0.25	0.35	0.075	0.15	0.21
(vii) inside typical bus	0.1	0.2	0.3	0.06	0.12	0.18

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.35	0.49	0.7	0.25	0.35	0.5
(ii) medium shielding building	0.035	0.07	0.14	0.025	0.05	0.1
(iii) high shielding building	0.007	0.021	0.063	0.005	0.015	0.045
(iv) basement family house	0.0021	0.007	0.021	0.0015	0.005	0.015
(v) basement of multi-story block	0.00021	0.0007	0.0021	0.00015	0.0005	0.0015
(vi) inside typical car	0.125	0.25	0.35	0.075	0.15	0.21
(vii) inside typical bus	0.1	0.2	0.3	0.06	0.12	0.18

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.35	0.49	0.7	0.25	0.35	0.5
(ii) medium shielding building	0.035	0.07	0.14	0.025	0.05	0.1
(iii) high shielding building	0.007	0.021	0.063	0.005	0.015	0.045
(iv) basement family house	0.0021	0.007	0.021	0.0015	0.005	0.015
(v) basement of multi-story block	0.00021	0.0007	0.0021	0.00015	0.0005	0.0015
(vi) inside typical car	0.125	0.25	0.35	0.075	0.15	0.21
(vii) inside typical bus	0.1	0.2	0.3	0.06	0.12	0.18

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.35	0.49	0.7	0.25	0.35	0.5
(ii) medium shielding building	0.035	0.07	0.14	0.025	0.05	0.1
(iii) high shielding building	0.007	0.021	0.063	0.005	0.015	0.045
(iv) basement family house	0.0021	0.007	0.021	0.0015	0.005	0.015
(v) basement of multi-story block	0.00021	0.0007	0.0021	0.00015	0.0005	0.0015
(vi) inside typical car	0.125	0.25	0.35	0.075	0.15	0.21
(vii) inside typical bus	0.1	0.2	0.3	0.06	0.12	0.18

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.35	0.49	0.7	0.25	0.35	0.5
(ii) medium shielding building	0.035	0.07	0.14	0.025	0.05	0.1
(iii) high shielding building	0.007	0.021	0.063	0.005	0.015	0.045
(iv) basement family house	0.0021	0.007	0.021	0.0015	0.005	0.015
(v) basement of multi-story block	0.00021	0.0007	0.0021	0.00015	0.0005	0.0015
(vi) inside typical car	0.125	0.25	0.35	0.075	0.15	0.21
(vii) inside typical bus	0.1	0.2	0.3	0.06	0.12	0.18

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.7	1
(ii) medium shielding building	0.03	0.1	0.2
(iii) high shielding building	0.003	0.03	0.1
(iv) basement family house	0.002	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.7	1
(ii) medium shielding building	0.03	0.1	0.2
(iii) high shielding building	0.003	0.03	0.1
(iv) basement family house	0.002	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.7	1
(ii) medium shielding building	0.03	0.1	0.2
(iii) high shielding building	0.003	0.03	0.1
(iv) basement family house	0.002	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.7	1
(ii) medium shielding building	0.03	0.1	0.2
(iii) high shielding building	0.003	0.03	0.1
(iv) basement family house	0.002	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.7	1
(ii) medium shielding building	0.03	0.1	0.2
(iii) high shielding building	0.003	0.03	0.1
(iv) basement family house	0.002	0.01	0.03
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.6

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.5	0.7
(ii) medium shielding building	0.03	0.07	0.15
(iii) high shielding building	0.003	0.01	0.03
(iv) basement family house	0.002	0.005	0.015
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.4	0.6
(vii) inside typical bus	0.2	0.3	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.5	0.7
(ii) medium shielding building	0.03	0.07	0.15
(iii) high shielding building	0.003	0.01	0.03
(iv) basement family house	0.002	0.005	0.015
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.4	0.6
(vii) inside typical bus	0.2	0.3	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.5	0.7
(ii) medium shielding building	0.03	0.07	0.15
(iii) high shielding building	0.003	0.01	0.03
(iv) basement family house	0.002	0.005	0.015
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.4	0.6
(vii) inside typical bus	0.2	0.3	0.5

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.5	0.7
(ii) medium shielding building	0.03	0.07	0.15
(iii) high shielding building	0.003	0.01	0.03
(iv) basement family house	0.002	0.005	0.015
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.4	0.6
(vii) inside typical bus	0.2	0.3	0.5

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.5	0.7
(ii) medium shielding building	0.03	0.07	0.15
(iii) high shielding building	0.003	0.01	0.03
(iv) basement family house	0.002	0.005	0.015
(v) basement of multi-story block	0.0003	0.001	0.003
(vi) inside typical car	0.2	0.4	0.6
(vii) inside typical bus	0.2	0.3	0.5

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 μm), Cs-137 (particulate, representative of ≈ 1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.2	0.3	0.5
Cs-137	0.3	0.5	0.7
I_2	0.2	0.3	0.5
CH_3I	0.9	0.95	0.99

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.1	0.2	0.3
Cs-137	0.15	0.3	0.6
I_2	0.1	0.2	0.3
CH_3I	0.99	0.999	0.9999

Question 12

Nuclide	Similar Ratio To	Specific Comments
Ru-103/Ru-106	Cs-137	
Te-129m/Te-132	Cs-137	
Cs-134	Cs-137	
Ba-140	Pu-240	
Ce-144	Pu-240	
Pu-238/Pu-241	Pu-240	
Cm-242	Pu-240	

Question 13 was not addressed.

EXPERT H

In all cases where the parent and daughter nuclides have been specified in the elicitation question, it has been assumed that 1 Bq/m^2 of the parent alone is deposited, with zero contribution from the daughter. Hence they are not in equilibrium upon deposition.

Questions 1, 2 and 3: Absorbed Dose-Rate in air at 1m above a uniform, flat open lawned area.

These three questions consider the uncertainties in absorbed dose-rate above a uniform surface as a function of time following initial deposition.

The first question deals with dry deposition, with the basic dose-rate values being taken from the work of Eckerman and Ryman (1993) calculated for a uniform, smooth plane surface. An additional reduction factor, *RF*, of 0.82 for dry deposition and 0.68 for wet deposition, has been used to account for the non-uniform nature of the open-lawn and the increased depth of the deposit during wet deposition episodes, together with a constant coefficient of 0.8 to translate between air kerma and effective dose.

All the tables in Eckerman and Ryman (1993) are given in the terms of effective dose. In that report, the values of effective dose equivalent normalized to air kerma 1 m above the air-ground interface (Sv/Gy) for different photon energy (Mev) are also given. The average mean of this parameter for the energy interval 0.1 - 100 Mev is 0.8. This exact value has been used in all my calculations.

Attenuation functions to account for the variation of dose-rate with time have been estimated using the work of Jacob and Likhtarev (1994), taking account of the fact that some data have been collected for the Ukraine and not western Europe. For dry and wet deposition mechanisms the following basic attenuation functions were used (*t* in years):

Dry: $\{0.3 \exp(0.155t) + 0.52\}$
Wet: $\{0.34 \exp(-0.55t) + 0.34\}$

The dry formulation reflects the results of Ukrainian measurements, and the wet reflects the increased rainfall environment in Bavaria (Jacob and Likhtarev, 1994). In considering the range of uncertainty in the estimated dose-rates following dry deposition (Question 1) two assumptions were made. For the 5th quantile, an alternative attenuation function has been used (which represents a 4-parameter average attenuation function for wet deposition, thus a likely lower range for the dry case):

Dry 5%: $\{0.31 \exp(-0.61t) + 0.37 \exp(-0.015t)\}$

where *t* is in years.

For the 95th quantile, a simple scaling of the median values for dry deposition by the factor 1.16 has been assumed.

For the wet deposition case (Question 2), the attenuation functions assumed for the 5th and 95th quantiles were (*t* in years):

Wet 5%: $\{\{0.31 \exp(-061t) + 0.37 \exp(-0.015t)\}$
$\times\ 0.81\}$
Wet 95%: $\{0.3 \exp(-0.55t) + 0.52\}$

It should be noted that the 95th quantile distribution is equivalent to the median value formulation for dry deposition, denoting the likely upper end of the range, and the 5th quantile is a reduction to 81% of the average formulation for wet deposition.

There are obviously high correlations between the dose-rate predictions with time and between nuclides, but no detailed correlation coefficients are suggested.

For Question 3, where the deposition mechanisms are not known, an arithmetic average of the values derived for wet and dry deposition in Questions 1 and 2 have been taken for the median values in answer to Question 3. For the 5th quantile, the lowest value of the dry/wet deposition cases has been used, namely the 5th quantile value for wet deposition. Similarly for the 95th quantile, the highest value (95th quantile for dry) has been taken. In addition, the initial coefficients were modified to be 0.6, 0.75 and 0.9 for the 5th, average and 95th quantiles respectively.

The formulations above were derived for cesium and due to lack of data, the same procedure has been applied to all nuclides.

The mathematical forms of the attenuation functions I have used for each deposition mechanism and each type of the uncertainty estimations are the following. These functions are the most likely reflection of the situations with different type of depositions, including unknown, we observed after the Chernobyl accident and which agreed with international experience.

Mean values:		
dry	$F_d(t) = 0.3 \exp(-0.55t) + 0.52$;	$F_d(0) = 0.82$;
wet	$F_w(t) = 0.34 \exp(-0.55t) + 0.34$;	$F_w(0) = 0.68$;
dry/wet	$F_{d/w}(t) = (F_d + F_w)/2$;	$F_{d/w}(0) = 0.75$;

The function $F_{d/w}(t)$ is estimated as the function which averaged the values derived with the attenuation functions $F_d(t)$ and $F_w(t)$.

5th quantile		
dry	$F_{d5\%}(t)$ $= 0.31 \exp(-0.61t) + 0.37 \exp(-0.15t)$;	$F_{d5\%}(0) = 0.68$;
wet	$F_{w5\%}(t) = 0.81\ F_{d5\%}$;	$F_{w5\%}(0) = 0.55$;

The coefficient 0.81 is used to decrease the attenuation functions to the lowest observed results ($F(0) = 0.55$).

dry/wet	$F_{d/w5\%}(t) = 0.88\ F_{d5\%}$;	$F_{d/w5\%}(0) = 0.6$

The coefficient 0.88 decreased the $F_{d5}\%$ and averaged the values of $F_{d5\%}(0) = 0.68$ and $F_{d5\%}(0) = 0.55$ ($F_{d/w5\%}(0) = 0.6$).

95th quantile		
dry	$F_{d95\%}(t) \cong 1.2\ F_d$	$F_{d95\%}(0) = 0.98$;
wet	$F_{w95\%}(t) \cong 1.2\ F_w$	$F_{w95\%}(0) = 0.82$;
dry/wet	$F_{d/w95\%}(t) \cong 1.2\ F_{d/w}$	$F_{d/w95\%}(0) = 0.9.$

The coefficient 1.2 increases the values for mean estimations to upper likelihood values.

Questions 4, 5 and 6: Effective Dose and Dose-Rate to an adult outdoors in urban and rural environments.

The dose-rate estimations from Questions 1, 2 and 3 were used here in answer to Questions 4, 5 and 6, together with the following modification functions for both the urban and rural environments:

Wet
- urban: $\{0.59 \exp(-0.213t) + 0.1\}$
- rural: $\{0.4 \exp(-0.213t) + 0.4$

Dry
- urban: $\{0.9 \exp(-0.693t) + 0.1\}$
- rural: $\{0.8 \exp(-0.693t) + 0.4$

The procedure for estimating the uncertainty ranges was based on the assumptions already discussed for Questions 1, 2 and 3. Correlations between the parameters are not explicitly discussed, but are assumed to be high between the integration times and between nuclides, given the common assumptions and as suggested in Questions 1, 2 and 3.

Question 7: Grouping of nuclides for which the assumptions are similar to those in Questions 1 to 6.

The behavior of all isotopes for one element are the same, with the obvious variations in external dose-rate for the open lawned area provided by a different scheme of radioactive decay. For the different nuclides under consideration, the variations in soil migration and surface fixation will cause variations in external dose, in addition to the effects of radioactive decay. Roughly two groups of nuclides may be established in accordance with these processes: the iodine/ruthenium group and the cesium group, with the following lists (based on those considered in the question):

- ^{103}Ru, ^{105}Ru, ^{131m}Te/^{132}Te, ^{99}Mo, and iodines: similar behavior to ^{105}Ru/^{131}I
- ^{134}Cs, ^{136}Cs, ^{140}Ba, ^{144}Ce (and La isotopes): similar to ^{137}Cs

More precisely speaking, it would be better to associate the Ce/La/Ba isotopes in an independent group with migration at an even slower rate than for cesium. From the point of view of migration, Ce is the slowest nuclide and Te the fastest.

In the urban environment, the surface fixation processes are more important than migration. Another important factor for these additional nuclides in the urban environment is the initial run-off processes, which inversely correlate to the fixation mechanisms. Here the following groupings are suggested:

- ^{103}Ru, ^{105}Ru, ^{131m}Te/^{132}Te: similar behavior to ^{105}Ru
- ^{140}Ba, ^{134}Cs, and ^{136}Cs: similar to ^{137}Cs
- Iodines all similar to ^{131}I
- ^{99}Mo and ^{144}Ce: similar to ^{95}Zr

Question 8, 9 and 10: Ratios (Location Factors) of Effective Dose received by an adult indoors to that received outdoors in an open lawned area for a variety of locations, including time-dependency of the Location Factors, and variations with dry and wet deposition.

One of the most difficult problems in calculating the external exposure of members of the public is the issue of their location within buildings or cars and the associated shielding effects. In addition, it was most appropriate in answering this question not to concentrate on data available from the Ukraine since the level of shielding is often much greater here than in other European dwellings.

The results of a Monte Carlo simulation of the exposure within European houses, as reported in the papers of Meckbach and Jacob (1988a,b), together with the results of a simulation of dwellings typical to the Ukraine (performed in collaboration with Dr. Meckbach), were used to address this question. The first set of data included results of calculations (kerma rates and location factors) for four types of European houses in a range of designs from very light (wood framed houses of prefabricated parts) to very heavy (old design house block) and a variety of environments. The second set of data included results of calculations for two types of houses (a low shielding wood-and-clay house and a brick house) and a five-story house block formed from prefabricated concrete panels. Partial kerma values were available only for 662 keV energy for all dwellings and for 360 keV for a one story brick house.

An analysis of the data revealed that both kerma rates and location factors differ within one class or type of buildings rather significantly. Since the task was to assess a range of location factors for houses with unspecified (unknown) design, the comparison of partial kermas (from different contaminated surfaces) provide certain guidelines about variations related to differences in design of the dwelling.

A very low shielded wood-framed house (Europe) and a rather solid wood-clay house (Ukraine) represent lower and upper bounds of shielding for the class of "low shielding buildings". It was assumed that all other possible house designs have intermediate shielding properties.

A *semi-detached* house (Europe) and a brick cottage (Ukraine) represent lower and upper bounds for "medium shielding buildings". In the case of "high shielding buildings", the European house block is shielded much better than concrete houses in Pripjat (Ukraine) and represent maximum shielding for this class.

A comparison of the ratio of "European"/"Ukrainian" for partial kermas was performed for the "medium shielding buildings" and energies of 360 and 662 keV. Energy dependence was found to be insignificant in this comparison and therefore the same range of kermas was assumed for all energies (in relative terms) as for 662 keV. This is possibly not true for the low energy edge (^{144}Ce), but for this energy, this deviation would be compensated by the dominance of penetration through windows, which depends mostly on the fraction of windows and is more uniform for all types of buildings.

Deposition patterns for dry and wet fallout (at time 0 and 1 year) were used as indicated in Jacob and Meckbach (1988b), with the effective source strength 10 years after the deposition assumed to be: 0.45 for lawn, 0.4 for ground, 0.03 for walls, 0.1 for roof, and 0 for windows and trees. Effective source strength for ground was estimated assuming that the fraction of paved area is 0.1 for small houses (classes 1 and 2) and 0.3 for multi-story blocks.

In order to assess the mean value of the location factor for each class as well as the 5th and 95th quantiles, a stochastic simulation package PRISM (R.H. Gardner, private communication) was used, running it with 1000 simulations for each combination of energy, deposition scenario and house design. For a multi-story house, distributions of location factors were obtained for ground, second and fourth floors separately and joined together afterwards in order to receive one overall distribution for this type of building. "Wet" and "dry" deposition scenarios were treated separately and in the case of an unknown deposition, the wet and dry depositions were aggregated by joining partial dry and wet distributions.

In the case of basements, data from European houses have been used. Location factors for the basement critically depend on design specifications (for instance presence of windows, level of basement ceiling relative to the ground surface, etc.). The work of Meckbach and Jacob (1988b) contains a large variety of basement designs, probably covering all ranges of possible situations. Therefore the extremes for "family houses" and "multi-story blocks" were used and which were simulated in this article as brackets of partial kermas in basements. The procedure of stochastic simulation is the same as described above.

Location factors for cars and buses were produced from the post-Chernobyl experience. Lognormal distributions with GSD of 1.4 were assumed. Although the window fraction for a bus is larger, the location factor is smaller due to the higher position of the individual above the contaminated surface and increased shielding by the engine compartment.

In all cases considered, no account was taken of any contamination indoors. Therefore the location factors are based on exposure from external sources only.

Questions 11 and 12: Ratio of Time Integrated Air Concentration Indoors compared to Outdoors

The Time Integrated Air Concentration (TIAC) indoors is determined by three main parameters:

- "filter" factor, f
- rate coefficient of ventilation, L_v
- rate coefficient of deposition, L_d

where:

$$TIAC = C_0 f L_v / (L_v + L_d)$$

and C_0 is the outdoor concentration in Bqsm^{-3}.

For gases (I_2 and CH_2I), L_d = 0, and the ratio of TIAC indoors to outdoors is equal to f. For aerosols (Pu-240 and ^{137}Cs), L_d is not equal to zero. The value of L_d according to Stokes depends very strongly on the size, shape, and density (p) of particles, viscosity of air, and the statistical distribution of these parameters.

Taking into account real situations (height of room), the following values may be used:

AMAD (p = 3 g cm^{-3})	µm	1	2	4	10
L_d	h^{-1}	0.02	0.93	3.7	23

Using the experience for ventilation conditions in Ukrainian houses (believed to be not too dissimilar from those in Western Europe), it is possible to establish four types of ventilation conditions for houses where people live:

- "bad ventilation" - all windows and doors are closed; number of cracks are very small and hence L_v = 1 h^{-1};
- "middle ventilation" - doors are closed, windows are opened rarely, and L_v = 2 h^{-1};
- "good ventilation" - windows and doors are opened relatively often, (in summertime, very often) and L_v = 4 h^{-1};
- "strong ventilation" - the same conditions as for good ventilation, along with electromechanical systems for ventilation also being used (e.g., western air conditioners, which are not used in Ukrainian houses), with L_v = 7 h^{-1}.

Little is known about the values of the filter factor, f. For very well sealed houses it has been assumed that f = 0.01 (e.g., western buildings with very good air conditioners). In reality, f will lie between 0.9 and 0.3, with a median value of about 0.6. For iodine (in molecular and organic forms) f = 0.9 * (1/0.8) in all situations.

The comparisons between nuclides (Question 12) were carried out by splitting the radionuclides into three groups:

1. ^{238}Pu, ^{240}Pu and ^{241}Pu; ^{241}Am and ^{242}Cm and related isotopes - all fuel-particles;
2. Ce, La, and Zr, which are mobile in different environmental and metabolic pathways, more so than those of the first group. The particle sizes are often smaller and the solubility is higher than the ones above.
3. The isotopes of I, Te and Cs. These are the most mobile in the atmosphere, soil, and water than those of the second group. The behavior on inhalation varies depending on how the nuclides are metabolized and contaminate internal organs, whereas the inhaled isotopes of the first and second groups are deposited and remain to a large extent in the lung.

Question 13: Population Behavior - Fractions of time spent indoors

The values presented in answer to this question are based on the demographic data for the Ukraine (1989 - 1994) and Likhtarev's own investigations after the Chernobyl accident.

The following age structure of the Ukrainian population has been used for the table containing population fractions:

Age-groups	thousands/ men	%
children < = 6 years old	4908	9.4
schoolchildren (7 - 17 years old)	12149	23.4
working population (18 - 59 years old)	25200	48.5
non-active (retired) adults (older than 60 years)	9732	18.7
TOTAL	51989	100

Practically all women in the Ukraine between 18 - 59 years old are working.

The average ratio of urban/rural population in the Ukraine is 0.68/0.32 (variation for urban is 0.41 - 0.86). For the urban environment the ratio of outdoor/indoor workers is 0.1/0.9, and for the rural environment it is 0.9/0.1. The ratio of outdoor and indoor workers for the whole working population is 0.32/0.64.

The fraction of time that people working indoors spend outdoors in a typical Ukrainian rural environment is not very much different from that for the people who are assumed to be working outdoors. This phenomenon exists because Ukrainian rural employees in small villages spend a lot of their time working in their private fields (like professional agricultural workers).

The time people spend in basements, cars and buses for all the groups have been estimated very roughly.

References

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Jacob, P. and Meckbach, R. 1990. "External exposure from deposited radionuclides." Proceedings of a Seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens May 7 - 11, 1990, Report EUR 13013, pp. 407-422, EC.

Note: **Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.**

Question 1. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	6.15	7.41	8.59
10 days	6.07	7.32	8.48
30 days	5.66	6.82	7.9
100 days	3.44	4.15	4.81
1 year	0.22	0.266	0.308

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.8	2.17	2.52
30 days	1.68	2.02	2.34
100 days	1.42	1.71	1.98
1 year	0.776	0.924	1.07
3 years	0.161	0.194	0.225

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.7	3.85	4.47
1 day	3.4	3.53	4.09
3 days	2.85	2.97	3.44
10 days	1.56	1.62	1.88
30 days	0.274	0.285	0.331
100 days	0.000633	0.000659	0.000764

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.98	6.01	6.96
3 months	4.62	5.69	6.6
1 year	3.82	4.96	5.75
3 years	2.76	3.95	4.58
10 years	1.86	3.03	3.51
30 years	0.864	1.91	2.21
100 years	0.06	0.378	0.438

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.97	6.15	7.41
10 days	4.9	6.06	7.31
30 days	4.55	5.62	6.78
100 days	2.73	3.37	4.07
1 year	0.166	0.205	0.248

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.46	1.8	2.17
30 days	1.34	1.67	2.01
100 days	1.12	1.39	1.67
1 year	0.578	0.715	0.862
3 years	0.11	0.136	0.164

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.59	3.2	3.85
1 day	1.87	2.31	2.79
3 days	1.19	1.47	1.77
10 days	0.548	0.678	0.817
30 days	0.097	0.12	0.145
100 days	0.000233	0.000288	0.000347

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.03	4.98	6.01
3 months	3.74	4.64	5.59
1 year	3.09	3.84	4.63
3 years	2.23	2.77	3.34
10 years	1.5	1.99	2.4
30 years	0.699	1.25	1.5
100 years	0.049	0.247	0.298

Question 3. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	5.42	6.78	8.13
10 days	5.35	6.69	8.03
30 days	4.98	6.22	7.47
100 days	3.01	3.76	4.5
1 year	0.188	0.236	0.283

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.59	1.99	2.38
30 days	1.47	1.84	2.21
100 days	1.24	1.55	1.86
1 year	0.655	0.819	0.983
3 years	0.132	0.165	0.198

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.82	3.53	4.23
1 day	2.34	2.92	3.51
3 days	1.78	2.22	2.67
10 days	0.918	1.15	1.38
30 days	0.162	0.203	0.243
100 days	0.000379	0.000474	0.000568

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.4	5.5	6.6
3 months	4.08	5.17	6.2
1 year	3.37	4.4	5.28
3 years	2.43	3.36	4.03
10 years	1.64	2.51	3.01
30 years	0.763	1.58	1.89
100 years	0.053	0.313	0.375

Question 4. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.38	5.94	7.13
10 days	3.32	5.77	6.93
30 days	3.05	5.2	6.24
100 days	1.76	2.81	3.37
1 year	0.0932	0.117	0.141

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.7×10^{-10}	4.89×10^{-10}	5.87×10^{-10}
30 days	7.89×10^{-10}	1.41×10^{-9}	1.69×10^{-9}
100 days	2.17×10^{-9}	3.75×10^{-9}	4.5×10^{-9}
1 year	3.48×10^{-9}	5.73×10^{-9}	6.88×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.992	1.74	2.09
30 days	0.902	1.54	1.85
100 days	0.724	1.16	1.39
1 year	0.324	0.408	0.489
3 years	0.0231	0.0332	0.0398

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	2.45×10^{-10}	4.25×10^{-10}	5.1×10^{-10}
100 days	7.35×10^{-10}	1.23×10^{-9}	1.48×10^{-9}
1 year	1.87×10^{-9}	2.87×10^{-9}	3.44×10^{-9}
3 years	2.73×10^{-9}	3.77×10^{-9}	4.53×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.76	3.09	3.71
1 day	1.61	2.83	3.39
3 days	1.35	2.37	2.84
10 days	0.734	1.28	1.53
30 days	0.127	0.218	0.261
100 days	0.00028	0.000446	0.000536

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	1.46×10^{-11}	2.56×10^{-11}	3.07×10^{-11}
3 days	4.01×10^{-11}	7.04×10^{-11}	8.44×10^{-11}
10 days	1.01×10^{-10}	1.77×10^{-10}	2.13×10^{-10}
30 days	1.61×10^{-10}	2.81×10^{-10}	3.37×10^{-10}
100 days	1.74×10^{-10}	3.02×10^{-10}	3.62×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.19	4.82	5.78
3 months	2.55	3.91	4.69
1 year	1.37	2.19	2.63
3 years	0.383	0.672	0.807
10 years	0.12	0.245	0.293
30 years	0.0551	0.152	0.183
100 years	0.0038	0.0302	0.0363

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.71×10^{-9}	3.43×10^{-9}	4.11×10^{-9}
1 year	5.23×10^{-9}	1.04×10^{-8}	1.25×10^{-8}
3 years	9.2×10^{-9}	1.81×10^{-8}	2.18×10^{-8}
10 years	1.3×10^{-8}	2.56×10^{-8}	3.07×10^{-8}
30 years	1.83×10^{-8}	3.78×10^{-8}	4.54×10^{-8}
100 years	2.25×10^{-8}	5.45×10^{-8}	6.54×10^{-8}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.94	5.8	6.96
3 months	3.46	4.92	5.9
1 year	2.49	3.2	3.84
3 years	1.5	1.59	1.91
10 years	0.95	0.981	1.18
30 years	0.441	0.615	0.738
100 years	0.0304	0.122	0.147

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.91×10^{-9}	4.21×10^{-9}	5.05×10^{-9}
1 year	9.82×10^{-9}	1.36×10^{-8}	1.64×10^{-8}
3 years	2.17×10^{-8}	2.74×10^{-8}	3.29×10^{-8}
10 years	4.69×10^{-8}	5.28×10^{-8}	6.34×10^{-8}
30 years	8.87×10^{-8}	1.02×10^{-7}	1.23×10^{-7}
100 years	1.23×10^{-7}	1.7×10^{-7}	2.03×10^{-7}

Question 5. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.71	3.38	5.94
10 days	2.65	3.32	5.77
30 days	2.44	3.05	5.2
100 days	1.41	1.76	2.81
1 year	0.0746	0.0932	0.117

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.16×10^{-10}	2.7×10^{-10}	4.89×10^{-10}
30 days	6.31×10^{-10}	7.89×10^{-10}	1.41×10^{-9}
100 days	1.74×10^{-9}	2.17×10^{-9}	3.75×10^{-9}
1 year	2.78×10^{-9}	3.48×10^{-9}	5.73×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.794	0.992	1.74
30 days	0.722	0.902	1.54
100 days	0.579	0.724	1.16
1 year	0.259	0.324	0.408
3 years	0.0345	0.0432	0.05

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	2.45×10^{-10}	4.25×10^{-10}	5.1×10^{-10}
100 days	7.35×10^{-10}	1.23×10^{-9}	1.48×10^{-9}
1 year	1.87×10^{-9}	2.87×10^{-9}	3.44×10^{-9}
3 years	2.73×10^{-9}	3.77×10^{-9}	4.53×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.41	1.76	3.09
1 day	1.29	1.61	2.83
3 days	1.08	1.35	2.37
10 days	0.587	0.734	1.28
30 days	0.102	0.127	0.218
100 days	0.000224	0.00028	0.000446

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	1.16×10^{-11}	1.46×10^{-11}	2.56×10^{-11}
3 days	3.21×10^{-11}	4.01×10^{-11}	7.04×10^{-11}
10 days	8.11×10^{-11}	1.01×10^{-10}	1.77×10^{-10}
30 days	1.29×10^{-10}	1.61×10^{-10}	2.81×10^{-10}
100 days	1.39×10^{-10}	1.74×10^{-10}	3.02×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.23	2.74	4.82
3 months	1.98	2.43	3.91
1 year	1.43	1.74	2.19
3 years	0.722	0.873	1.22
10 years	0.19	0.251	0.345
30 years	0.0555	0.1	0.152
100 years	0.0038	0.0198	0.0302

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.66×10^{-9}	2.04×10^{-9}	3.43×10^{-9}
1 year	5.65×10^{-9}	6.9×10^{-9}	1.04×10^{-8}
3 years	1.21×10^{-8}	1.47×10^{-8}	1.81×10^{-8}
10 years	2.01×10^{-8}	2.47×10^{-8}	2.56×10^{-8}
30 years	2.62×10^{-8}	3.38×10^{-8}	3.78×10^{-8}
100 years	3.04×10^{-8}	4.47×10^{-8}	5.45×10^{-8}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.55	3.28	5.8
3 months	2.31	2.97	4.92
1 year	1.78	2.27	3.2
3 years	1.08	1.37	1.59
10 years	0.522	0.719	0.981
30 years	0.221	0.411	0.615
100 years	0.0152	0.0814	0.122

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.91×10^{-9}	2.46×10^{-9}	4.21×10^{-9}
1 year	6.71×10^{-9}	8.59×10^{-9}	1.36×10^{-8}
3 years	1.54×10^{-8}	1.96×10^{-8}	2.74×10^{-8}
10 years	3.11×10^{-8}	4.02×10^{-8}	5.28×10^{-8}
30 years	5.26×10^{-8}	7.39×10^{-8}	1.02×10^{-7}
100 years	6.95×10^{-8}	1.19×10^{-7}	1.7×10^{-7}

Question 6. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.05	4.66	6.54
10 days	2.99	4.55	6.35
30 days	2.74	4.12	5.72
100 days	1.58	2.28	3.09
1 year	0.0839	0.105	0.129

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.43×10^{-10}	3.8×10^{-10}	5.38×10^{-10}
30 days	7.1×10^{-10}	1.1×10^{-9}	1.55×10^{-9}
100 days	1.95×10^{-9}	2.96×10^{-9}	4.13×10^{-9}
1 year	3.13×10^{-9}	4.6×10^{-9}	6.3×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.794	1.37	2.09
30 days	0.722	1.22	1.85
100 days	0.579	0.94	1.39
1 year	0.259	0.366	0.489
3 years	0.0345	0.0381	0.0398

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.96×10^{-10}	3.35×10^{-10}	5.1×10^{-10}
100 days	5.88×10^{-10}	9.85×10^{-10}	1.48×10^{-9}
1 year	1.5×10^{-9}	2.37×10^{-9}	3.44×10^{-9}
3 years	2.18×10^{-9}	3.25×10^{-9}	4.53×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.41	2.42	3.71
1 day	1.29	2.22	3.39
3 days	1.08	1.86	2.84
10 days	0.587	1	1.53
30 days	0.102	0.173	0.261
100 days	0.000224	0.000363	0.000536

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	1.16×10^{-11}	2.01×10^{-11}	3.07×10^{-11}
3 days	3.21×10^{-11}	5.52×10^{-11}	8.44×10^{-11}
10 days	8.11×10^{-11}	1.39×10^{-10}	2.13×10^{-10}
30 days	1.29×10^{-10}	2.21×10^{-10}	3.37×10^{-10}
100 days	1.39×10^{-10}	2.38×10^{-10}	3.62×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.23	3.78	5.78
3 months	1.98	3.17	4.69
1 year	1.43	1.96	2.63
3 years	0.722	0.773	0.807
10 years	0.19	0.248	0.293
30 years	0.055	0.126	0.183
100 years	0.0038	0.025	0.0363

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.66×10^{-9}	2.73×10^{-9}	4.11×10^{-9}
1 year	5.65×10^{-9}	8.65×10^{-9}	1.25×10^{-8}
3 years	1.21×10^{-8}	1.64×10^{-8}	2.18×10^{-8}
10 years	2.01×10^{-8}	2.51×10^{-8}	3.07×10^{-8}
30 years	2.62×10^{-8}	3.58×10^{-8}	4.54×10^{-8}
100 years	3.04×10^{-8}	4.96×10^{-8}	6.54×10^{-8}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.55	4.54	6.96
3 months	2.31	3.94	5.9
1 year	1.78	2.73	3.84
3 years	1.08	1.48	1.91
10 years	0.522	0.85	1.18
30 years	0.221	0.513	0.738
100 years	0.0152	0.102	0.147

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.91×10^{-9}	3.34×10^{-9}	5.05×10^{-9}
1 year	6.71×10^{-9}	1.11×10^{-8}	1.63×10^{-8}
3 years	1.54×10^{-8}	2.35×10^{-8}	3.29×10^{-8}
10 years	3.11×10^{-8}	4.65×10^{-8}	6.34×10^{-8}
30 years	5.26×10^{-8}	8.8×10^{-8}	1.23×10^{-7}
100 years	6.95×10^{-8}	1.44×10^{-7}	2.03×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140	Cs-137	
Te-131m/Te-132	Ru-106 / I-131	
I-132/I-133/ I-134/I-135	Ru-106 / I-131	
Mo-99	Ru-106 / I-131	
Ce-144	Cs-137	

Urban Environment

Nuclide	Similar Behavior To (delete as appropriate)	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140	Cs-137	
Te-131m/Te-132	Ru-106	
I-132/I-133/ I-134/I-135	I-131	
Mo-99	Zr-95	
Ce-144	Zr-95	

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m² of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.39	0.68
(ii) medium shielding building	0.08	0.11	0.15
(iii) high shielding building	0.00054	0.0039	0.029
(iv) basement family house	0.0034	0.0097	0.021
(v) basement of multi-story block	0.000031	0.00008	0.00021
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.39	0.67
(ii) medium shielding building	0.073	0.097	0.14
(iii) high shielding building	0.00052	0.0036	0.028
(iv) basement family house	0.003	0.0089	0.019
(v) basement of multi-story block	0.000025	0.000065	0.00017
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.19	0.37	0.65
(ii) medium shielding building	0.063	0.083	0.12
(iii) high shielding building	0.0005	0.0029	0.024
(iv) basement family house	0.0018	0.0065	0.015
(v) basement of multi-story block	0.000015	0.000031	0.000083
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.2	0.39	0.68
(ii) medium shielding building	0.076	0.1	0.15
(iii) high shielding building	0.00053	0.0037	0.029
(iv) basement family house	0.0033	0.0093	0.02
(v) basement of multi-story block	0.000029	0.000075	0.00019
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.19	0.36	0.63
(ii) medium shielding building	0.054	0.072	0.1
(iii) high shielding building	0.00048	0.0022	0.02
(iv) basement family house	0.0012	0.0051	0.012
(v) basement of multi-story block	0.00001	0.000016	0.000054
(vi) inside typical car	0.2	0.4	0.78
(vii) inside typical bus	0.1	0.2	0.39

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.18	0.31	0.44	0.15	0.26	0.39
(ii) medium shielding building	0.07	0.089	0.11	0.062	0.08	0.1
(iii) high shielding building	0.00045	0.0031	0.0087	0.00061	0.0024	0.0048
(iv) basement family house	0.0023	0.0065	0.011	0.0016	0.0064	0.012
(v) basement of multi-story block	0.000024	0.000057	0.0001	0.000029	0.000053	0.000081
(vi) inside typical car	0.17	0.33	0.65	0.05	0.1	0.2
(vii) inside typical bus	0.1	0.2	0.39	0.03	0.06	0.12

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.17	0.3	0.43	0.15	0.26	0.38
(ii) medium shielding building	0.065	0.081	0.099	0.057	0.073	0.091
(iii) high shielding building	0.00043	0.0028	0.0082	0.00058	0.0021	0.0043
(iv) basement family house	0.002	0.0059	0.0099	0.0014	0.0059	0.011
(v) basement of multi-story block	0.00002	0.000047	0.000084	0.000025	0.000044	0.000067
(vi) inside typical car	0.17	0.33	0.65	0.05	0.1	0.2
(vii) inside typical bus	0.1	0.2	0.39	0.03	0.06	0.12

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.17	0.29	0.41	0.14	0.25	0.37
(ii) medium shielding building	0.055	0.068	0.083	0.048	0.061	0.077
(iii) high shielding building	0.00041	0.002	0.007	0.00055	0.0015	0.0035
(iv) basement family house	0.0013	0.0044	0.0075	0.00094	0.0044	0.0082
(v) basement of multi-story block	0.000012	0.000024	0.00004	0.000015	0.000023	0.0032
(vi) inside typical car	0.17	0.33	0.65	0.05	0.1	0.2
(vii) inside typical bus	0.1	0.2	0.39	0.03	0.06	0.12

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.18	0.3	0.43	0.15	0.26	0.39
(ii) medium shielding building	0.066	0.084	0.1	0.059	0.075	0.094
(iii) high shielding building	0.00044	0.003	0.0085	0.00059	0.0023	0.0046
(iv) basement family house	0.0022	0.0062	0.01	0.0015	0.0062	0.011
(v) basement of multi-story block	0.000023	0.000054	0.000096	0.000028	0.00005	0.000076
(vi) inside typical car	0.17	0.33	0.65	0.05	0.1	0.2
(vii) inside typical bus	0.1	0.2	0.39	0.03	0.06	0.12

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.16	0.28	0.4	0.14	0.24	0.35
(ii) medium shielding building	0.047	0.059	0.072	0.041	0.052	0.066
(iii) high shielding building	0.00039	0.0016	0.0061	0.0005	0.0011	0.0031
(iv) basement family house	0.00086	0.0034	0.0059	0.00068	0.0035	0.0065
(v) basement of multi-story block	8.1E-06	0.000013	0.000023	0.00001	0.000014	0.000017
(vi) inside typical car	0.14	0.27	0.53	0.041	0.08	0.16
(vii) inside typical bus	0.066	0.13	0.25	0.26	0.5	0.098

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.28	0.5	0.73
(ii) medium shielding building	0.096	0.13	0.16
(iii) high shielding building	0.0029	0.0041	0.033
(iv) basement family house	0.0053	0.014	0.022
(v) basement of multi-story block	0.00012	0.00017	0.00022
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.28	0.5	0.72
(ii) medium shielding building	0.088	0.12	0.15
(iii) high shielding building	0.0027	0.0038	0.031
(iv) basement family house	0.0048	0.013	0.02
(v) basement of multi-story block	0.00011	0.00014	0.00018
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.27	0.48	0.7
(ii) medium shielding building	0.074	0.098	0.13
(iii) high shielding building	0.0021	0.0033	0.027
(iv) basement family house	0.0035	0.0096	0.016
(v) basement of multi-story block	0.000061	0.000072	0.000085
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.28	0.5	0.73
(ii) medium shielding building	0.09	0.12	0.15
(iii) high shielding building	0.0028	0.004	0.032
(iv) basement family house	0.0051	0.013	0.021
(v) basement of multi-story block	0.00012	0.00016	0.002
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.26	0.46	0.68
(ii) medium shielding building	0.063	0.085	0.11
(iii) high shielding building	0.0017	0.0033	0.023
(iv) basement family house	0.0027	0.0077	0.013
(v) basement of multi-story block	0.000032	0.000043	0.000057
(vi) inside typical car	0.2	0.4	0.78
(vii) inside typical bus	0.1	0.2	0.39

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.19	0.31	0.43
(ii) medium shielding building	0.077	0.095	0.11
(iii) high shielding building	0.000043	0.0033	0.01
(iv) basement family house	0.0029	0.0076	0.012
(v) basement of multi-story block	0.000028	0.000049	0.00007
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.19	0.31	0.43
(ii) medium shielding building	0.071	0.087	0.1
(iii) high shielding building	0.0004	0.0031	0.0085
(iv) basement family house	0.0029	0.0076	0.012
(v) basement of multi-story block	0.000023	0.000039	0.000057
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.18	0.3	0.41
(ii) medium shielding building	0.06	0.074	0.088
(iii) high shielding building	0.00039	0.0023	0.0041
(iv) basement family house	0.0015	0.0048	0.0081
(v) basement of multi-story block	0.000014	0.000021	0.000027
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.19	0.31	0.43
(ii) medium shielding building	0.073	0.089	0.11
(iii) high shielding building	0.00041	0.0032	0.0095
(iv) basement family house	0.0027	0.0073	0.012
(v) basement of multi-story block	0.000026	0.000046	0.000065
(vi) inside typical car	0.26	0.5	0.98
(vii) inside typical bus	0.15	0.3	0.59

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.17	0.29	0.39
(ii) medium shielding building	0.052	0.065	0.077
(iii) high shielding building	0.00037	0.0016	0.0029
(iv) basement family house	0.00097	0.0036	0.0062
(v) basement of multi-story block	0.00001	0.000012	0.000015
(vi) inside typical car	0.2	0.4	0.78
(vii) inside typical bus	0.1	0.2	0.39

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 μm), Cs-137 (particulate, representative of ≈ 1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.05	0.2	0.6
Cs-137	0.2	0.9	1
I_2	0.4	0.9	1
CH_3I	0.4	0.9	1

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.02	0.06	0.2
Cs-137	0.03	0.09	0.3
I_2	0.02	0.1	0.4
CH_3I	0.02	0.07	0.3

Question 12

Nuclide	Similar Ratio To (delete as appropriate)	Specific Comments
Ru-103/Ru-106	Cs-137	
Te-129m/Te-132	I_2 / CH_3I	
Cs-134	Cs-137	
Ba-140	Cs-137	
Ce-144	Cs-137	
Pu-238/Pu-241	Pu-240	
Cm-242	Pu-240	

Question 13. *Population Fractions.*

POPULATION FRACTION	5th Quantile	Median	95th Quantile
(i) agricultural and other outdoor workers	0.087	0.17	0.28
(ii) indoor workers	0.19	0.31	0.42
(iii) non-active adult population[a]	0.1	0.19	0.25
(ii) schoolchildren	0.15	0.23	0.32

a. All adults are considered to be in category i, ii, or iii. The non-active adult population are those that are not agricultural and outdoor workers or indoor workers. Activity here refers to employment not amount of energy expended.

People Working Outdoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.08	0.12	0.18
(ii) medium shielding, e.g., single brick family house	0.028	0.042	0.063
(iii) high shielding, e.g., multi-story office block	0.33	0.5	0.75
(iv) basement of single family house	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(v) basement multi-story office block	0.000028	0.000042	0.000063
(vi) inside typical car	0.000028	0.000042	0.000063
(vii) inside typical bus	0.0014	0.0021	0.0032

People Working Indoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.000011	0.000017	0.000026
(ii) medium shielding, e.g., single brick family house	0.0023	0.0035	0.0053
(iii) high shielding, e.g., multi-story office block	0.53	0.79	0.9
(iv) basement of single family house	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(v) basement multi-story office block	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(vi) inside typical car	0.00028	0.00042	0.00063
(vii) inside typical bus	0.0014	0.0021	0.0032

Non-Active Adult Population Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.00028	0.00042	0.00063
(ii) medium shielding, e.g., single brick family house	0.055	0.083	0.1
(iii) high shielding, e.g., multi-story office block	0.55	0.83	0.9
(iv) basement of single family house	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(v) basement multi-story office block	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(vi) inside typical car	0.000028	0.000042	0.000063
(vii) inside typical bus	0.000028	0.000042	0.000063

Schoolchildren Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	2.8E-06	4.2E-06	0.00063
(ii) medium shielding, e.g., single brick family house	0.42	0.63	0.95
(iii) high shielding, e.g., multi-story office block	0.14	0.21	0.32
(iv) basement of single family house	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(v) basement multi-story office block	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(vi) inside typical car	0.000028	0.000042	0.000063
(vii) inside typical bus	0.000055	0.000083	0.00012

People Working Outdoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.0035	0.0052	0.0079
(ii) medium shielding, e.g., single brick family house	0.011	0.016	0.024
(iii) high shielding, e.g., multi-story office block	0.014	0.021	0.028
(iv) basement of single family house	0.00055	0.00083	0.0012
(v) basement multi-story office block	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(vi) inside typical car	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(vii) inside typical bus	5.5×10^{-6}	8.3×10^{-6}	0.000012

People Working Indoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.00058	0.00087	0.0013
(ii) medium shielding, e.g., single brick family house	0.011	0.016	0.024
(iii) high shielding, e.g., multi-story office block	0.14	0.21	0.28
(iv) basement of single family house	0.00055	0.00083	0.0012
(v) basement multi-story office block	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(vi) inside typical car	2.8×10^{-6}	4.2×10^{-6}	6.3×10^{-6}
(vii) inside typical bus	5.5×10^{-6}	8.3×10^{-6}	0.000012

Non-Active Adult Population Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.083	0.12	0.18
(ii) medium shielding, e.g., single brick family house	0.33	0.5	0.75
(iii) high shielding, e.g., multi-story office block	0.0055	0.0083	0.012
(iv) basement of single family house	0.00055	0.00083	0.0012
(v) basement multi-story office block	NR	NR	NR
(vi) inside typical car	2.8×10^{-6}	4.6×10^{-6}	6.3×10^{-6}
(vii) inside typical bus	5.5×10^{-6}	8.3×10^{-6}	0.000012

Schoolchildren Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.0055	0.0083	0.012
(ii) medium shielding, e.g., single brick family house	0.36	0.54	0.81
(iii) high shielding, e.g., multi-story office block	0.14	0.21	0.28
(iv) basement of single family house	0.000028	0.000042	0.000063
(v) basement multi-story office block	0.000028	0.000042	0.000063
(vi) inside typical car	2.8×10^{-6}	4.2×10^{-6}	0.000063
(vii) inside typical bus	5.5×10^{-6}	8.3×10^{-6}	0.000012

Estimated Dosages from Outdoor Exposure in Sample Countries

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.028	0.042	0.052
(ii) medium shielding, e.g., single brick family house	0.14	0.21	0.26
(iii) high shielding, e.g., multi-story office block	0.37	0.56	0.69
(iv) basement of single family house	0.00011	0.00017	0.00021
(v) basement multi-story office block	3.6×10^{-6}	5.4×10^{-6}	6.7×10^{-6}
(vi) inside typical car	0.000056	0.000083	0.0001
(vii) inside typical bus	0.000014	0.000021	0.000026

EXPERT I

Rationale – Expert Panel on Deposited Materials and External Doses

In all cases where the parent and daughter nuclides have been specified in the elicitation question, it has been assumed that they are both in equilibrium upon deposition to the surfaces considered. Hence initial equilibrium mixtures of: $^{95}Zr/^{95}Nb$; $^{106}Ru/^{106}Rh$; $^{137}Cs/^{137}Ba$; and $^{144}Ce/^{144}Pr$, have been considered.

Questions 1, 2 and 3: Absorbed Dose-Rate in air at 1m above a uniform, flat open lawned area.

These three questions consider the uncertainties in absorbed dose-rate above a uniform surface as a function of time following initial deposition.

The first question deals with dry deposition, and the basic dose-rate values have been taken from the work of Eckerman and Ryman (1993) calculated for a uniform, smooth plane surface. An additional roughness factor of 0.7 has been used to account for the non-uniform nature of the open-lawn - a factor which has been reconfirmed by Merwin and Balonov (1993). The dose-rate factors together with a simple ratio of 1.2 to account for the fact that deposition occurs by dry mechanisms only.

The median dose-rate at time zero is calculated according to:

$$\dot{D}(0) = \frac{\dot{D}(EPA-12) \times 0.7 \times 1.2}{CF}$$

where

D(EPA-12) is the effective dose equivalent (EDE) rate at 1 m above a uniform flat terrain (taken from EPA-12); and
CF is a conversion factor translating EDE rate back to dose in air (ranging between 0.77 - 0.78 Sv/Gy).

The time dependency of the dose-rate is formed around the basic equation:

$$\dot{D}(t) = \frac{\dot{D}(EPA-12)}{CF} \times \left\{0.68 \exp(-\lambda_r t) + 0.16 \exp\left(-\left(\lambda_r + \frac{\ln 2}{15}\right)t\right)\right\} = \frac{\dot{D}(EPA-12)}{CF} \times WE(t)$$

where 15 days is taken as the half-life of the weathering component, and λ_r is the radioactive decay constant. For time periods of less than 100 days, the weathering component for cesium is taken to be (ignoring radioactive decay):

$$WE(t) = 0.68 + 0.16 \exp\left(-\frac{\ln 2}{15}t\right)$$

For time periods greater than or equal to 100 days, the basic model and data has been taken from Balonov et al. (1995) given an assumed 4.4 years weathering half-life for cesium:

$$\dot{D}(t) = \frac{\dot{D}(EPA-12)}{CF} \times AT(t) \times \exp(-\lambda_r t)$$

where

$$AT(t) = 0.42 \exp\left(-\frac{\ln 2}{4.4}t\right) + 0.26$$

The weathering half-life of cesium has been taken from data collected by Balonov and co-authors and has been applied to all nuclides.

In addressing uncertainty in the absorbed dose-rate in air, the upper bound (95th quantile) for each nuclide has been taken to be equivalent to zero roughness length, i.e., effectively a uniform, smooth surface. The lower bound (5th quantile) has been assessed in two ways. The first considered merely a symmetrical level of uncertainty, equivalent to that from the median to the 95th quantile. Then a more detailed look at the post-Chernobyl measurements revealed that the 5th/50th quantiles of dose-rate, reduced by soil migration between 1 and 3 years, is approximately equal to 1.7, which has resulted in a decrease of the lower bound. In addition, the known high mobility of ^{131}I was also taken into account for the lower estimate of the uncertainty range.

There are obviously high correlations between the dose-rate predictions with time and between nuclides, but no detailed correlation coefficients are suggested.

The assumptions for Question 2 are essentially the same as for Question 1, differing only in the removal of the factor of "1.2" in the calculation of dose-rate at time zero – a factor which accounted for dry deposition mechanisms only. The uncertainties in the values were also estimated using the same assumptions as in Question 2, with no variations of rain intensity being taken into account. The upper bound (95th quantile) was taken to be equivalent to that for dry deposition, with the lower bound reduced from that for dry by the factor 1.2.

For Question 3, where the deposition mechanisms are not known, an average of the values derived for wet and dry deposition in Questions 1 and 2 have been taken by assuming that dry deposition occurs 80% of the time, and hence:

$$\dot{D}(t) = 0.8\dot{D}_{dry}(t) + 0.2\dot{D}_{wet}(t)$$

Questions 4, 5 and 6: Effective Dose and Dose-Rate to an adult outdoors in urban and rural environments.

The dose-rate estimations from Questions 1, 2 and 3 were used here in combination with a location factor *LF*, and the previously defined conversion factor *CF* to translate back from dose in air to effective dose. The basic equation was therefore:

$$\dot{E} = \dot{D} \times CF \times \overline{LF}$$

where *D* is taken from Questions 1, 2 or 3.

CF was taken to be 0.8 Sv/Gy for the first year following deposition and 0.7 Sv/Gy thereafter (Merwin and Balonov, 1993; p. 253).

For the estimates of effective dose-rate outdoors in the urban environment, the average location factor, *LF*, varied between 0.5 for the first year to 0.4 thereafter, again taken from the Chernobyl papers (Merwin and Balonov, 1993; p 280). The rural environment was assumed to be identical to the uniform open lawn (as in Questions 1/2/3) and therefore the location factor was always taken to be equal to 1.0.

The uncertainty ranges were based on the assumptions already discussed for Questions 1, 2 and 3, with the additional assumption of an uncertainty of ~5% in the values of *CF*. For the urban environment, variations in the location factor were also taken into account for a variety of possible settlements. The ratio of the 95th/50th and 50th/5th quantiles for the values of *LF* are estimated to be ~1.3, using Balonov and co-authors' own data and relevant literature, and this value was used in combination with the other estimated levels of uncertainty.

Correlations between the parameters are not explicitly discussed, but are assumed to be high between the integration times and between nuclides, given the common assumptions and as suggested in Questions 1, 2 and 3.

Question 7: Grouping of nuclides for which the assumptions are similar to those in Questions 1 to 6.

The same groups were given for both the open lawned area and the urban environment, where in both cases the following comparisons were suggested:

- ^{103}Ru and ^{105}Ru similar behavior to ^{106}Ru
- ^{134}Cs and ^{136}Cs similar to ^{137}Cs
- Iodines all similar to ^{131}I
- ^{99}Mo and ^{144}Ce similar to ^{95}Zr

No comparisons could be made for ^{140}Ba, since the behavior in terms of soil fixation and migration lies between Ce/Mo and Cs. Again no analogy could be suggested for ^{131m}Te/^{132}Te due to lack of knowledge of this element.

Question 8: Ratios (Location Factors) of Effective Dose received by an adult indoors to that received outdoors in an open lawned area for a variety of locations.

The results here assume that the location factor has been calculated immediately following deposition and are based on Balonov and co-authors' own data collection in combination with information obtained from the literature (Jacob and Likhtarev, 1996, p. 274-282; Roed, 1990). The uncertainty ranges estimated for each of the location factors were a combination of the range of measurement results taken in Russia after the Chernobyl accident, data from associated literature and an educated interpretation of the likely uncertainties for the locations described in the question. No penetration of the activity indoors has been assumed in estimating the location factors.

For each individual nuclide, a high correlation (70-80%) is suggested between the location factors defined for (ii) the medium shielding building and (iv) the basement of a family house. Similarly, a high correlation is also suggested between the values for the high shielding building (iii) and the basement of a multi-story block (v). The data given for a typical car and bus, (vi) and (vii), are less correlated and a figure of ~50% is suggested. No automatic correlations are assumed between nuclides since there would be strong variations with gamma energy across the range.

Questions 9 and 10: Time-dependency of the Location Factors Given in Question 8, and variations with dry and wet deposition.

Scaling factors to modify the initial location factors in Question 8 have been suggested in answer to Question 9 for ^{106}Ru, ^{137}Cs and ^{144}Ce. These scaling factors take account of the variations in the location factor resulting from the movement of activity within the urban area, e.g., caused by traffic disturbance.

Question 10 has been approached in essentially the same way as Question 8, taking account of the fact that the influence of the initial deposition mechanisms will be removed after the first two or three months.

Questions 11 and 12: Ratio of Time Integrated Air Concentration Indoors compared to Outdoors

The author has limited experience in this area and has relied on work of other authors in particular Roed (1990).

Question 13: Population Behavior – Fractions of time spent indoors

Data used were taken from Russia, Ukraine and Belorussia, in particular from a poll of the population in towns and villages in Russia following the Chernobyl accident, as discussed in Merwin and Balonov (1993) and Jacob and Likhtarev (1996).

References

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Jacob, P. and I. Likhtarev (Eds.). 1996. *Joint Study Project No. 5, Pathway analysis and dose distributions*, Final report, EUR 16541 EN.

Roed, J. 1990. *Deposition and Removal of Radioactive Substances in an Urban Area*, Risø, Denmark.

Note: **Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.**

Question 1. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	13	15.8	19
10 days	11	13.8	17
30 days	8	11.1	13
100 days	3.9	5.8	7
1 year	0.22	0.36	0.47

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.9	2.3	2.8
30 days	1.2	1.85	2.2
100 days	1	1.51	1.8
1 year	0.5	0.86	1.1
3 years	0.11	0.18	0.25

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.4	4.1	4.9
1 day	2.9	3.7	4.5
3 days	2.2	3.1	3.7
10 days	1	1.58	1.9
30 days	0.16	0.26	0.31
100 days	0.0003	0.0006	0.0007

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	5.3	6.4	7.7
3 months	3.3	5	6
1 year	2.9	4.6	6
3 years	2.2	3.7	5.2
10 years	1.1	2.1	3.2
30 years	0.4	1	2
100 years	0.07	0.2	0.4

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	10	13.2	17
10 days	9	12.6	17
30 days	7.2	10.9	15
100 days	3.6	5.8	7.6
1 year	0.21	0.35	0.5

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.5	1.93	2.5
30 days	1.2	1.83	2.4
100 days	0.9	1.51	2
1 year	0.5	0.86	1.2
3 years	0.1	0.18	0.27

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.6	3.42	4.4
1 day	2.4	3.15	4.1
3 days	1.2	2.63	3.4
10 days	1	1.44	1.9
30 days	0.16	0.26	0.34
100 days	0.0004	0.0006	0.0008

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.6	5.3	6.9
3 months	3.3	5	6.5
1 year	2.9	4.6	6
3 years	2.2	3.7	5.2
10 years	1.1	2.1	3.2
30 years	0.4	1	2
100 years	0.07	0.2	0.4

Question 3. *Gamma dose-rate ($Gy \bullet s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	13	15.3	19
10 days	11	13.7	17
30 days	8	11	14
100 days	3.9	5.8	7
1 year	0.22	0.35	0.5

Nuclide Ru-106

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.8	2.23	2.7
30 days	1.2	1.85	2.2
100 days	1	1.51	1.8
1 year	0.5	0.86	1.1
3 years	0.11	0.18	0.25

Nuclide I-131

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.3	4	4.8
1 day	2.8	3.6	4.4
3 days	2.2	3	3.8
10 days	1	1.55	1.9
30 days	0.16	0.26	0.31
100 days	0.0004	0.0006	0.0007

Nuclide Cs-137

Dose-Rate ($Gy \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	5.1	6.2	7.5
3 months	3.3	5	6
1 year	2.9	4.6	6
3 years	2.2	3.7	5.2
10 years	1.1	2.1	3.2
30 years	0.4	1	2
100 years	0.07	0.2	0.4

Question 4. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	6.3	9.8
10 days	3.3	5.6	8.7
30 days	2.4	4.4	6.8
100 days	1.3	2.3	3.6
1 year	0.07	0.14	0.24

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3×10^{-10}	5×10^{-10}	8×10^{-10}
30 days	8×10^{-10}	1.3×10^{-9}	2.1×10^{-9}
100 days	2.2×10^{-9}	3.3×10^{-9}	5.1×10^{-9}
1 year	2.7×10^{-9}	5.1×10^{-9}	7.9×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.6	0.93	1.4
30 days	0.4	0.74	1.2
100 days	0.31	0.61	0.9
1 year	0.16	0.34	0.6
3 years	0.023	0.05	0.09

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.2×10^{-10}	2.1×10^{-10}	3.2×10^{-10}
100 days	3.2×10^{-10}	6×10^{-10}	9×10^{-10}
1 year	1×10^{-9}	1.8×10^{-9}	3×10^{-9}
3 years	1.1×10^{-9}	2.2×10^{-9}	4×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.1	1.7	2.6
1 day	0.9	1.5	2.3
3 days	0.7	1.2	1.9
10 days	0.35	0.63	1
30 days	0.05	0.1	0.16
100 days	0.00011	0.00024	0.0004

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	8×10^{-12}	1.3×10^{-11}	2×10^{-11}
3 days	2.1×10^{-11}	3.6×10^{-11}	5.6×10^{-11}
10 days	4.9×10^{-11}	9×10^{-11}	1.4×10^{-10}
30 days	7×10^{-11}	1.4×10^{-10}	2.2×10^{-10}
100 days	8×10^{-11}	1.5×10^{-10}	2.4×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.6	2.6	4
3 months	1	1.9	2.9
1 year	0.8	1.7	2.9
3 years	0.5	1	1.9
10 years	0.23	0.6	1.2
30 years	0.08	0.27	0.7
100 years	0.014	0.06	0.15

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	8×10^{-10}	1.3×10^{-9}	2×10^{-9}
1 year	3.1×10^{-9}	6×10^{-9}	9×10^{-9}
3 years	6.8×10^{-9}	1.41×10^{-8}	2.4×10^{-8}
10 years	1.4×10^{-8}	3.07×10^{-8}	5.6×10^{-8}
30 years	2.1×10^{-8}	5.6×10^{-8}	1.09×10^{-7}
100 years	2.6×10^{-8}	8.4×10^{-8}	2.17×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.3	5.1	6.1
3 months	2.6	4	4.8
1 year	2.3	3.7	4.8
3 years	1.5	2.6	3.6
10 years	0.7	1.5	2.2
30 years	0.3	0.7	1.4
100 years	0.05	0.15	0.3

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	2.4×10^{-9}	2.9×10^{-9}	3.5×10^{-9}
1 year	8×10^{-9}	1.2×10^{-8}	1.5×10^{-8}
3 years	1.9×10^{-8}	3×10^{-8}	3.9×10^{-8}
10 years	4.3×10^{-8}	7.3×10^{-8}	1.02×10^{-7}
30 years	6.8×10^{-8}	1.35×10^{-7}	2.03×10^{-7}
100 years	8.3×10^{-8}	2.07×10^{-7}	4.1×10^{-7}

Question 5. *Effective Dose Rate ($Sv \cdot s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.5	5.4	8.4
10 days	3	5	7.7
30 days	2.7	4.4	6.9
100 days	1.2	2.3	3.6
1 year	0.07	0.14	0.24

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	2.5×10^{-10}	3.9×10^{-10}	6×10^{-10}
30 days	7×10^{-10}	1.2×10^{-9}	1.9×10^{-9}
100 days	1.9×10^{-9}	3.2×10^{-9}	5×10^{-9}
1 year	2.5×10^{-9}	4.9×10^{-9}	7.6×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.5	0.77	1.2
30 days	0.4	0.73	1.1
100 days	0.31	0.61	1
1 year	0.16	0.34	0.6
3 years	0.02	0.05	0.09

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.2×10^{-10}	2×10^{-10}	3.1×10^{-10}
100 days	3.2×10^{-10}	5.9×10^{-10}	8×10^{-10}
1 year	9×10^{-10}	1.8×10^{-9}	3×10^{-9}
3 years	1.1×10^{-9}	2.2×10^{-9}	4×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.9	1.4	2.1
1 day	0.8	1.3	2
3 days	0.6	1.1	1.6
10 days	0.3	0.6	0.9
30 days	0.05	0.1	0.16
100 days	0.00011	0.00024	0.0004

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	7×10^{-12}	1×10^{-11}	1.6×10^{-11}
3 days	1.8×10^{-11}	3×10^{-11}	4.7×10^{-11}
10 days	4.3×10^{-11}	7.8×10^{-11}	1.2×10^{-10}
30 days	6.5×10^{-11}	1.3×10^{-10}	2×10^{-10}
100 days	7×10^{-11}	1.4×10^{-10}	2.1×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.4	2.1	3.3
3 months	1	2	3.1
1 year	0.8	1.7	2.9
3 years	0.5	1	1.9
10 years	0.23	0.59	1.2
30 years	0.08	0.27	0.7
100 years	0.014	0.06	0.15

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	8×10^{-10}	1.3×10^{-9}	2×10^{-9}
1 year	3.1×10^{-9}	6×10^{-9}	9.4×10^{-9}
3 years	6.8×10^{-9}	1.41×10^{-8}	2.4×10^{-8}
10 years	1.4×10^{-8}	3×10^{-8}	5.5×10^{-8}
30 years	2.1×10^{-8}	5.6×10^{-8}	1.09×10^{-7}
100 years	2.6×10^{-8}	8.4×10^{-8}	2.17×10^{-7}

Effective Dose Rate and Integrated Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.7	4.3	5.1
3 months	2	4	4.8
1 year	1.8	3.7	4.8
3 years	1.2	2.6	4.7
10 years	0.6	1.5	2.9
30 years	0.21	0.7	1.8
100 years	0.04	0.15	0.4

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.9×10^{-9}	2.9×10^{-9}	3.5×10^{-9}
1 year	6.2×10^{-9}	1.21×10^{-8}	1.45×10^{-8}
3 years	1.5×10^{-8}	3×10^{-8}	4.7×10^{-8}
10 years	3.3×10^{-8}	7.3×10^{-8}	1.32×10^{-7}
30 years	5.2×10^{-8}	1.35×10^{-7}	2.63×10^{-7}
100 years	6.4×10^{-8}	2.07×10^{-7}	5.38×10^{-7}

Question 6. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.1	6.2	9.7
10 days	3.2	5.5	8.5
30 days	2.4	4.4	6.8
100 days	1.2	2.3	3.6
1 year	0.07	0.14	0.22

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3.2×10^{-10}	4.7×10^{-10}	7.4×10^{-10}
30 days	8×10^{-10}	1.3×10^{-9}	2×10^{-9}
100 days	1.8×10^{-9}	3.3×10^{-9}	5.2×10^{-9}
1 year	2.6×10^{-9}	5×10^{-9}	7.9×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.6	0.89	1.4
30 days	0.4	0.74	1.2
100 days	0.3	0.61	1
1 year	0.16	0.34	0.6
3 years	0.023	0.05	0.09

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.2×10^{-10}	2.1×10^{-10}	3.2×10^{-10}
100 days	3×10^{-10}	6×10^{-10}	9×10^{-10}
1 year	8×10^{-10}	1.55×10^{-9}	2.6×10^{-9}
3 years	1×10^{-9}	2×10^{-9}	3.6×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1	1.6	2.5
1 day	0.9	1.4	2.3
3 days	0.7	1.2	1.9
10 days	0.32	0.63	1
30 days	0.05	0.1	0.16
100 days	0.00011	0.00024	0.00037

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	9×10^{-12}	1.2×10^{-11}	1.9×10^{-11}
3 days	2.1×10^{-11}	3.5×10^{-11}	5×10^{-11}
10 days	5×10^{-11}	8.8×10^{-11}	1.4×10^{-10}
30 days	7×10^{-11}	1.4×10^{-10}	2.2×10^{-10}
100 days	8×10^{-11}	1.5×10^{-10}	2.3×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.6	2.5	3.9
3 months	1	2	3.1
1 year	0.9	1.9	3
3 years	0.5	1	1.9
10 years	0.23	0.6	1.2
30 years	0.08	0.27	0.7
100 years	0.013	0.06	0.15

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	8×10^{-10}	1.3×10^{-9}	2×10^{-9}
1 year	3.1×10^{-9}	6×10^{-9}	9.4×10^{-9}
3 years	7×10^{-9}	1.41×10^{-8}	2.4×10^{-8}
10 years	1.4×10^{-8}	3.1×10^{-8}	5.6×10^{-8}
30 years	2.1×10^{-8}	5.6×10^{-8}	1.09×10^{-7}
100 years	2.6×10^{-8}	8.4×10^{-8}	2.17×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.2	5	7.7
3 months	2	4	6.2
1 year	1.8	3.7	6.1
3 years	1.2	2.6	4.7
10 years	0.6	1.5	2.9
30 years	0.21	0.7	1.8
100 years	0.04	0.15	0.4

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.9×10^{-9}	2.9×10^{-9}	4.5×10^{-9}
1 year	6.2×10^{-9}	1.2×10^{-9}	1.9×10^{-9}
3 years	1.5×10^{-9}	3×10^{-9}	5.1×10^{-9}
10 years	3.3×10^{-9}	$7. \times 10^{-9}$	1.32×10^{-7}
30 years	5.2×10^{-9}	1.35×10^{-7}	2.63×10^{-7}
100 years	6.4×10^{-9}	2.07×10^{-7}	5.38×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140		No comparison suggested.
Te-131m/Te-132		No response
I-132/I-133/ I-134/I-135	I-131	
Mo-99	Zr-95	
Ce-144	Zr-95	

Urban Environment

Nuclide	Similar Behavior To	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140		No comparison suggested.
Te-131m/Te-132		No response
I-132/I-133/ I-134/I-135	I-131	
Mo-99	Zr-95	
Ce-144	Zr-95	

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m^2 of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.2	0.35
(ii) medium shielding building	0.05	0.1	0.15
(iii) high shielding building	0.01	0.03	0.05
(iv) basement family house	0.02	0.05	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.4	0.6	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.15	0.3
(ii) medium shielding building	0.04	0.07	0.15
(iii) high shielding building	0.01	0.02	0.04
(iv) basement family house	0.02	0.05	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.12	0.25
(ii) medium shielding building	0.03	0.05	0.1
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.01	0.03	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.4	0.6
(vii) inside typical bus	0.2	0.3	0.5

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.15	0.3
(ii) medium shielding building	0.04	0.07	0.15
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.02	0.05	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.05	0.1	0.2
(ii) medium shielding building	0.03	0.05	0.1
(iii) high shielding building	0.005	0.01	0.02
(iv) basement family house	0.01	0.02	0.04
(v) basement of multi-story block	0.001	0.005	0.01
(vi) inside typical car	0.3	0.4	0.5
(vii) inside typical bus	0.2	0.3	0.4

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.105	0.21	NR	NR	NR
(ii) medium shielding building	0.028	0.049	0.105	NR	NR	NR
(iii) high shielding building	0.008	0.016	0.032	NR	NR	NR
(iv) basement family house	0.02	0.05	0.1	NR	NR	NR
(v) basement of multi-story block	0.005	0.01	0.02	NR	NR	NR
(vi) inside typical car	0.18	0.3	0.42	NR	NR	NR
(vii) inside typical bus	0.12	0.24	0.3	NR	NR	NR

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.049	0.105	0.21	0.049	0.105	0.21
(ii) medium shielding building	0.028	0.049	0.105	0.028	0.049	0.105
(iii) high shielding building	0.008	0.016	0.04	0.008	0.016	0.04
(iv) basement family house	0.02	0.05	0.1	0.02	0.05	0.1
(v) basement of multi-story block	0.005	0.01	0.02	0.005	0.01	0.02
(vi) inside typical car	0.18	0.3	0.42	0.09	0.15	0.21
(vii) inside typical bus	0.12	0.24	0.3	0.06	0.12	0.15

Nuclide Ce-144, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.035	0.07	0.14	NR	NR	NR
(ii) medium shielding building	0.021	0.035	0.07	NR	NR	NR
(iii) high shielding building	0.004	0.008	0.016	NR	NR	NR
(iv) basement family house	0.01	0.02	0.04	NR	NR	NR
(v) basement of multi-story block	0.001	0.005	0.01	NR	NR	NR
(vi) inside typical car	0.18	0.24	0.3	NR	NR	NR
(vii) inside typical bus	0.12	0.18	0.24	NR	NR	NR

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.2	0.35
(ii) medium shielding building	0.05	0.1	0.15
(iii) high shielding building	0.01	0.03	0.05
(iv) basement family house	0.02	0.05	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.4	0.6	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.15	0.3
(ii) medium shielding building	0.04	0.07	0.15
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.02	0.05	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.12	0.25
(ii) medium shielding building	0.03	0.05	0.1
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.01	0.03	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.4	0.6
(vii) inside typical bus	0.2	0.3	0.5

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.15	0.3
(ii) medium shielding building	0.04	0.07	0.15
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.02	0.05	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.05	0.1	0.2
(ii) medium shielding building	0.03	0.05	0.1
(iii) high shielding building	0.005	0.01	0.02
(iv) basement family house	0.01	0.02	0.04
(v) basement of multi-story block	0.001	0.005	0.01
(vi) inside typical car	0.3	0.4	0.5
(vii) inside typical bus	0.2	0.3	0.4

(ii) Wet Deposition Mechanisms Only:

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.15	0.3
(ii) medium shielding building	0.04	0.07	0.15
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.02	0.04	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.3	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.12	0.25
(ii) medium shielding building	0.03	0.06	0.1
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.02	0.04	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.11	0.25
(ii) medium shielding building	0.02	0.04	0.1
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.01	0.02	0.07
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.4	0.6
(vii) inside typical bus	0.2	0.3	0.5

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.07	0.12	0.25
(ii) medium shielding building	0.03	0.06	0.1
(iii) high shielding building	0.01	0.02	0.05
(iv) basement family house	0.02	0.04	0.1
(v) basement of multi-story block	0.005	0.01	0.02
(vi) inside typical car	0.3	0.5	0.7
(vii) inside typical bus	0.2	0.4	0.5

Nuclide Ce-144 Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.05	0.08	0.15
(ii) medium shielding building	0.02	0.04	0.1
(iii) high shielding building	0.005	0.01	0.02
(iv) basement family house	0.01	0.02	0.04
(v) basement of multi-story block	0.002	0.004	0.01
(vi) inside typical car	0.3	0.4	0.5
(vii) inside typical bus	0.2	0.3	0.4

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈10 μm), Cs-137 (particulate, representative of ≈1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.3	0.5	0.7
Cs-137	0.5	0.7	0.9
I_2	0.6	0.8	0.95
CH_3I	0.6	0.8	0.95

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.02	0.1	0.2
Cs-137	0.1	0.2	0.4
I_2	0.1	0.3	0.5
CH_3I	0.1	0.3	0.5

Question 12

Nuclide	Similar Ratio To (delete as appropriate)	Specific Comments
Ru-103/Ru-106	Cs-137	
Te-129m/Te-132	Cs-137	
Cs-134	Cs-137	
Ba-140	Cs-137	
Ce-144	Pu-240	Present in refractory fuel particles.
Pu-238/Pu-241	Pu-240	Present in refractory fuel particles.
Cm-242	Pu-240	Present in refractory fuel particles.

Question 13. *Population Fractions.*

POPULATION FRACTION	5th Quantile	Median	95th Quantile
(i) agricultural and other outdoor workers	0.15	0.2	0.25
(ii) indoor workers	0.3	0.4	0.5
(iii) non-active adult population[a]	0.1	0.15	0.2
(ii) schoolchildren	0.1	0.15	0.2

a. All adults are considered to be in category i, ii, or iii. The non-active adult population are those that are not agricultural and outdoor workers or indoor workers. Activity here refers to employment not amount of energy expended.

People Working Outdoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.15	0.25
(ii) medium shielding, e.g., single brick family house	0.15	0.2	0.3
(iii) high shielding, e.g., multi-story office block	0.1	0.15	0.25
(iv) basement of single family house	0.02	0.05	0.1
(v) basement multi-story office block	0.01	0.02	0.05
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.01	0.02	0.04

People Working Indoors, and Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.2	0.3
(ii) medium shielding, e.g., single brick family house	0.1	0.2	0.3
(iii) high shielding, e.g., multi-story office block	0.1	0.2	0.3
(iv) basement of single family house	0.005	0.1	0.15
(v) basement multi-story office block	0.03	0.07	0.1
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.01	0.02	0.04

Non-Active Adult Population Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.2	0.3
(ii) medium shielding, e.g., single brick family house	0.1	0.2	0.3
(iii) high shielding, e.g., multi-story office block	0.1	0.2	0.3
(iv) basement of single family house	0.005	0.13	0.2
(v) basement multi-story office block	0.02	0.05	0.1
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.005	0.01	0.02

Schoolchildren Living in an Urban Environment

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.2	0.3
(ii) medium shielding, e.g., single brick family house	0.1	0.2	0.3
(iii) high shielding, e.g., multi-story office block	0.2	0.3	0.4
(iv) basement of single family house	0.02	0.05	0.1
(v) basement multi-story office block	0.02	0.05	0.1
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.01	0.02	0.04

People Working Outdoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.2	0.3
(ii) medium shielding, e.g., single brick family house	0.1	0.2	0.3
(iii) high shielding, e.g., multi-story office block	0.05	0.1	0.15
(iv) basement of single family house	0.03	0.05	0.07
(v) basement multi-story office block	0.01	0.02	0.03
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.01	0.02	0.04

People Working Indoors and Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.15	0.25
(ii) medium shielding, e.g., single brick family house	0.15	0.3	0.4
(iii) high shielding, e.g., multi-story office block	0.1	0.2	0.3
(iv) basement of single family house	0.05	0.1	0.15
(v) basement multi-story office block	0.01	0.02	0.03
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.01	0.02	0.04

Non-Active Adult Population Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.15	0.25	0.3
(ii) medium shielding, e.g., single brick family house	0.15	0.25	0.3
(iii) high shielding, e.g., multi-story office block	0.05	0.1	0.2
(iv) basement of single family house	0.05	0.1	0.15
(v) basement multi-story office block	0.01	0.02	0.03
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.01	0.02	0.04

Schoolchildren Living in a Rural Area

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.2	0.3
(ii) medium shielding, e.g., single brick family house	0.1	0.2	0.3
(iii) high shielding, e.g., multi-story office block	0.15	0.2	0.3
(iv) basement of single family house	0.05	0.1	0.15
(v) basement multi-story office block	0.01	0.02	0.03
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.01	0.02	0.04

Estimated Dosages from Outdoor Exposure in Sample Countries

FRACTION OF TIME IN:	5th Quantile	Median	95th Quantile
(i) low shielding, e.g., wooden framed houses	0.1	0.2	0.3
(ii) medium shielding, e.g., single brick family house	0.1	0.2	0.3
(iii) high shielding, e.g., multi-story office block	0.1	0.2	0.3
(iv) basement of single family house	0.05	0.1	0.15
(v) basement multi-story office block	0.01	0.02	0.05
(vi) inside typical car	0.005	0.01	0.02
(vii) inside typical bus	0.01	0.02	0.04

EXPERT J

Question 1

For estimation of the downward migration of ^{95}Zr, ^{106}Ru and ^{131}I into soil and estimation of the resultant external dose-rates from the contaminated ground, the model MLSOIL was applied. This model uses a five compartment linear transfer system to calculate the migration. The transfer coefficients were calculated from k_d values mainly based on the recently released "Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments" (IAEA, 1994) and estimates of the water surplus (precipitation minus evapotranspiration). The dose-rate conversion factors were calculated using the DFSOIL code. This was done by use of energy absorption build-up factors in air and soil. The following parameter values were used:

Annual average precipitation: 63 cm/y;
Annual average evapotranspiration: 44 cm/y;
Volumetric water content of soil: 0.3 ml/cm^3;
bulk density of soil: 1.4 g/cm^3;
k_d factor (ml/g):
- Zr=3000;
- Nb=350;
- Ru=350;
- Rh=60;
- I=60;
- Cs=1000;
- Ba=60.

The figures obtained by these calculations are therefore correlated in the sense that certain soil parameters (water content, density, etc.) have been kept constant.

The estimates of dose-rate due to deposition of ^{137}Cs were found using the URGENT model, which has four compartments for simulation of downward migration of radionuclides in grassed areas. The resultant dose-rates were found using the results of Monte Carlo calculations (Meckbach et al., 1988) for a large (but not infinite) plane lawn in a suburban environment. The transfer coefficients used in the URGENT code are mainly based on in situ/ experimental observations. Calculations of the dose-rate 1 m over a lawn have been compared with other observations and found to be in good agreement (shown in: USER'S GUIDE TO URGENT, Risø, 1994). The kerma-to-dose conversion factor was set to 0.9.

Question 2

Wet deposition will cause a slight penetration of the isotopes into the soil giving some attenuation. At the energy range of the radionuclides examined, this was assumed to reduce the dose-rate by a factor of 0.8, compared with the dry deposition case investigated in Question 1, immediately following deposition. The calculations for cesium were made separately using the URGENT code. It was assumed that 0.2 Bq/m^2 was deposited on the grass cover, 0.2 Bq/cm^2 directly on top of the soil, and 0.6 cm^2 immediately reached the 2-5 cm layer. This corresponds to an initial dose-rate which is 82% of the initial dose-rate of the dry deposition scenario. It must be stressed that the 30-year and especially the 100-year predictions are based on calculations using a model that has not been adequately validated for such long period simulations.

Question 3

The deposition mechanisms are not specified, but otherwise the calculations would follow the patterns of Questions 1 and 2.

Questions 4 and 5

The person is outdoors in a typical urban environment. This was interpreted for the calculations as a person standing on the pavement in front of a multistory building. Although it is only stated that deposition occurs to the lawned areas of the ground, it was assumed that deposition also occurred to the other urban surfaces. The initial deposition relations (both wet and dry) were based on the figures given in Roed (1990) and Roed et al. (1990). Once again, the URGENT model, comprising 16 compartments, each representing a state in which ^{137}Cs may be found on an urban surface, was used for the cesium calculations. Most of the isotopes have gamma energies in the same range as ^{137}Cs and this facilitated a "scaling" of the results of Question 1 with the relationship between the urban and rural figures for cesium. The accumulated doses for other isotopes than ^{137}Cs were found by interpolation/extrapolation.

Question 6

Here, the deposition mechanisms are among those items which are not specified. As the deposition mechanism is no longer restricted to either wet or dry deposition, the results lie between the answers given to Questions 4 and 5.

Question 7

More specific comments are given in the table. The reference that has been used for the open lawned areas is Coughtrey et al.'s series of six books (1986) on radionuclide transport, and the urban environment answers were based on Roed (1987).

Question 8

The deposition mechanism has not been specified in the question, but was assumed to be dry. The relative deposition figures were taken from the references given under Questions 4 and 5. The calculations were made using the kerma factors of Meckbach et al. (1988) for 300 keV (approx. energy of ^{131}I) and 662 keV. The house of prefabricated parts was used for the low shielding building, the semidetached house was used as the medium shielding building, while the multistory block was used as the high-shielding building. The basement of the semidetached house was used as "basement of family house," and the multistory block basement was used as such. The figures for shielding of cars were based on the calculations of P. Hedemann Jensen, Risø. The numbers would be a bit higher for ^{95}Zr and ^{95}Nb, which emit gammas that have higher energies than cesium and therefore penetrate walls easier. Likewise, $^{106}Ru/^{106}Rh$ would be in the lower end. The figures were recalculated to evaluate the importance of an indoor deposition. The calculations of indoor deposition were made in the following way:

From the assumption of a constant aerosol concentration outside a building, and the knowledge of the rate coefficient of ventilation (the fraction termed λ_r of air exchanged per unit time), the rate coefficient of deposition (the fraction termed λ_d of aerosols in the building deposited per unit time), the filtering factor f (the fraction of aerosols in air entering the building which is not retained in cracks and fissures of the building structure), the relationship between the equilibrium indoor aerosol concentration (C_i) and the outdoor aerosol concentration (C_o) can be calculated as:

$$C_i / C_o = f \lambda_r / (\lambda_r + \lambda_d).$$

If the average local indoor deposition velocity ($v_d = \lambda_d V/A$, where V is the indoor volume and A is the indoor surface area), and V_{dg} (the average deposition velocity on a grassed outdoor surface) are also known, a relationship can be established between the average deposited contaminant concentration on indoor surfaces (D_i) and the deposited contaminant concentration on a smooth, cut lawn (the common reference surface for outdoor contamination) here termed D_o:

$$D_i / D_o = (V_d / V_{dg}) f \lambda_r / (\lambda_r + \lambda_d).$$

Field investigations by Roed showed the cesium aerosol to have a typical deposition velocity of 4.3 10^{-4} m/s on cut grass surfaces (V_{dg}). A representative value of the relationship V/A for a furnished room is 0.5 m. Following the Chernobyl accident, a series of experiments (Roed and Cannell, 1987) were made in which the typical values of λ_r, λ_d and f were determined for the Chernobyl ^{137}Cs aerosol in a furnished Danish house. These values were used in the calculations of the mean indoor deposition (kBq/m^2) that form the basis for the calculations of doses received from indoor relative to outdoor deposited ^{137}Cs. The following parameter values were considered to be realistic: $\lambda_d = 0.8$ h^{-1}, $\lambda_r = 0.4$ h^{-1}, $f = 1.0$. The iodine is assumed to be particulate.

The corresponding dose estimates for indoor surfaces were made equivalent to a target position 1m above the ground in a room with height 3 m and in the center of a ground area of 4 m by 4 m. The dose contribution from scattered radiation and deposition on internal surfaces of neighboring rooms was not included. It was stipulated in the dynamic calculations that the average cesium contamination level on indoor surfaces decreases to 85% in one year and to 70% in 10 years. The dose relations for ^{137}Cs and ^{131}I were found from Lauridsen (1982).

Question 9

The assumptions are here the same as those used for the answer to Question 8. However, here the URGENT model has been included in the calculations to reflect the time dependence. Also here, the influence of an indoor deposition was assessed.

Question 10

As Question 8 was answered for a dry deposition, half of this question has already been answered. As for the wet deposition case, the calculations were made with the URGENT model. The deposition assumptions were the same as used for other questions regarding wet deposition.

References

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Note: **Effective dose data given in tables for Questions 1-6 should be multiplied by 10^{-16}. This translation is not necessary for the integrated dose data in Questions 4-6.**

Question 1. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial "dry" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	9	13.2	20
10 days	8.5	12.5	20
30 days	7.5	10.9	17
100 days	4	6.11	9.8
1 year	0.24	0.403	0.69

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.3	1.85	2.8
30 days	1.2	1.75	2.6
100 days	1.1	1.53	2.3
1 year	0.55	0.928	1.6
3 years	0.12	0.234	0.45

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.5	3.53	5.3
1 day	2.3	3.25	4.9
3 days	1.9	2.74	4.1
10 days	1	1.49	2.2
30 days	0.19	0.265	0.4
100 days	0.0003	0.000625	0.0012

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4	5.6	8.4
3 months	3.3	5.31	8.4
1 year	2.8	4.74	8.1
3 years	2	4.01	7.5
10 years	1.2	2.53	5.6
30 years	0.5	1.46	4.4
100 years	0.02	0.22	1.98

Question 2. *Gamma dose-rate (Gy • s^{-1}) in air at 1 m above a uniform, flat and open lawned area following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	7.7	11.6	17
10 days	7.5	11.2	17
30 days	6.9	10.4	16
100 days	3.6	5.8	9.3
1 year	0.24	0.403	0.69

Nuclide Ru-106

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.1	1.63	2.4
30 days	1	1.58	2.4
100 days	0.9	1.45	2.3
1 year	0.55	0.928	1.6
3 years	0.12	0.234	0.45

Nuclide I-131

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.1	3.1	4.7
1 day	1.9	2.85	4.3
3 days	1.6	2.41	3.6
10 days	0.9	1.34	2
30 days	0.16	0.252	0.4
100 days	0.00035	0.000595	0.00101

Nuclide Cs-137

Dose-Rate (Gy • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.3	4.93	7.5
3 months	3	4.78	7.5
1 year	2.6	4.5	7.5
3 years	2	4.01	7.5
10 years	1.2	2.53	5.6
30 years	0.5	1.46	4.4
100 years	0.02	0.22	1.98

Question 3. *Gamma dose-rate ($Gy \cdot s^{-1}$) in air at 1 m above a uniform, flat and open lawned area following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the ground.*

Nuclide Zr-95

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	7.7	12.4	20
10 days	7.5	13.1	20
30 days	6.9	10.6	17
100 days	4	5.96	9.3
1 year	0.24	0.403	0.69

Nuclide Ru-106

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.1	1.74	2.8
30 days	1	1.62	2.6
100 days	0.9	1.49	2.3
1 year	0.55	0.928	1.6
3 years	0.12	0.234	0.45

Nuclide I-131

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	2.1	2.31	5.3
1 day	1.9	3.05	4.9
3 days	1.6	2.57	4.1
10 days	0.9	1.41	2.2
30 days	0.16	0.259	0.4
100 days	0.00035	0.0006	0.0012

Nuclide Cs-137

Dose-Rate ($Gy \cdot s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.3	5.27	8.4
3 months	3	5.02	8.4
1 year	2.6	4.62	8.1
3 years	2	4.01	7.5
10 years	1.2	2.53	5.6
30 years	0.5	1.46	4.4
100 years	0.02	0.22	2

Question 4. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "dry" and uniform deposition of 1 Bq/m² of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.4	6.65	9.8
10 days	4	6	9
30 days	3.2	5.14	8.2
100 days	1.5	2.58	4.4
1 year	0.09	0.148	0.25

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3.6×10^{-10}	5.46×10^{-10}	8.2×10^{-10}
30 days	9.6×10^{-10}	1.53×10^{-9}	2.4×10^{-9}
100 days	2.3×10^{-9}	3.99×10^{-9}	6.8×10^{-9}
1 year	3×10^{-9}	5.17×10^{-9}	8.8×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.62	0.93	1.39
30 days	0.53	0.84	1.34
100 days	0.37	0.636	1.08
1 year	0.19	0.339	0.61
3 years	0.039	0.0749	0.142

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.44×10^{-10}	2.3×10^{-10}	3.68×10^{-10}
100 days	3.99×10^{-10}	6.79×10^{-10}	1.15×10^{-9}
1 year	1.1×10^{-9}	2×10^{-9}	3.6×10^{-9}
3 years	2.5×10^{-9}	4.78×10^{-9}	9.08×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.19	1.78	2.67
1 day	1.09	1.64	2.46
3 days	0.92	1.38	2.07
10 days	0.5	0.751	1.126
30 days	0.084	0.134	0.214
100 days	0.000185	0.000315	0.000536

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	9.8×10^{-12}	1.48×10^{-11}	2.22×10^{-11}
3 days	2.72×10^{-11}	4.09×10^{-11}	6.14×10^{-11}
10 days	7.3×10^{-11}	1.09×10^{-10}	1.64×10^{-10}
30 days	1.24×10^{-10}	1.86×10^{-10}	2.79×10^{-10}
100 days	1.45×10^{-10}	2.18×10^{-10}	3.27×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.88	2.82	4.23
3 months	1.38	2.35	4
1 year	0.98	1.76	3.17
3 years	0.64	1.27	2.54
10 years	0.309	0.681	1.5
30 years	0.099	0.297	0.89
100 years	0.005	0.0447	0.402

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.01×10^{-9}	1.72×10^{-9}	2.92×10^{-9}
1 year	3.4×10^{-9}	6.12×10^{-9}	1.1×10^{-8}
3 years	8.4×10^{-9}	1.6×10^{-8}	3.04×10^{-8}
10 years	1.81×10^{-8}	3.61×10^{-8}	7.22×10^{-8}
30 years	2.05×10^{-8}	6.15×10^{-8}	1.85×10^{-7}
100 years	2×10^{-8}	8×10^{-8}	3.2×10^{-7}

Effective Dose Rate and Integrated Effective Dose in an average "rural" area

Nuclide Cs-137, Outdoors "Rural" Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	3.2	4.48	6
3 months	2.4	3.52	6
1 year	2.08	3.6	6
3 years	1.6	3.2	6
10 years	0.96	2.02	4.5
30 years	0.4	1.16	3.52
100 years	0.016	0.176	1.58

Nuclide Cs-137, Outdoors "Rural" Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.59×10^{-9}	2.71×10^{-9}	4.6×10^{-9}
1 year	5.4×10^{-9}	9.7×10^{-9}	1.75×10^{-8}
3 years	1.37×10^{-8}	2.74×10^{-8}	5.48×10^{-8}
10 years	3.68×10^{-8}	7.35×10^{-8}	1.47×10^{-7}
30 years	7.7×10^{-8}	1.54×10^{-7}	3.08×10^{-7}
100 years	1.25×10^{-7}	2.49×10^{-7}	4.98×10^{-7}

Question 5. *Effective Dose Rate (Sv • s^{-1}) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial "wet" and uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/ Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.6	6.86	10.3
10 days	4.1	6.2	9.3
30 days	3.27	5.23	8.37
100 days	1.47	2.5	4.25
1 year	0.07	0.126	0.227

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3.6×10^{-10}	5.63×10^{-10}	8.2×10^{-10}
30 days	9.6×10^{-10}	1.58×10^{-9}	2.4×10^{-9}
100 days	2.3×10^{-9}	4.11×10^{-9}	6.8×10^{-9}
1 year	3×10^{-9}	5.1×10^{-9}	8.8×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult (Sv • s^{-1}) × 10^{-16}	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.64	0.96	1.44
30 days	0.52	0.84	1.34
100 days	0.36	0.612	1.04
1 year	0.161	0.29	0.52
3 years	0.029	0.058	0.116

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.45×10^{-10}	2.33×10^{-10}	3.72×10^{-10}
100 days	3.95×10^{-10}	6.72×10^{-10}	$1.14E \times 10^{-9}$
1 year	1×10^{-9}	1.7×10^{-9}	2.89×10^{-9}
3 years	2.34×10^{-9}	4.45×10^{-9}	8.45×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.22	1.83	2.74
1 day	1.12	1.69	2.53
3 days	0.94	1.42	2.13
10 days	0.492	0.738	1.107
30 days	0.079	0.127	0.203
100 days	0.000114	0.000195	0.000332

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	1.01×10^{-11}	$1.52E \times 10^{-11}$	2.28×10^{-11}
3 days	3.08×10^{-11}	4.63×10^{-11}	6.95×10^{-11}
10 days	7.4×10^{-11}	1.11×10^{-10}	1.67×10^{-10}
30 days	9.5×10^{-11}	1.43×10^{-10}	2.15×10^{-10}
100 days	1.25×10^{-10}	1.87×10^{-10}	2.8×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \bullet s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.94	2.91	4.36
3 months	1.29	2.2	3.74
1 year	0.83	1.49	2.69
3 years	0.5	0.99	2
10 years	0.184	0.46	1.1
30 years	0.067	0.2	0.6
100 years	0.0033	0.03	0.18

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1.22×10^{-9}	1.96×10^{-9}	3.13×10^{-9}
1 year	3.62×10^{-9}	6.17×10^{-9}	1.05×10^{-8}
3 years	7.6×10^{-9}	1.38×10^{-8}	2.47×10^{-8}
10 years	1.42×10^{-8}	2.82×10^{-8}	5.62×10^{-8}
30 years	1.92×10^{-8}	4.8×10^{-8}	1.2×10^{-7}
100 years	2.14×10^{-8}	6.43×10^{-8}	1.9×10^{-7}

Question 6. *Effective Dose Rate ($Sv \bullet s^{-1}$) and Integrated Effective Dose (Sv) to an adult outdoors in a typical "urban" environment following the initial uniform deposition of 1 Bq/m^2 of Zr-95/Nb-95, Ru-106/Rh-106, I-131 and Cs-137/Ba-137m to the lawned areas of the ground.*

Nuclide Zr-95, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	4.4	6.67	9.9
10 days	4	6.02	9.1
30 days	3.2	5.15	8.3
100 days	1.5	2.57	4.4
1 year	0.09	0.146	0.25

Nuclide Zr-95, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
10 days	3.6×10^{-10}	5.44×10^{-10}	8.2×10^{-10}
30 days	9.6×10^{-10}	1.54×10^{-9}	2.4×10^{-9}
100 days	2.3×10^{-9}	4×10^{-9}	6.8×10^{-9}
1 year	3×10^{-9}	5.16×10^{-9}	8.8×10^{-9}

Nuclide Ru-106, Outdoors Urban Environment

Effective Dose-Rate to Adult ($Sv \bullet s^{-1}$) $\times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	0.62	0.93	1.4
30 days	0.53	0.84	1.35
100 days	0.37	0.632	1.08
1 year	0.18	0.334	0.61
3 years	0.038	0.0732	0.142

Nuclide Ru-106, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
30 days	1.44×10^{-10}	2.3×10^{-10}	3.68×10^{-10}
100 days	3.9×10^{-10}	6.7×10^{-10}	1.15×10^{-9}
1 year	1.05×10^{-9}	1.95×10^{-9}	3.6×10^{-9}
3 years	2.4×10^{-9}	4.68×10^{-9}	9.1×10^{-9}

Nuclide I-131, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.19	1.79	2.7
1 day	1.09	1.65	2.5
3 days	0.92	1.39	2.1
10 days	0.495	0.749	1.126
30 days	0.082	0.133	0.214
100 days	0.00014	0.00028	0.0005

Nuclide I-131, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
1 day	9.8×10^{-12}	1.48×10^{-11}	2.23×10^{-11}
3 days	2.72×10^{-11}	4.1×10^{-11}	$6.15E \times 10^{-11}$
10 days	7.3×10^{-11}	1.09×10^{-10}	1.64×10^{-10}
30 days	1.23×10^{-10}	1.84×10^{-10}	2.77×10^{-10}
100 days	1.4×10^{-10}	2×10^{-10}	3×10^{-10}

Nuclide Cs-137, Outdoors Urban Environment

Effective Dose-Rate to Adult $(Sv \cdot s^{-1}) \times 10^{-16}$	5th Quantile	Median	95th Quantile
Immediately after Deposition	1.88	2.83	4.25
3 months	1.38	2.33	4
1 year	0.95	1.73	3.17
3 years	0.6	1.24	2.54
10 years	0.285	0.661	1.5
30 years	0.08	0.287	0.89
100 years	0.005	0.0425	0.4

Nuclide Cs-137, Outdoors Urban Environment

Integrated Adult Effective Dose (Sv)	5th Quantile	Median	95th Quantile
3 months	1×10^{-9}	1.75×10^{-9}	3×10^{-9}
1 year	3.4×10^{-9}	6.16×10^{-9}	1.1×10^{-8}
3 years	8.4×10^{-9}	1.55×10^{-8}	3×10^{-8}
10 years	1.8×10^{-8}	3.55×10^{-8}	7×10^{-8}
30 years	2×10^{-8}	5.53×10^{-8}	1.8×10^{-7}
100 years	2×10^{-8}	7×10^{-8}	3×10^{-7}

Question 7

Open Lawned Area

Nuclide	Similar Behavior To	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140	Cs-137	
Te-131m/Te-132	Ru-106 (Zr-95)	
I-132/I-133/ I-134/I-135	I-131	
Mo-99	(Cs-137)	
Ce-144	(Cs-137)	

Urban Environment

Nuclide	Similar Behavior To	Specific Comments
Ru-103/Ru-105	Ru-106	
Cs-134/Cs-136	Cs-137	
Ba-140	Cs-137	
Te-131m/Te-132	Ru-106 (Zr-95)	
I-132/I-133/ I-134/I-135	I-131	
Mo-99	(Cs-137)	
Ce-144	(Cs-137)	

Question 8. *Ratio (or location factor) of Effective Dose in Sv received by an adult indoors to that received outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m² of Zr-95, Ru-106, I-131, Cs-137 and Ce-144 to the ground.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.35	0.63	0.88
(ii) medium shielding building	0.08	0.15	0.4
(iii) high shielding building	0.02	0.034	0.1
(iv) basement family house	0.001	0.04	0.1
(v) basement of multi-story block	0.0001	0.04	0.1
(vi) inside typical car	0.5	0.64	0.88
(vii) inside typical bus	0.2	0.37	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.34	0.61	0.87
(ii) medium shielding building	0.07	0.14	0.38
(iii) high shielding building	0.016	0.04	0.1
(iv) basement family house	0.0001	0.04	0.1
(v) basement of multi-story block	0.00001	0.04	0.1
(vi) inside typical car	0.5	0.62	0.87
(vii) inside typical bus	0.2	0.35	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.58	0.82
(ii) medium shielding building	0.05	0.1	0.35
(iii) high shielding building	0.01	0.08	0.18
(iv) basement family house	0.0001	0.03	0.08
(v) basement of multi-story block	0.00001	0.03	0.08
(vi) inside typical car	0.3	0.59	0.8
(vii) inside typical bus	0.2	0.3	0.45

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.34	0.62	0.87
(ii) medium shielding building	0.07	0.14	0.38
(iii) high shielding building	0.015	0.05	0.1
(iv) basement family house	0.0001	0.03	0.1
(v) basement of multi-story block	0.00001	0.03	0.1
(vi) inside typical car	0.5	0.63	0.88
(vii) inside typical bus	0.2	0.36	0.5

Question 9. *Location factors for 1 and 10 years following initial deposition.*

Nuclide Zr-95, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.35	0.63	0.88	0.35	0.63	0.88
(ii) medium shielding building	0.08	0.15	0.4	0.08	0.15	0.4
(iii) high shielding building	0.02	0.034	0.1	0.02	0.034	0.1
(iv) basement family house	0.001	0.04	0.1	0.001	0.04	0.1
(v) basement of multi-story block	0.0001	0.04	0.1	0.0001	0.04	0.1
(vi) inside typical car	0.5	0.64	0.88	0.5	0.64	0.88
(vii) inside typical bus	0.2	0.37	0.5	0.2	0.37	0.5

Nuclide Ru-106, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.34	0.61	0.87	0.34	0.61	0.87
(ii) medium shielding building	0.07	0.14	0.38	0.07	0.14	0.38
(iii) high shielding building	0.016	0.04	0.1	0.016	0.04	0.1
(iv) basement family house	0.0001	0.04	0.1	0.0001	0.04	0.1
(v) basement of multi-story block	0.00001	0.04	0.1	0.00001	0.04	0.1
(vi) inside typical car	0.5	0.62	0.87	0.5	0.62	0.87
(vii) inside typical bus	0.2	0.35	0.5	0.2	0.35	0.5

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.58	0.82	0.3	0.58	0.82
(ii) medium shielding building	0.05	0.1	0.35	0.05	0.1	0.18
(iii) high shielding building	0.01	0.08	0.18	0.01	0.08	0.18
(iv) basement family house	0.0001	0.03	0.8	0.0001	0.03	0.08
(v) basement of multi-story block	0.00001	0.03	0.8	0.00001	0.03	0.08
(vi) inside typical car	0.3	0.59	0.8	0.3	0.59	0.8
(vii) inside typical bus	0.2	0.3	0.45	0.2	0.3	0.45

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	1 Year			10 Years		
	5th Quantile	Median	95th Quantile	5th Quantile	Median	95th Quantile
(i) low shielding building	0.34	0.62	0.87	0.34	0.62	0.87
(ii) medium shielding building	0.07	0.14	0.38	0.07	0.14	0.38
(iii) high shielding building	0.015	0.05	0.1	0.015	0.05	0.1
(iv) basement family house	0.0001	0.03	0.1	0.0001	0.03	0.1
(v) basement of multi-story block	0.00001	0.03	0.1	0.00001	0.03	0.1
(vi) inside typical car	0.5	0.63	0.88	0.5	0.63	0.88
(vii) inside typical bus	0.2	0.36	0.5	0.2	0.36	0.5

Question 10. *Location factors for dry and wet deposition mechanisms.*

(i) Dry Deposition Mechanisms Only:

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.4	0.58	0.8
(ii) medium shielding building	0.05	0.1	0.4
(iii) high shielding building	0.01	0.05	0.1
(iv) basement family house	0.0001	0.05	0.1
(v) basement of multi-story block	0.00001	0.05	0.1
(vi) inside typical car	0.4	0.59	0.8
(vii) inside typical bus	0.2	0.3	0.5

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.4	0.62	0.8
(ii) medium shielding building	0.05	0.14	0.4
(iii) high shielding building	0.01	0.05	0.1
(iv) basement family house	0.01	0.05	0.1
(v) basement of multi-story block	0.01	0.05	0.1
(vi) inside typical car	0.4	0.63	0.8
(vii) inside typical bus	0.2	0.36	0.6

(ii) Wet Deposition Mechanisms Only:

Nuclide I-131, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.25	0.53	0.8
(ii) medium shielding building	0.04	0.085	0.25
(iii) high shielding building	0.01	0.02	0.04
(iv) basement family house	0.0001	0.00029	0.001
(v) basement of multi-story block	0.00001	0.000026	0.0001
(vi) inside typical car	0.5	0.73	0.9
(vii) inside typical bus	0.2	0.38	0.6

Nuclide Cs-137, Ratio Dose Indoors/Outdoors Open Lawned Area

Dose Ratio (location factor)	5th Quantile	Median	95th Quantile
(i) low shielding building	0.3	0.63	0.8
(ii) medium shielding building	0.05	0.13	0.3
(iii) high shielding building	0.01	0.03	0.06
(iv) basement family house	0.0003	0.0013	0.01
(v) basement of multi-story block	0.00002	0.000064	0.0003
(vi) inside typical car	0.5	0.79	0.9
(vii) inside typical bus	0.2	0.45	0.8

Question 11. *Ratio of the Time Integrated Air Concentration (TIAC) indoors to that outdoors, given an outdoor value of 1 Bq s m^{-3} for Pu-240 (particulate, representative of ≈ 10 μm), Cs-137 (particulate, representative of ≈ 1 μm) and I-131 (gaseous, forms I_2 and CH_3I).*

(i) Doors or Windows Normally Open for Ventilation

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.09	0.18	0.36
Cs-137	0.2	0.4	0.6
I_2	0.15	0.3	0.5
CH_3I	0.91	0.95	0.99

(ii) All Doors and Windows Closed

TIAC Ratio	5th Quantile	Median	95th Quantile
Pu-240	0.05	0.1	0.2
Cs-137	0.15	0.27	0.5
I_2	0.1	0.2	0.4
CH_3I	0.9	0.92	0.95

Questions 12 and 13 were not addressed.

APPENDIX D

Short Biographies of the Deposited Material and External Doses Experts

Short Biographies of the Deposited Materials and External Doses Expert Panels

Michael I. Balonov, Russia

Dr. Balonov graduated in nuclear physics at the Polytechnic Institute of Leningrad in 1967. He received his Ph.D. in biophysics in Moscow in 1972 at the Institute of Biophysics where he also obtained his DSc in radiobiology and radiation hygiene in 1986. He has unique experience in radiation monitoring, dose reconstruction, and population protection after the nuclear disaster in Chernobyl. Dr. Balonov is a member of the International Union of Radioecologists and of the Russian Commission on Radiation Protection. He has published over 100 articles and is author of the book *Dosimetry and Standardization of Tritium* (1983) and editor of the book *Chernobyl Papers, Volume I* (1993). As head of the Radioecology Department of the Institute of Radiation Hygiene, Dr. Balonov continues his work in radiation monitoring, risk assessment, and population protection in regions of Russia contaminated by the Chernobyl nuclear accident.

André Bouville, USA

André Bouville was born and raised in France. He obtained a Ph.D. degree in physics at the University of Toulouse and worked for many years at the French Atomic Energy Commission. In the US, he was associated with the National Atmospheric and Oceanic Administration (NOAA) and with the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Dr. Bouville now works for the National Cancer Institute (NCI). His areas of expertise include the environmental transfer of radionuclides and the assessment of radiation doses arising from the presence of natural and man-made radionuclides in the environment. He is currently involved in dose reconstruction efforts carried out in the framework of epidemiological studies related to the Chernobyl accident. As a member of both the National Council on Radiation Protection and Measurements (NCRP) and the ICRP, he participates in the preparation of reports on the reliability of dose coefficients that the two organizations have undertaken.

Joanne Brown, UK

Ms. Brown earned a BSc (Hons) in physics in 1982 at the University of Nottingham and an MSc. in radiation biophysics in 1983 at the University of Dundee. Since 1983 she has been employed at the National Radiological Protection Board where she works in the Environmental Assessments Department in the area of assessing the consequences of potential accidental releases from nuclear installations. Her principal areas of expertise are in the modeling of the behavior of radionuclides in urban environments and in terrestrial foodchains and in the evaluation of the implementation of decontamination and agricultural countermeasures. She has been a consultant on the Urban Working Group of the International Atomic Energy Agency's VAMP program.

M.J. Crick, Austria

Dr. Crick received his BA in physics in 1980 and his MA in 1982 at Oxford University. Later, he attended the post-graduate course on radiological protection at NRPB. After working as a senior scientific officer at NRPB, he moved to Austria where he was an environmental radiation protection specialist at the International Atomic Energy Agency (IAEA) in Vienna. Currently he is working at IAEA on radiation protection of the public and the environment, intervention, dose constraints, optimization of protection, environmental transfer models, countermeasures, dose assessment, and follow-up to the international Chernobyl project.

Eduardo Gallego, Spain

Professor Gallego is a graduate of the Universidad Politécnica de Madrid (1982) where he also earned his Ph.D. in industrial engineering in 1990. Along with teaching radiation protection and nuclear safety, Dr. Gallego participates in several post-graduate courses at UPM and the Institute of Energy Study (IEE-CIEMAT) in Madrid, performs research as coordinator of the UPM project on Radiological Consequences of Accidents in Nuclear Power Plants, and works with the MACCS, UFOMOD, and COSYMA codes and the adaption of these codes to the Spanish nuclear sites. He also participates in the VAMP Urban Working Group (IAEA) on the URBAPAT model for the evaluation of external doses from deposited material in urban environments, and in the NEA/OECD-EC "Intercomparison Exercise on Probabilistic Accident Consequence Assessment Models" with the MACCS, COSYMA and MECA2 codes. He has led the UPM group in the EC project "Methodology for evaluating the radiological impact of radioactive effluents released in accidents - the MARIA project" with participation of NRPB, FZK and KEMA.

Peter Jacob, Germany

Dr. Jacob earned his Ph.D. (Dr.rer.nat.) at the physics faculty of the Technischen Universität München in 1979. He has worked as a scientist at the Max-Planck-Institut in Starnberg as well as in München. Currently he is head of the Risk Analysis Section of GSF Institut für Strahlenschutz and as such performs research in the fields radioecology, retrospective dosimetry and models of radiation effects. Dr. Jacob has published a considerable number of peer-reviewed papers.

Olof Karlberg, Sweden

Dr. Karlberg has an MSc including mathematics, physics and health physics as major subjects. He worked as a health physicist in various hospitals before being employed at the Studsvik nuclear research establishment in 1973 where he was conducting research on radioecology in general and specializing in the area of reactor accident consequences. After the Chernobyl accident he was responsible for several measurement programs in high-contamination regions in Sweden. Since 1989 Dr. Karlberg has worked at the Swedish Radiation Protection Institute and is responsible for environmental control of the Swedish nuclear power plants. He recently took part in the NEA/EC inter-comparison of accident consequence models.

Ilya A. Likhtarev, Ukraine

Prof. Likhtarev was the head of the Dosimetric Physics Laboratory in the Leningrad Institute of Radiation Hygiene. He presently is General Director of the Ukraine Radiation Protection Institute and Head of the Department of Dosimetry and Radiation Hygiene of the Ukraine Scientific Center for Radiation Medicine and has over 30 years experience in the field of external and internal dosimetric processes related to human beings exposed to nuclear radiation. He is a member of the International Committee for Radiation Protection (ICRP) as well as a professor of radiation physics, and is the author of over 100 peer-reviewed publications.

Kevin M. Miller, USA

Mr. Miller received a BS degree in physics from St. John's University (1972) and an MS degree in energetics from New York University (1980) where he also performed additional graduate work in atmospheric science. He has been employed with the US Department of Energy Environmental Measurements Laboratory (formerly US Atomic Energy Commission Health and Safety Laboratory) since 1972. He has worked principally on the development of radiation instrumentation and metrology and studies of natural and anthropogenic radiation which has led to over 60 publications in these fields. His experiences with environmental radiation assessment have included nuclear power plant monitoring, the emergency response at Three Mile Island, dose reconstruction from Nevada Test Site fallout, evaluations of natural radionuclide emissions from fossil fuel plants, and measurements of fallout from the Chernobyl accident. His professional activities have included serving as team leader for an IAEA mission to the former USSR during the International Chernobyl Project; senior scientific advisor to the Federal Radiation Measurement and Assessment Center; consultant to the Nuclear Regulatory Commission; committee member for the ICRU; short-course faculty member for the Harvard School of Public Health; short-course organizer for the Institute of Electrical and Electronics Engineers; review panel member for the Health Physics Society, the American Nuclear Society, and the Three Mile Island Public Health Fund. His current work is focused on radiological surveys associated with environmental remediation and nuclear facility decommissioning.

Jørn Roed, Denmark

Dr. Roed is the head of the Contamination Physics Group at Risø National Laboratory in Denmark. For the past few years, one of this groups task's has been the identification of important parameters concerning deposition of radioactive matter under various conditions. During the last five years he has participated in the following projects, which have been funded in part or fully by the European Community (EC) or NKA (Northern Liaison Committee): Recl (NKA), AKTU (NKA), RAD (NKA), Collaboration between Nordic and SNG Countries (NKA), MARIA (EC), Contamination (EC), Decontamination (EC), Ressac (EC), Deposition and Run-Off (EC), Reduction in Inhalation Dose (EC), Indoor Deposition (EC) and CHECIR (EC).

APPENDIX E

Aggregated Results of Expert Responses

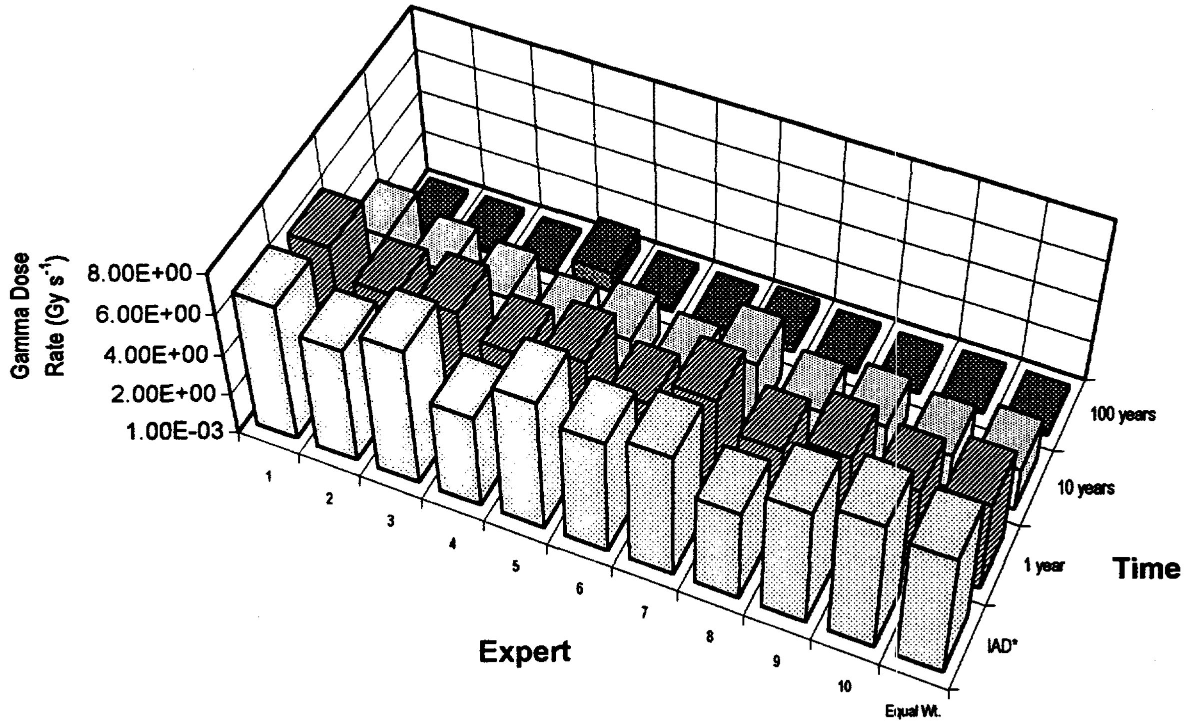

Figure E.1 Median results for the distributions of gamma dose rate (Gy s^{-1}) above an open lawned area following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs. *Immediately after deposit.

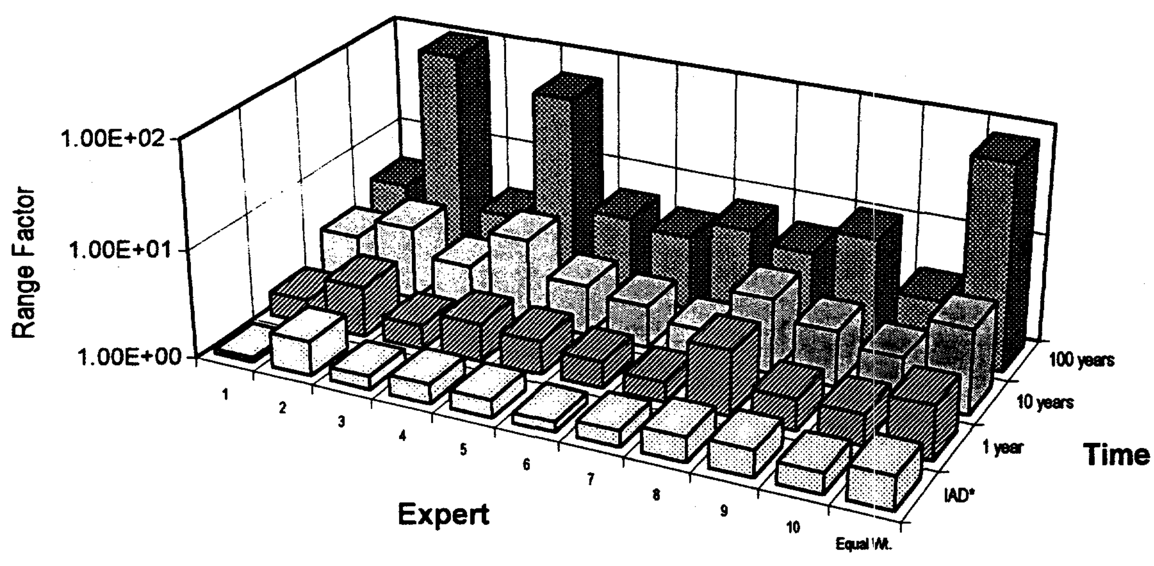

Figure E.2 Range factors (ratio of 95th/5th percentile) for the distributions of gamma dose rate (Gy s^{-1}) above an open lawned area following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs. * Immediately after deposit.

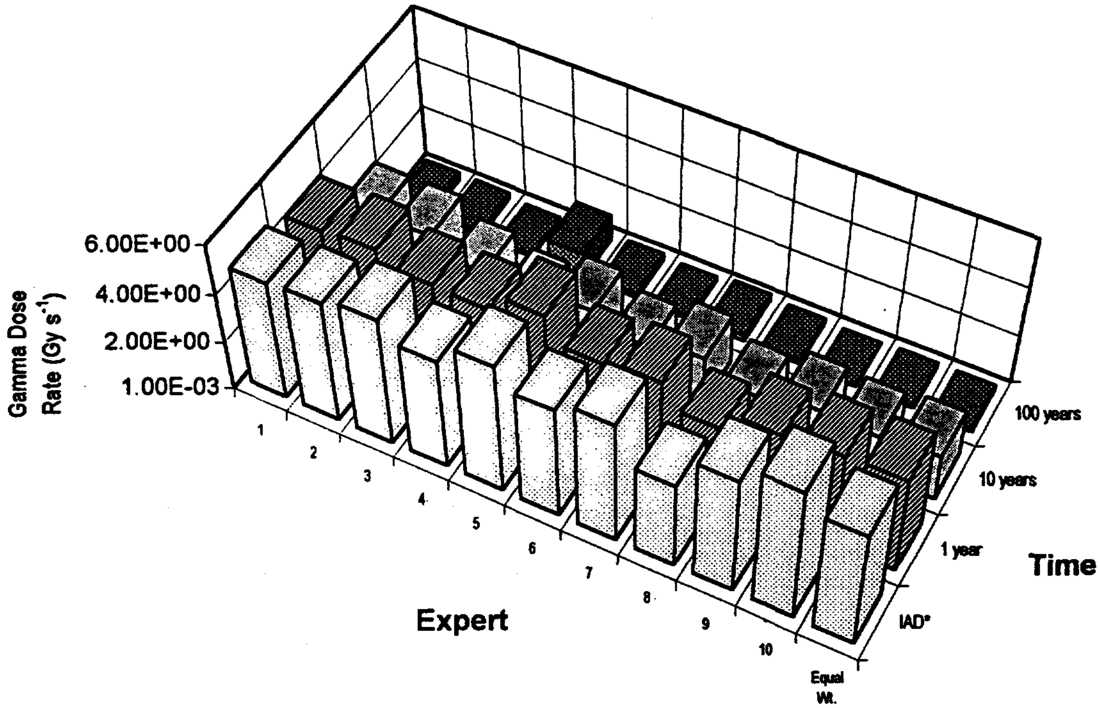

Figure E.3 Median results for the distributions of gamma dose rate (Gy s^{-1}) above an open lawned area following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs. *Immediately after deposit.

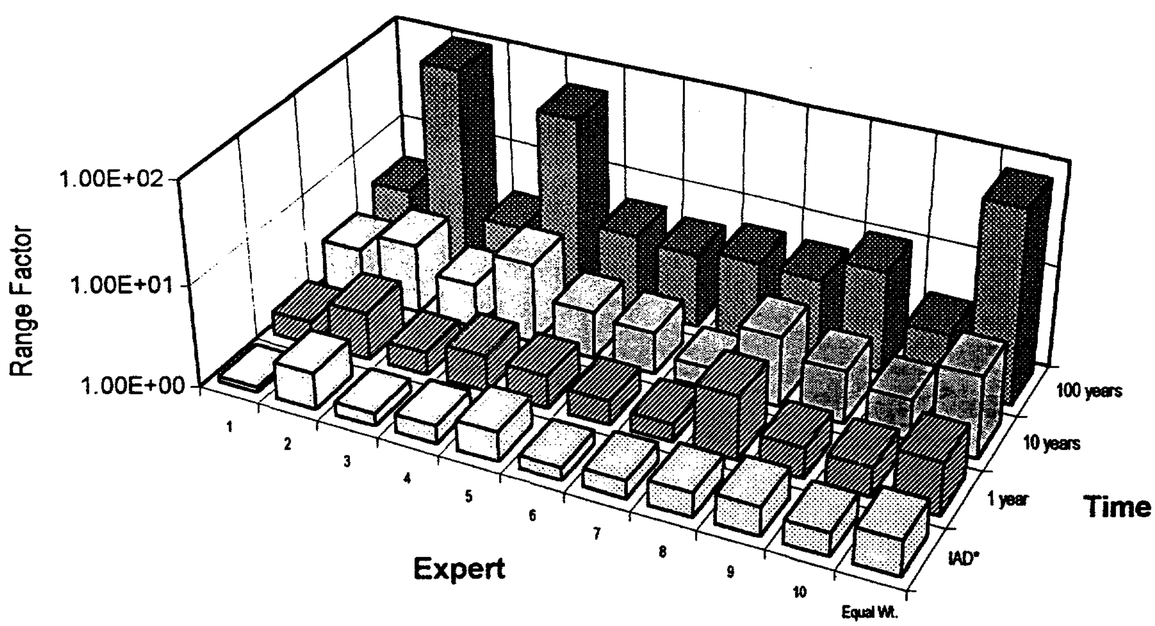

Figure E.4 Range factors (ratio of 95th/5th percentile) for the distributions of gamma dose rate (Gy s^{-1}) above an open lawned area following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs. * Immediately after deposit.

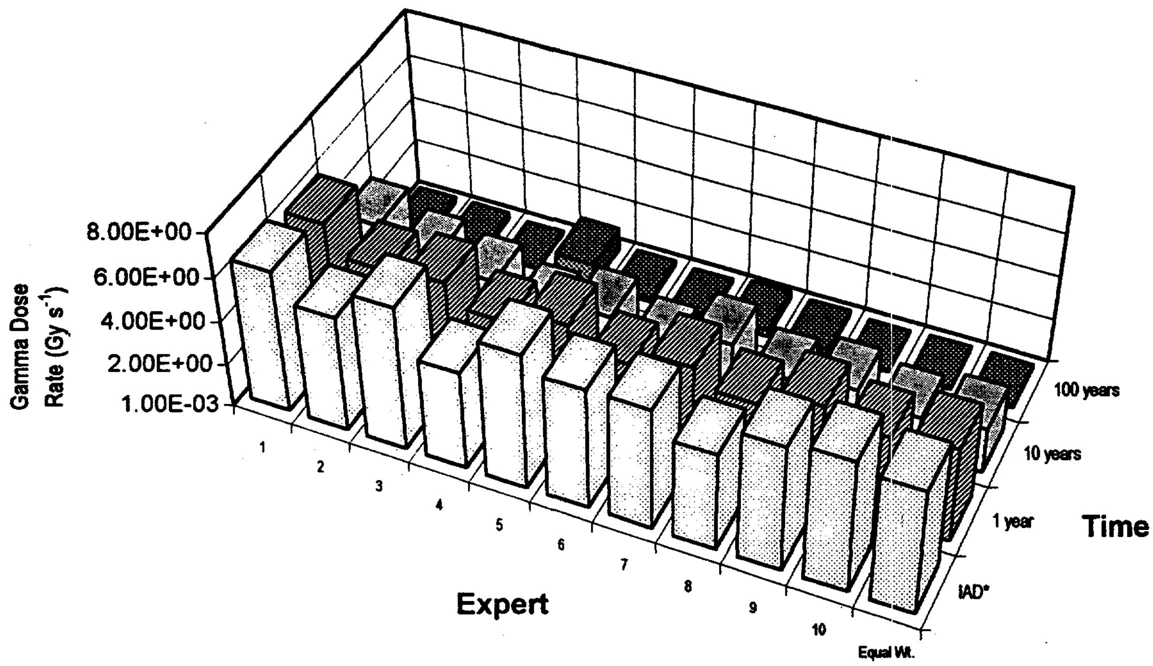

Figure E.5 Median results for the distributions of gamma dose rate (Gy s^{-1}) above an open lawned area following an initial average deposition of 1 Bq/m^2 of ^{137}Cs. *Immediately after deposit.

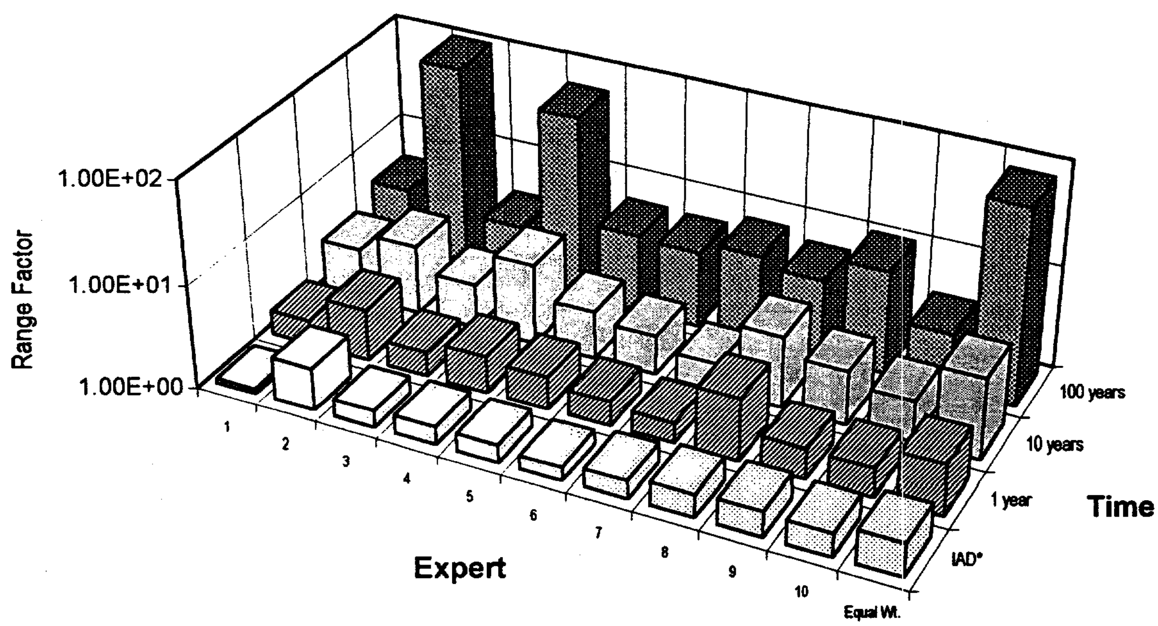

Figure E.6 Range factors (ratio of 95th/5th percentile) for the distributions of gamma dose rate (Gy s^{-1}) above an open lawned area following an initial average deposition of 1 Bq/m^2 of ^{137}Cs. * Immediately after deposit.

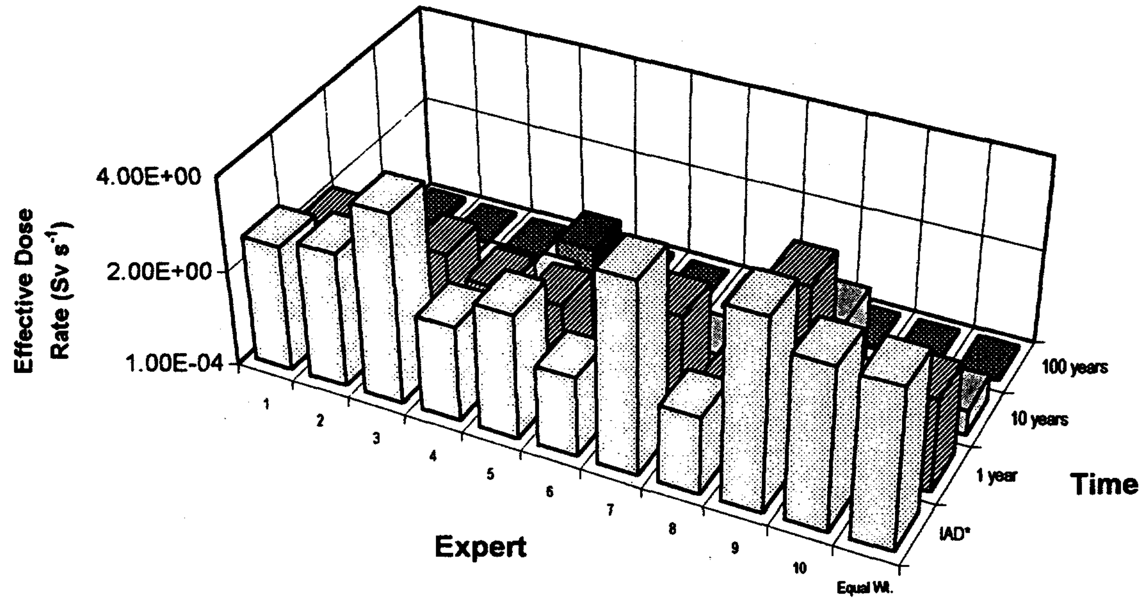

Figure E.7 Median results for the distributions of effective dose rate (Sv s^{-1}) in a typical urban environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground. *Immediately after deposit.

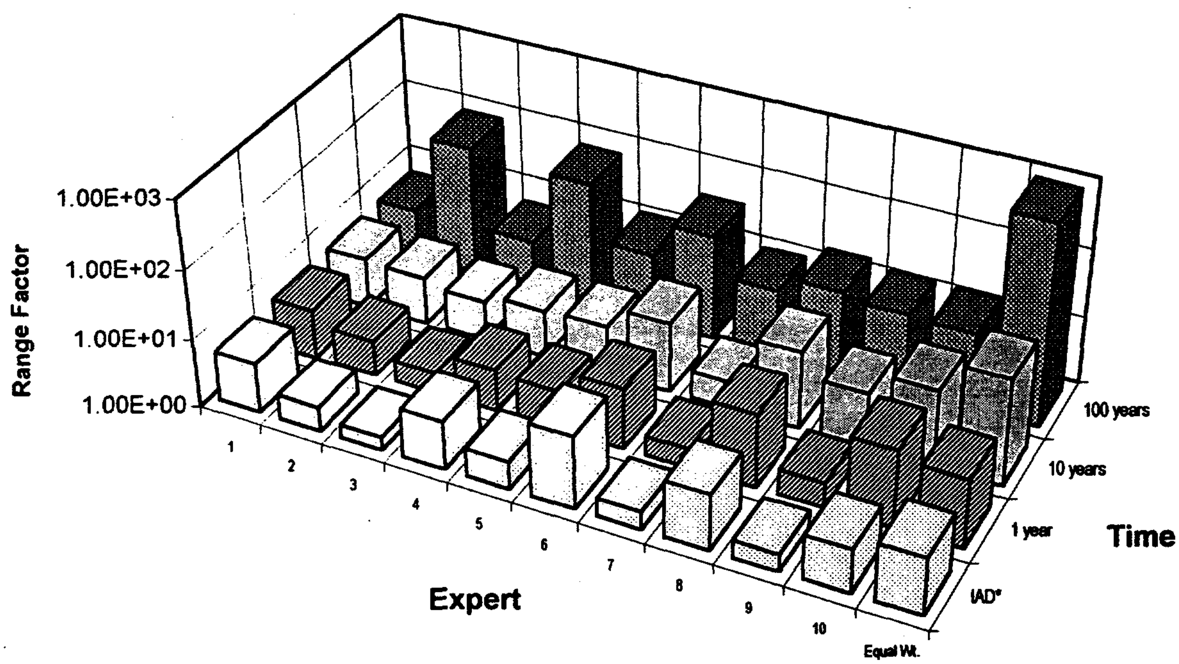

Figure E.8 Range factors (ratio of 95th/5th percentile) for the distributions of effective dose rate (Sv s^{-1}) in a typical urban environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground. * Immediately after deposit.

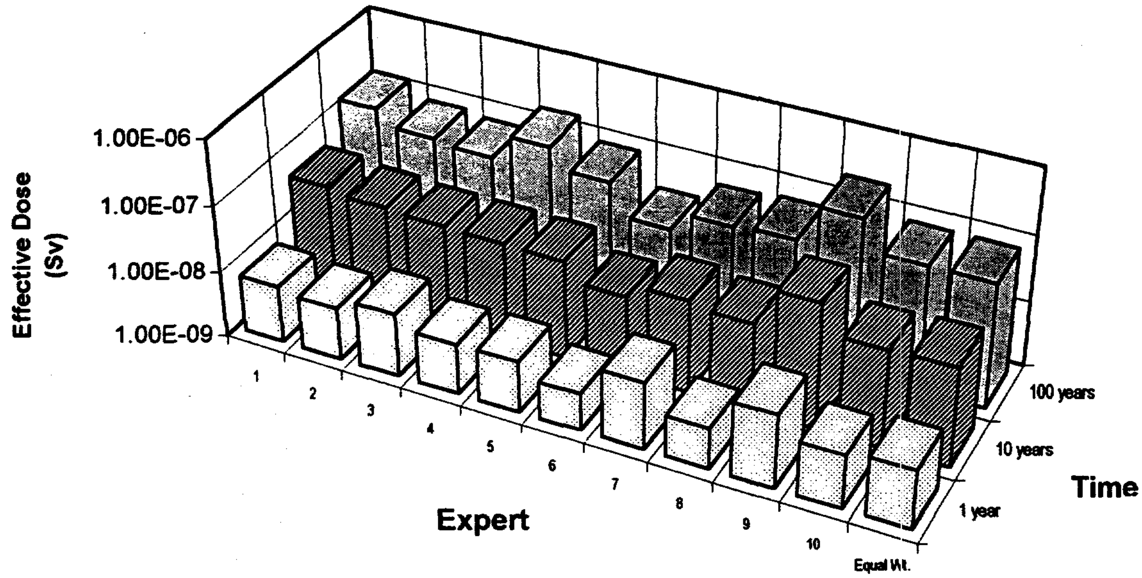

Figure E.9 Median results for the distributions of the integrated adult effective dose (Sv) in a typical urban environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

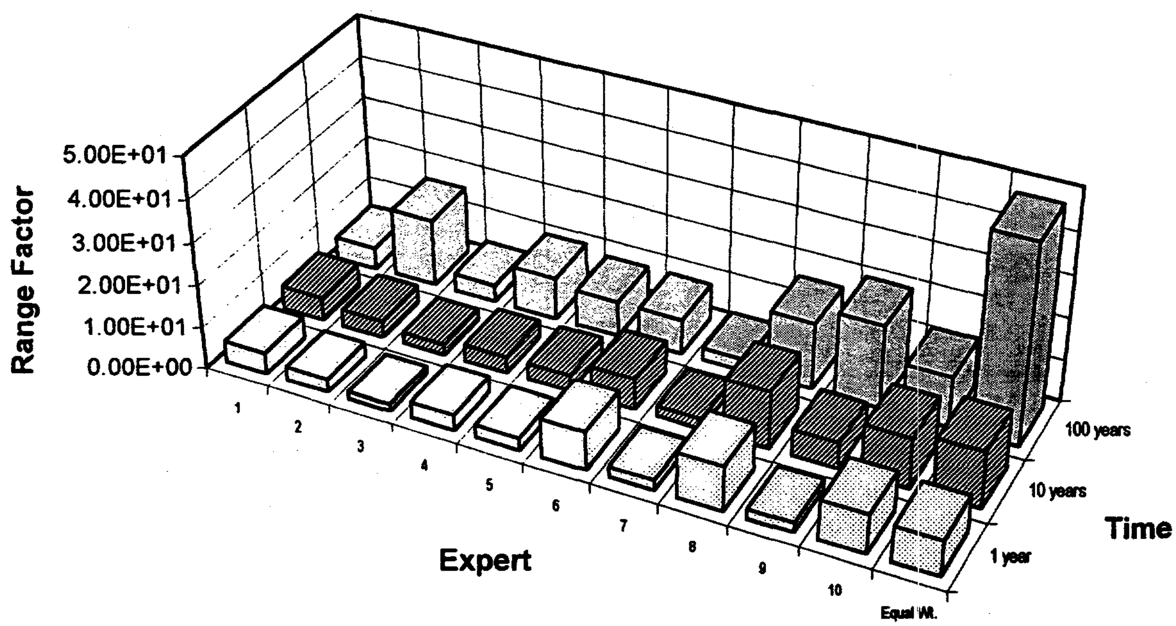

Figure E.10 Range factors (ratio of 95th/5th percentile) for the distributions of the integrated adult effective dose (Sv) in a typical urban environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

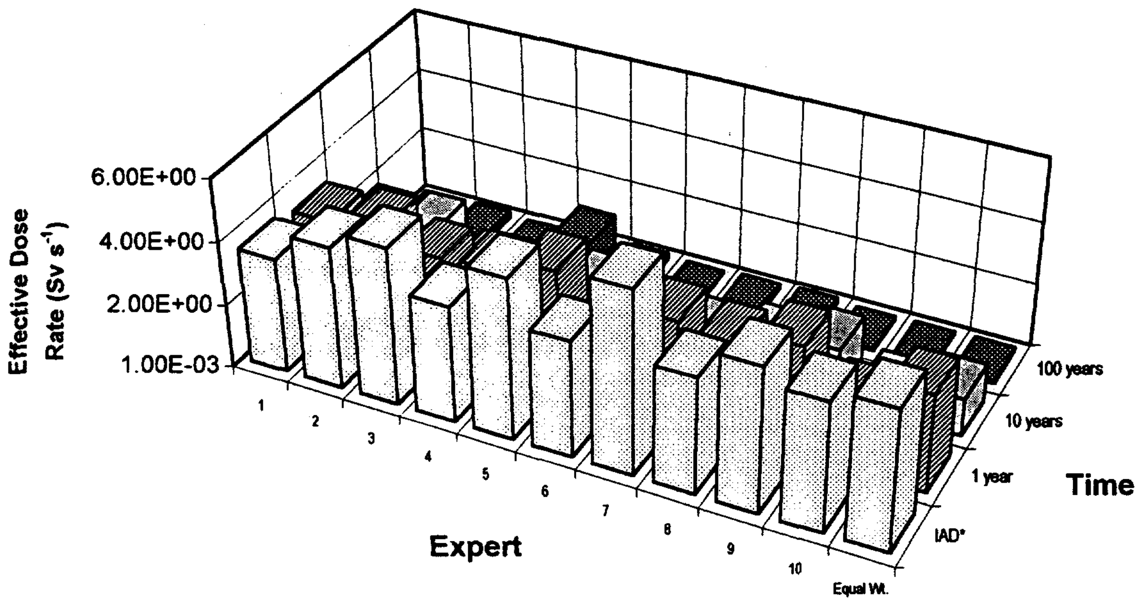

Figure E.11 Median results for the distributions of effective dose rate (Sv s^{-1}) in a typical rural environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground. *Immediately after deposit.

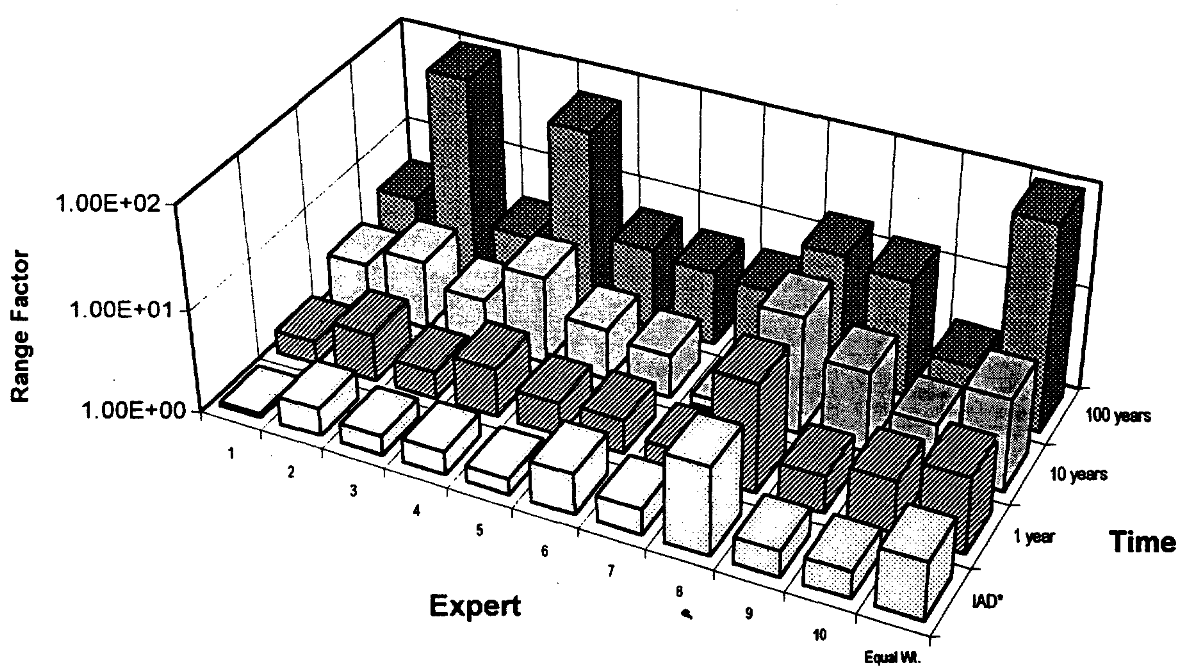

Figure E.12 Range factors (ratio of 95th/5th percentile) for the distributions of effective dose rate (Sv s^{-1}) in a typical rural environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground. * Immediately after deposit.

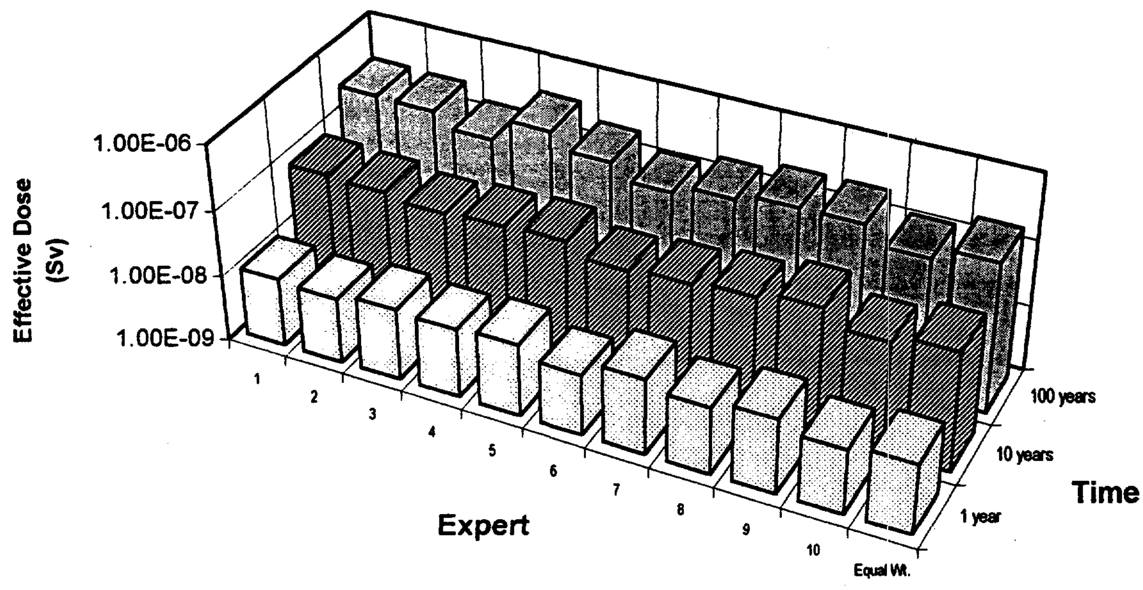

Figure E.13 Median results for the distributions of the integrated adult effective dose (Sv) in a typical rural environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

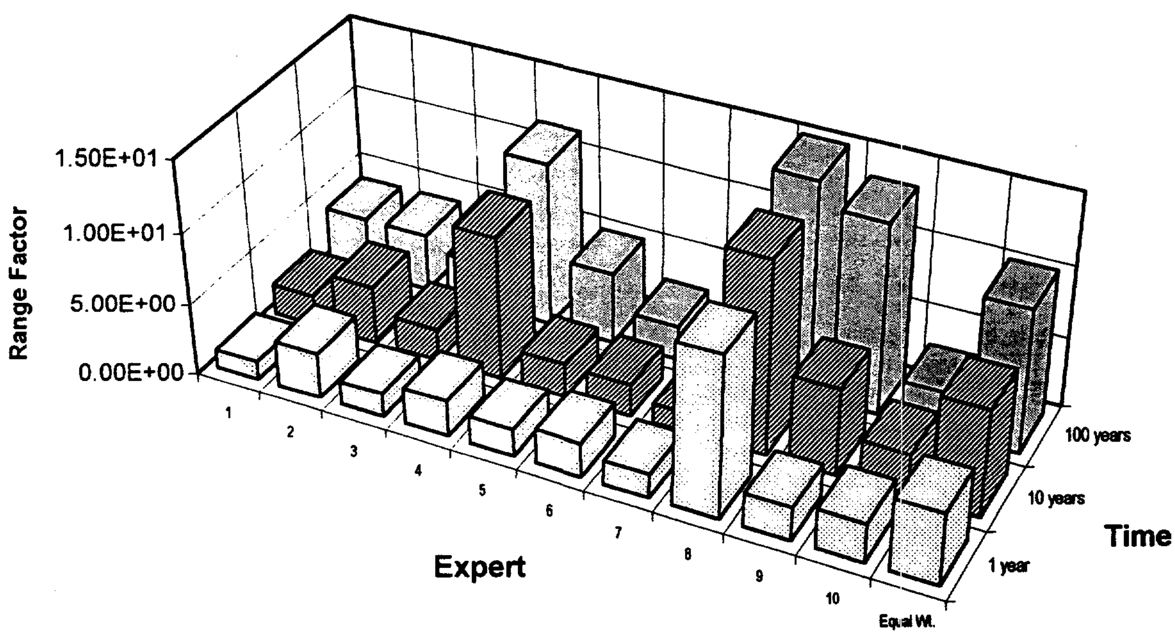

Figure E.14 Range factors (ratio of 95th/5th percentile) for the distributions of the integrated adult effective dose (Sv) in a typical rural environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

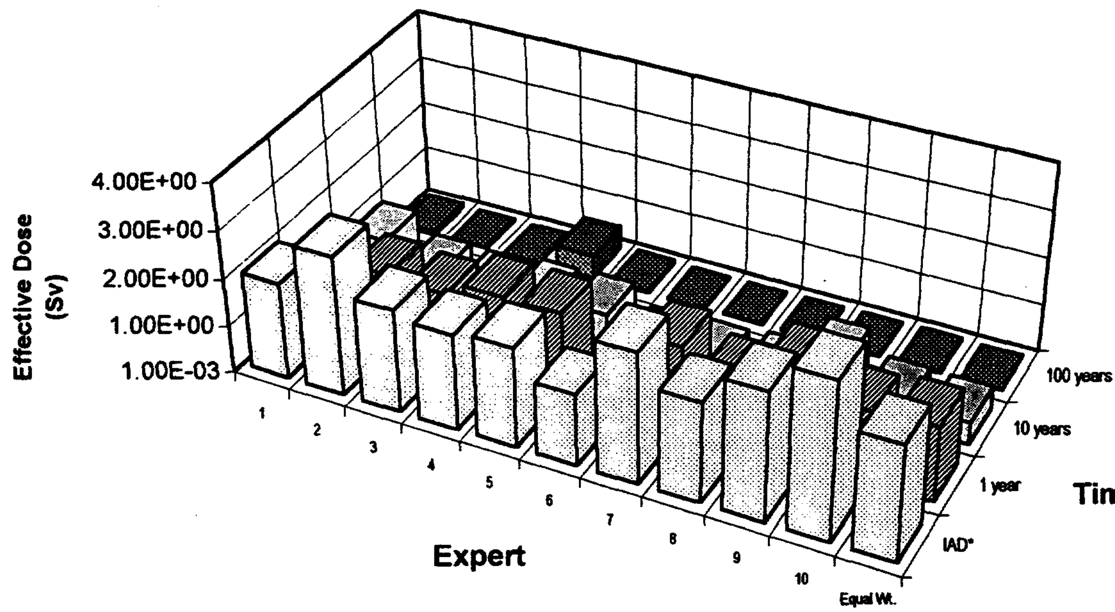

Figure E.15 Median results for the distributions of effective dose (Sv) in a typical urban environment following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground. *Immediately after deposit.

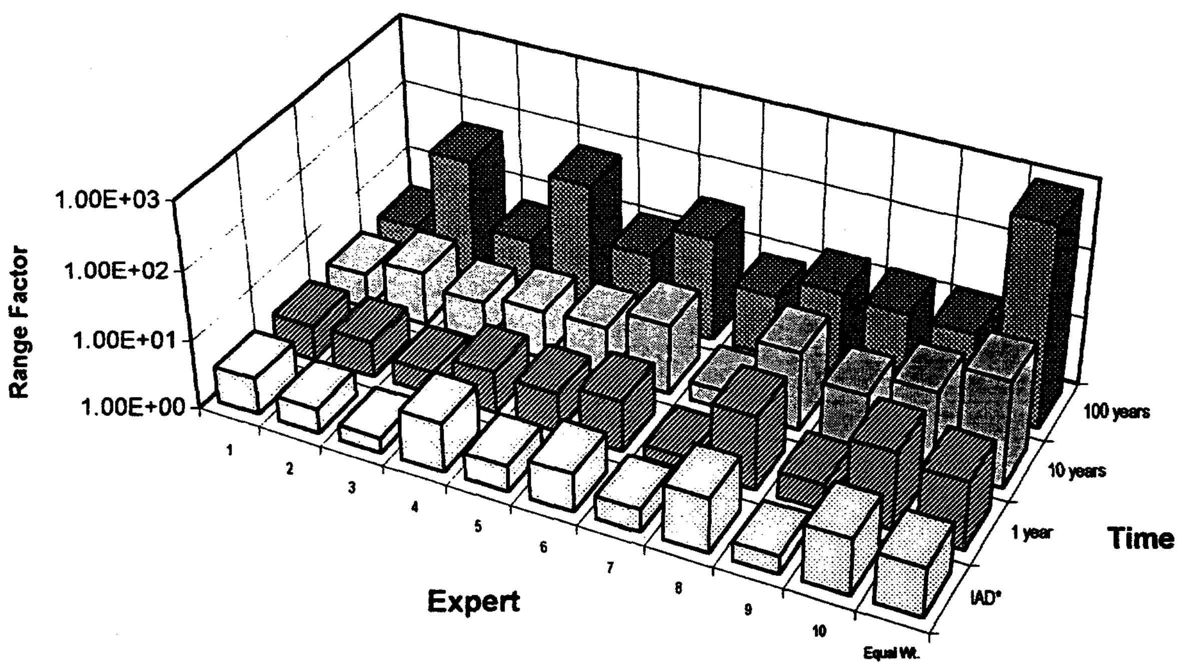

Figure E.16 Range factors (ratio of 95th/5th percentile) of the distributions of effective dose (Sv) in a typical urban environment following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground. * Immediately after deposit.

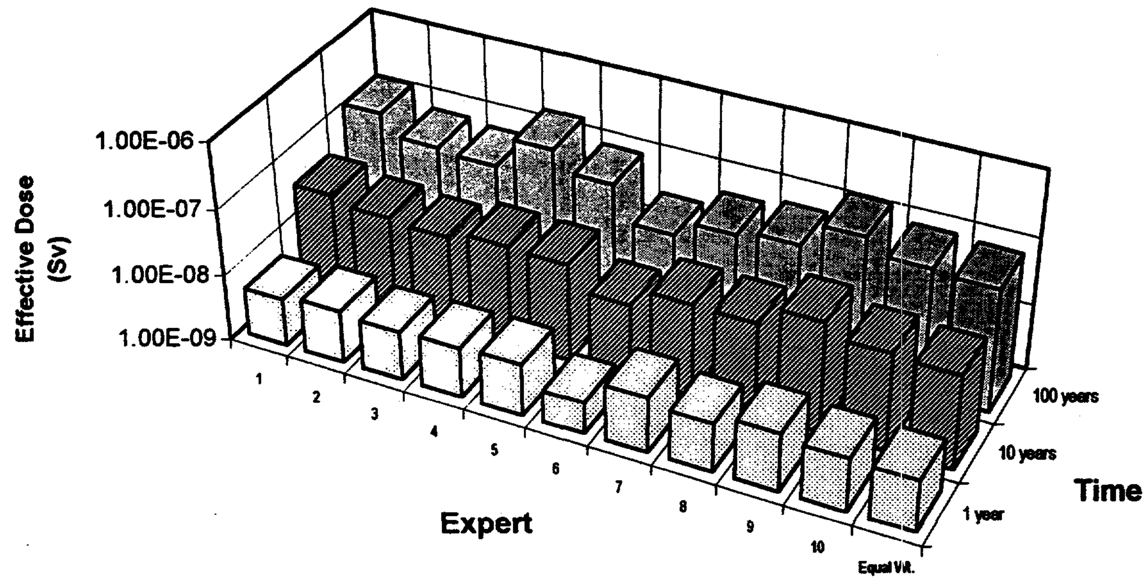

Figure E.17 Median results of the distributions of the integrated adult effective dose (Sv) in a typical urban environment following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

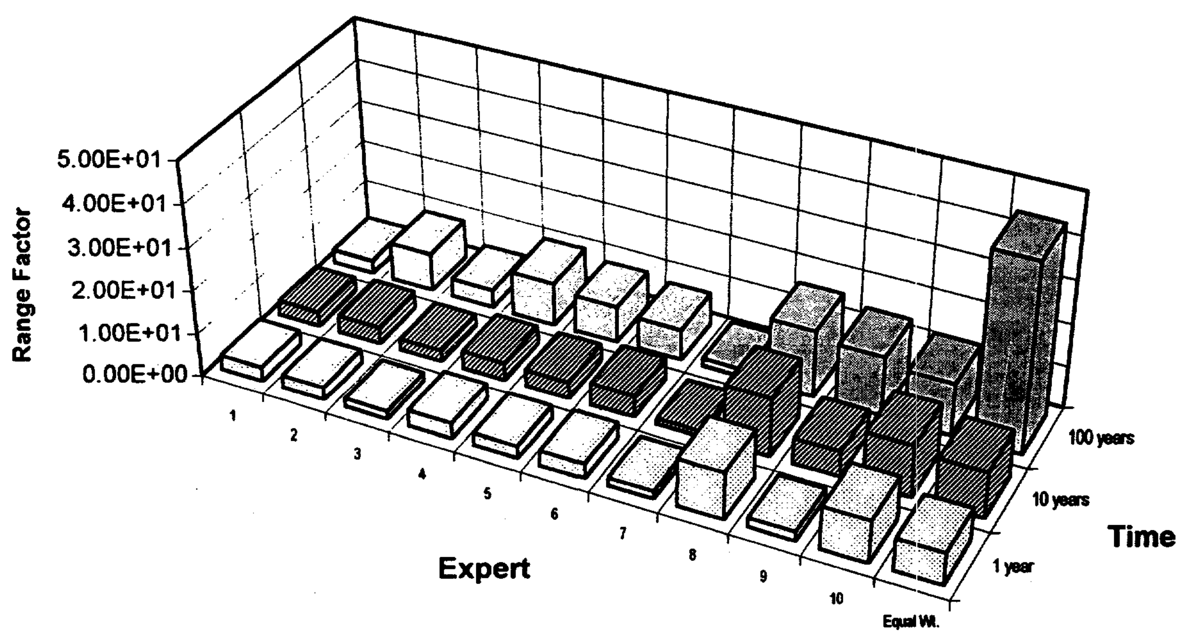

Figure E.18 Range factors (ratio of 95th/5th percentile) of the distributions of the integrated adult effective dose (Sv) in a typical urban environment following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

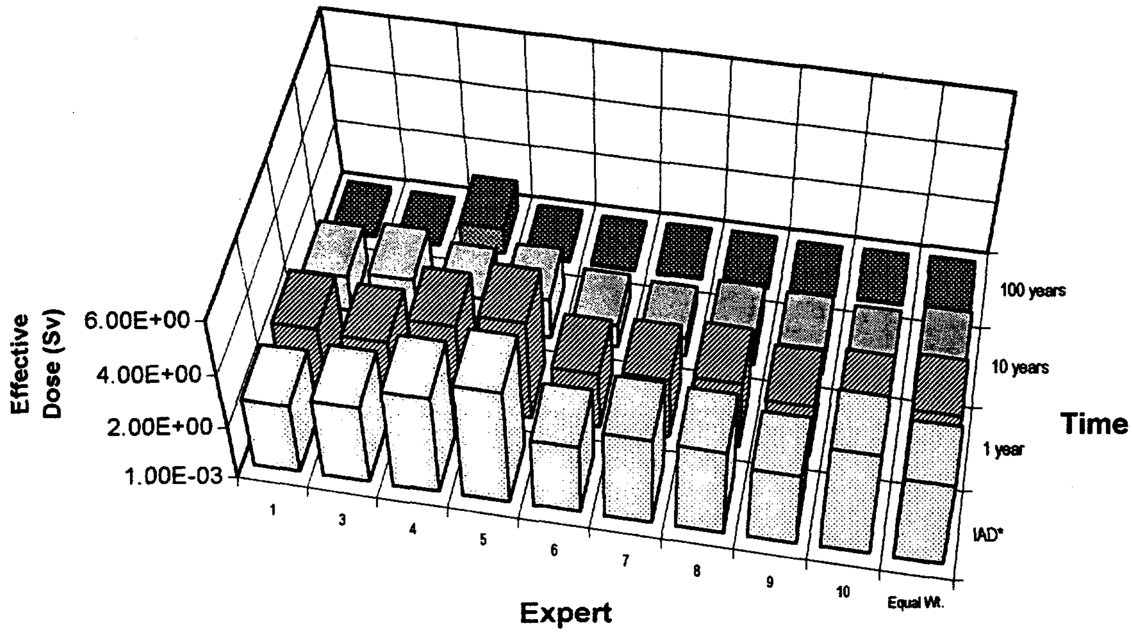

Figure E.19 Median results for the distributions of effective dose (Sv) in a typical rural environment following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground. *Immediately after deposit.

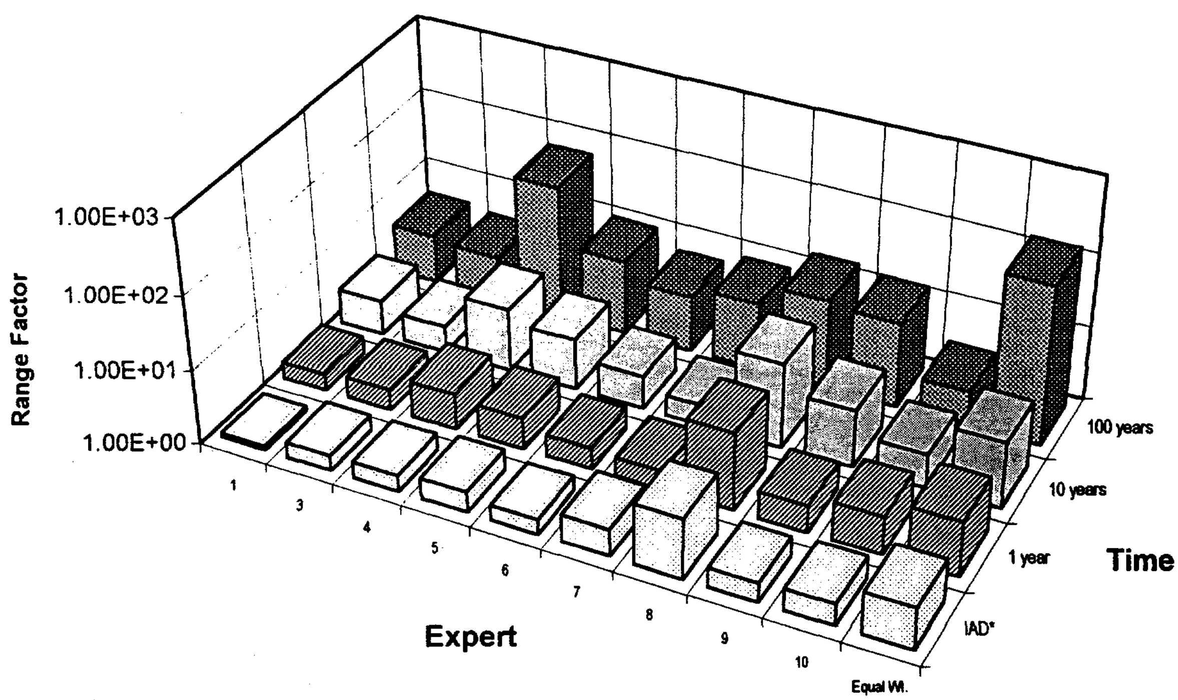

Figure E.20 Range factors (ratio of 95th/5th percentile) of the distributions of effective dose (Sv) in a typical rural environment following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground. * Immediately after deposit.

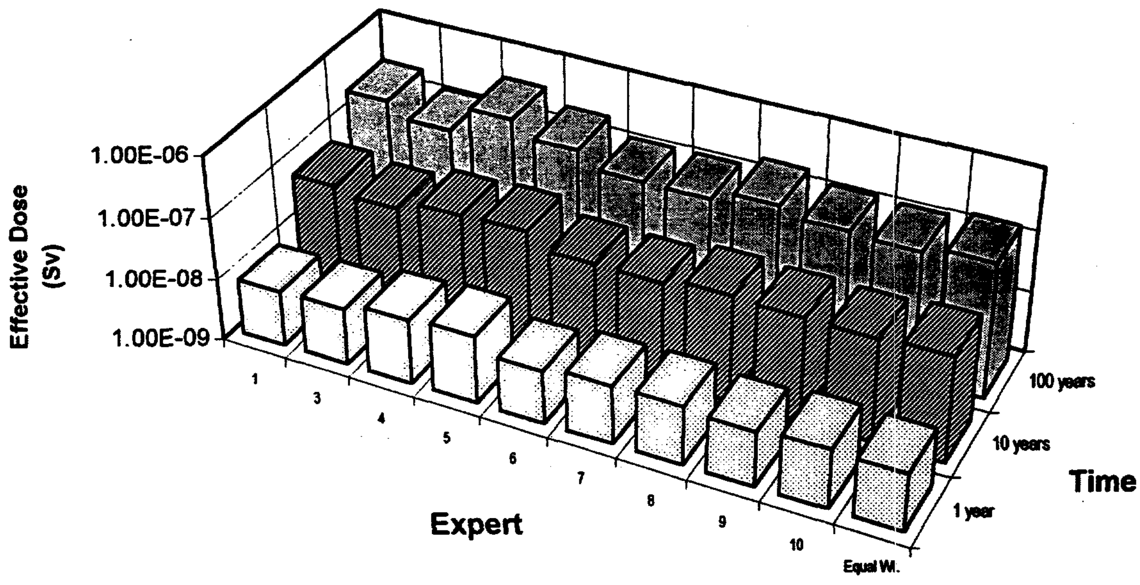

Figure E.21 Median results of the distributions of the integrated adult effective dose (Sv) in a typical rural environment following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

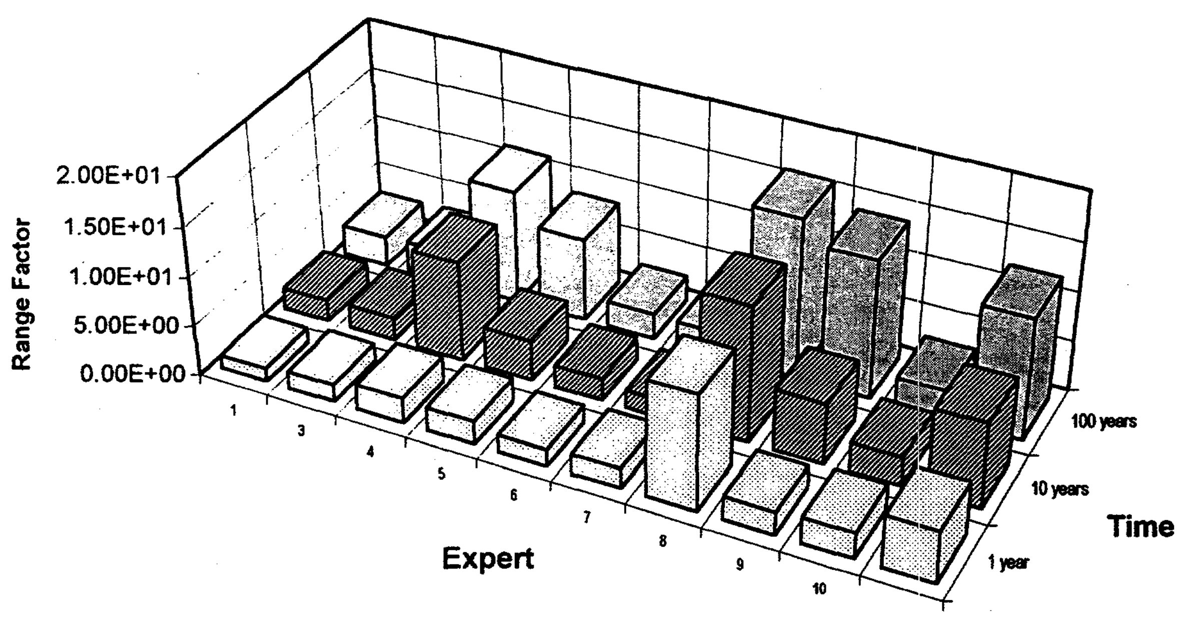

Figure E.22 Range factors (ratio of 95th/5th percentile) of the distributions of the integrated adult effective dose (Sv) in a typical rural environment following an initial wet deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

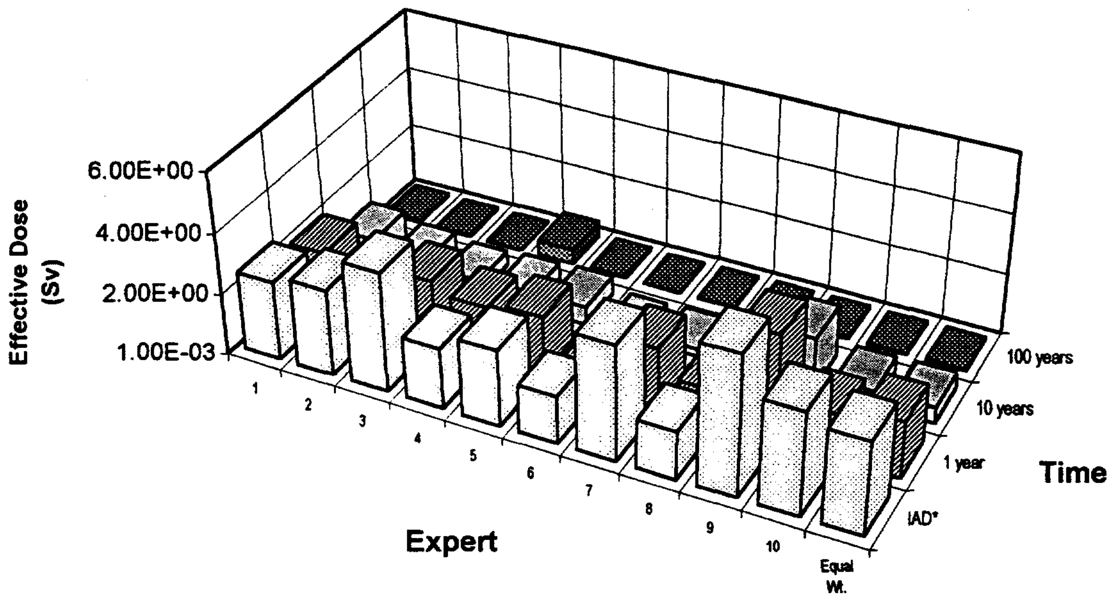

Figure E.23 Median results for the distributions of the integrated adult effective dose (Sv) in a typical urban environment following an initial uniform deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground (type of deposition--e.g., wet or dry is not specified). *Immediately after deposit.

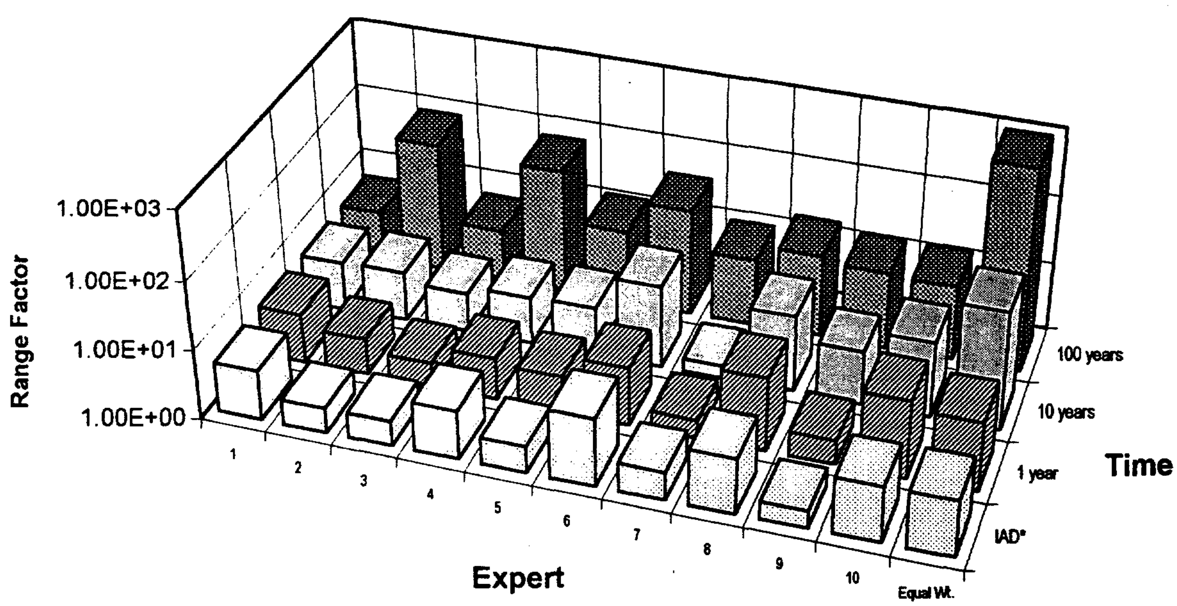

Figure E.24 Range factors (ratio of 95th/5th percentile) for the distributions of the integrated adult effective dose (Sv) in a typical urban environment following an initial uniform deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground (type of deposition--e.g., wet or dry is not specified). * Immediately after deposit.

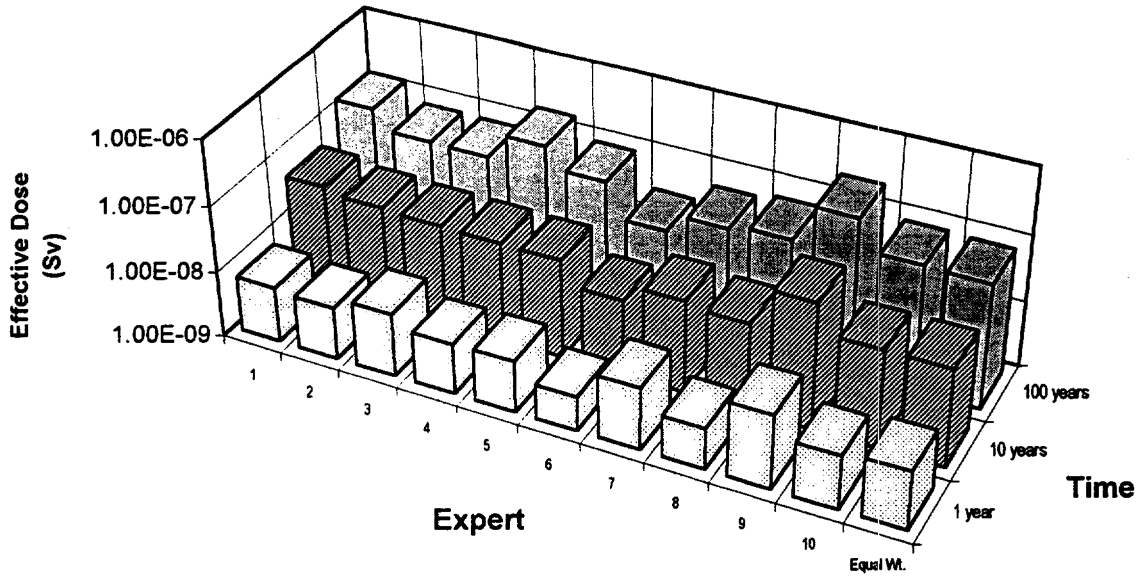

Figure E.25 Median results for the distributions of the integrated adult effective dose (Sv) in a typical urban environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

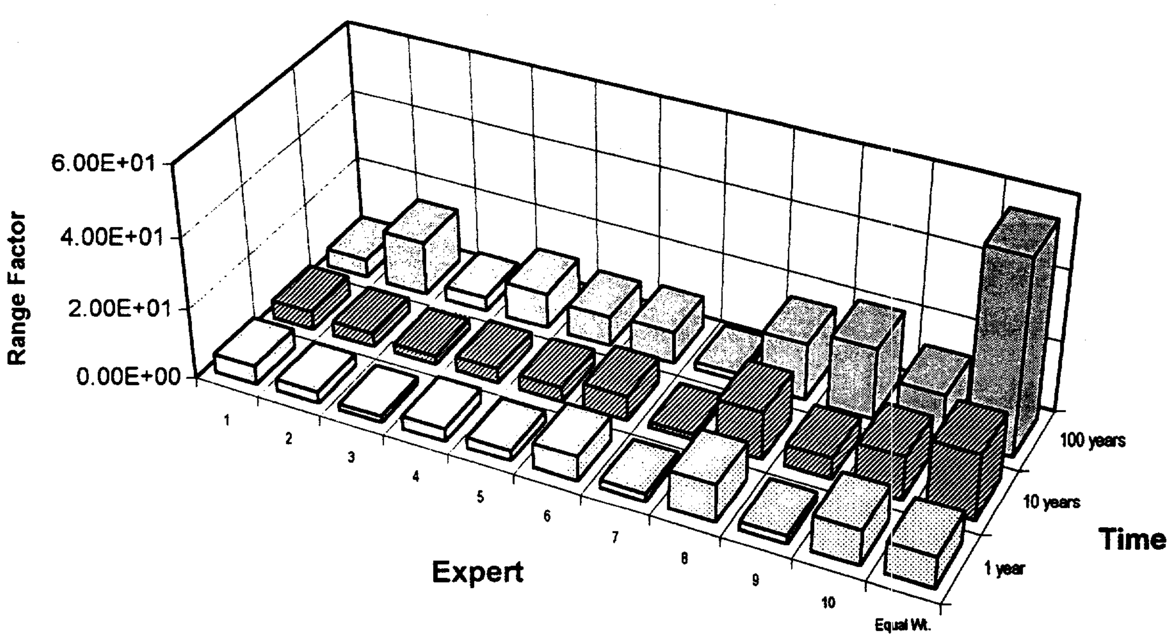

Figure E.26 Range factors (ratio of 95th/5th percentile) for the distributions of the integrated adult effective dose (Sv) in a typical urban environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

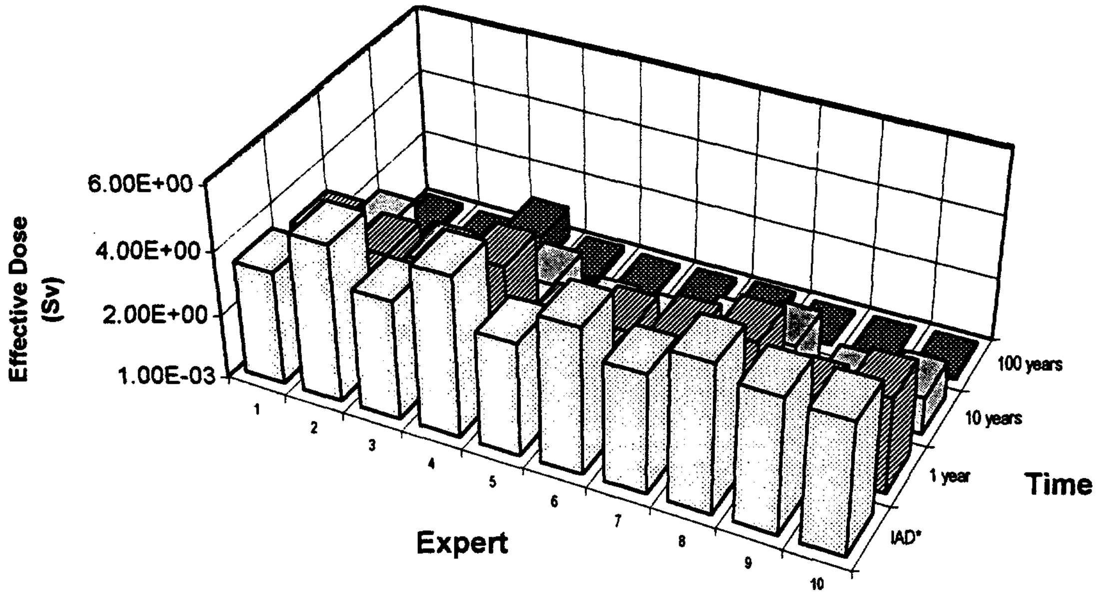

Figure E.27 Median results for the distributions of the integrated adult effective dose (Sv) in a typical rural environment following an initial uniform deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground (type of deposition--e.g., wet or dry is not specified). *Immediately after deposit.

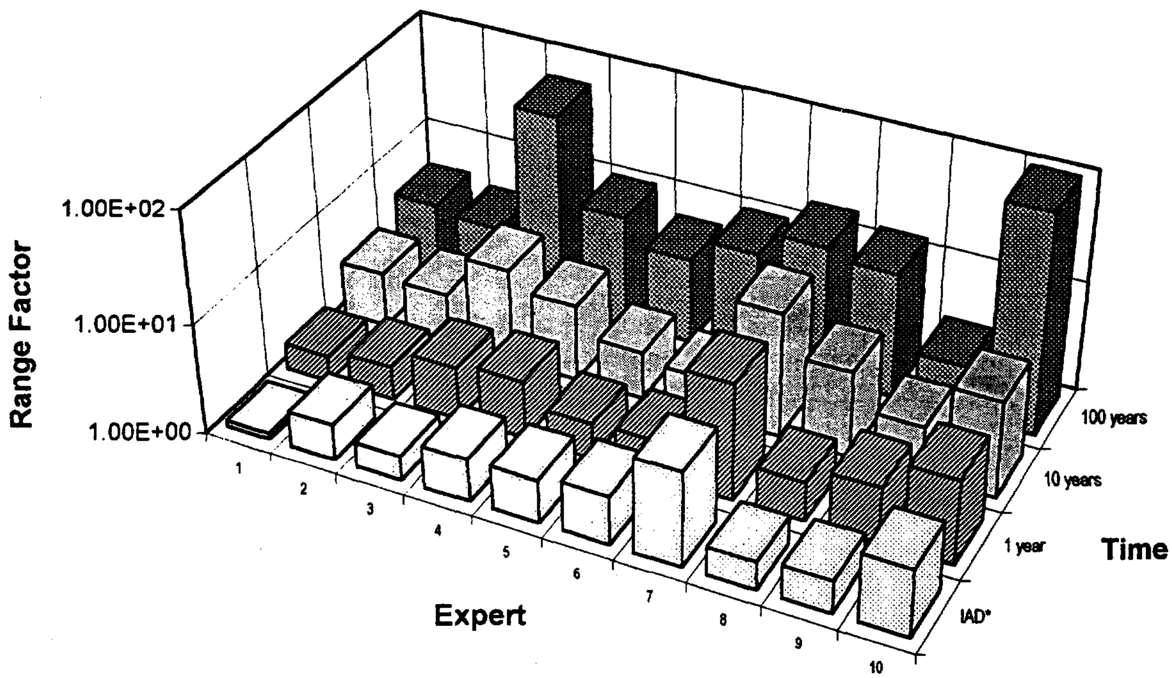

Figure E.28 Range factors (ratio of 95th/5th percentile) for the distributions of the integrated adult effective dose (Sv) in a typical rural environment following an initial uniform deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground (type of deposition--e.g., wet or dry is not specified).
*** Immediately after deposit.**

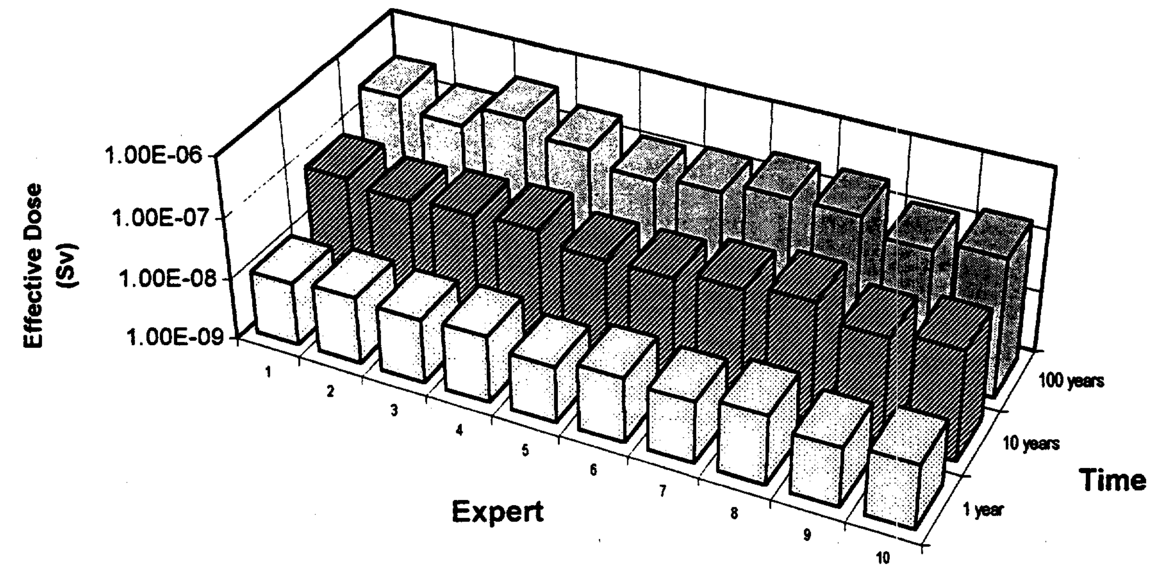

Figure E.29 Median results for the distributions of the integrated adult effective dose (Sv) in a typical rural environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

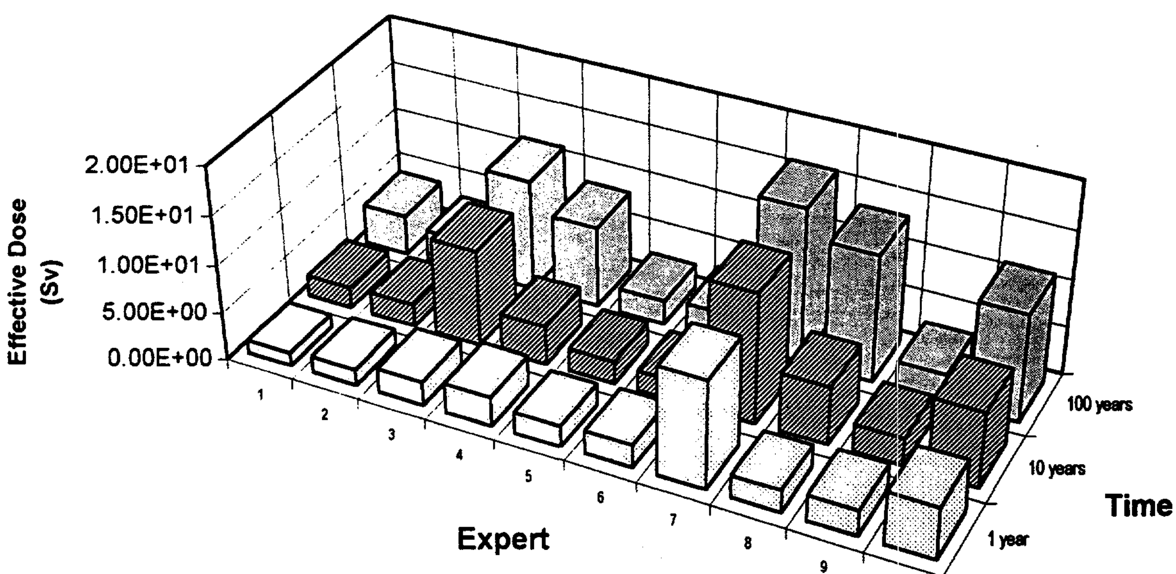

Figure E.30 Range factors (ratio of 95th/5th percentile) for the distributions of the integrated adult effective dose (Sv) in a typical rural environment following an initial dry deposition of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

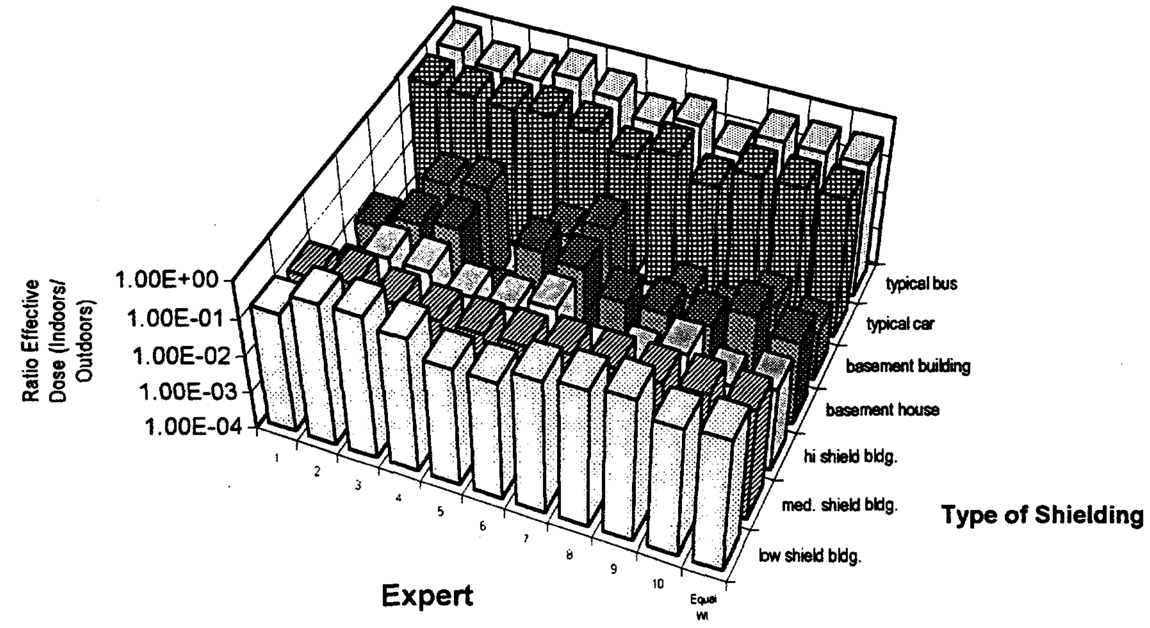

Figure E.31 Median results for the ratio of the effective dose received by an adult at several indoor locations to the effective dose received by an adult outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

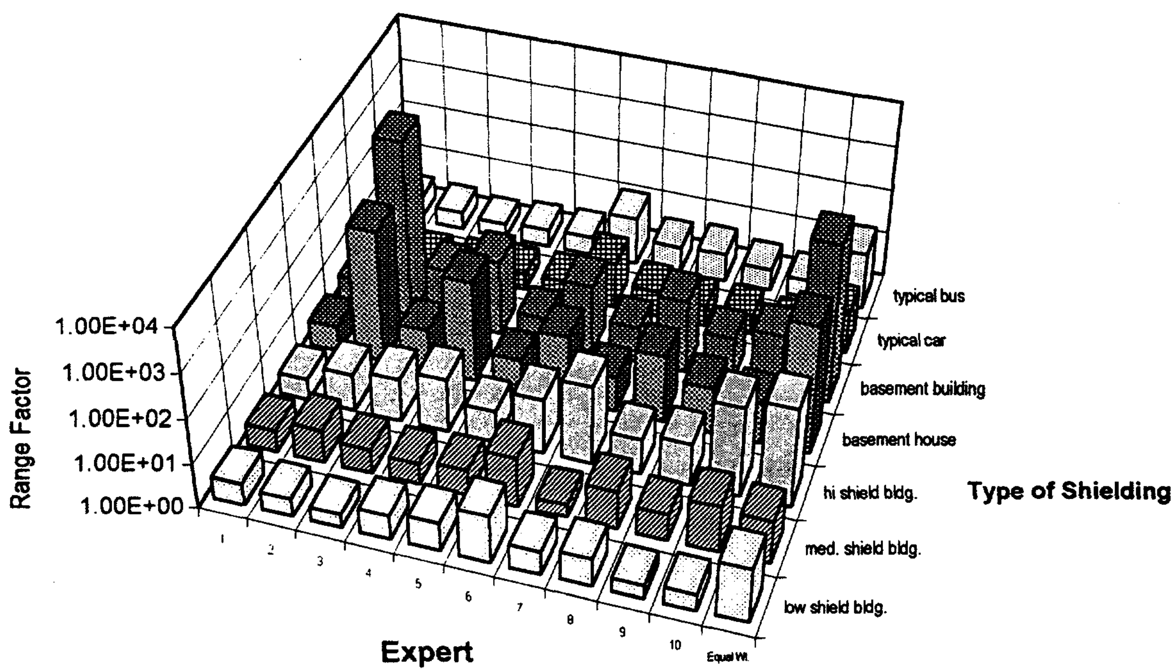

Figure E.32 Range factors (ratio of 95th/5th percentile) for the ratio of the effective dose received by an adult at several indoor locations to the effective dose received by an adult outdoors in an open lawned area shortly after an initial uniform deposit of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

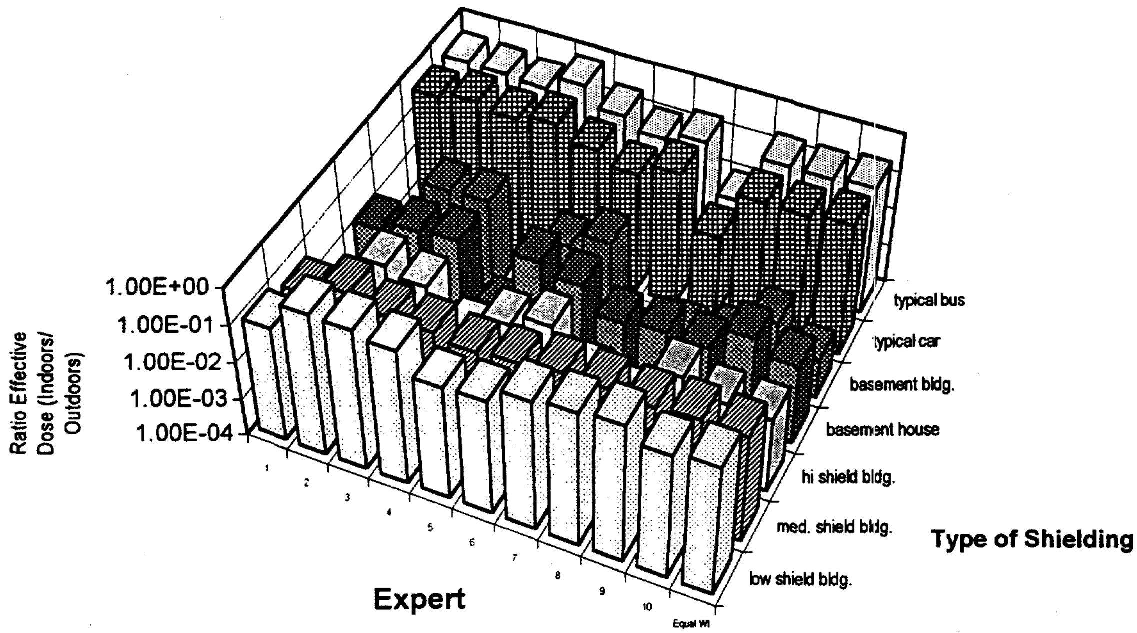

Figure E.33 Median results for the ratio of the effective dose received by an adult at several indoor locations to the effective dose received by an adult outdoors in an open lawned area one year after an initial uniform deposit of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

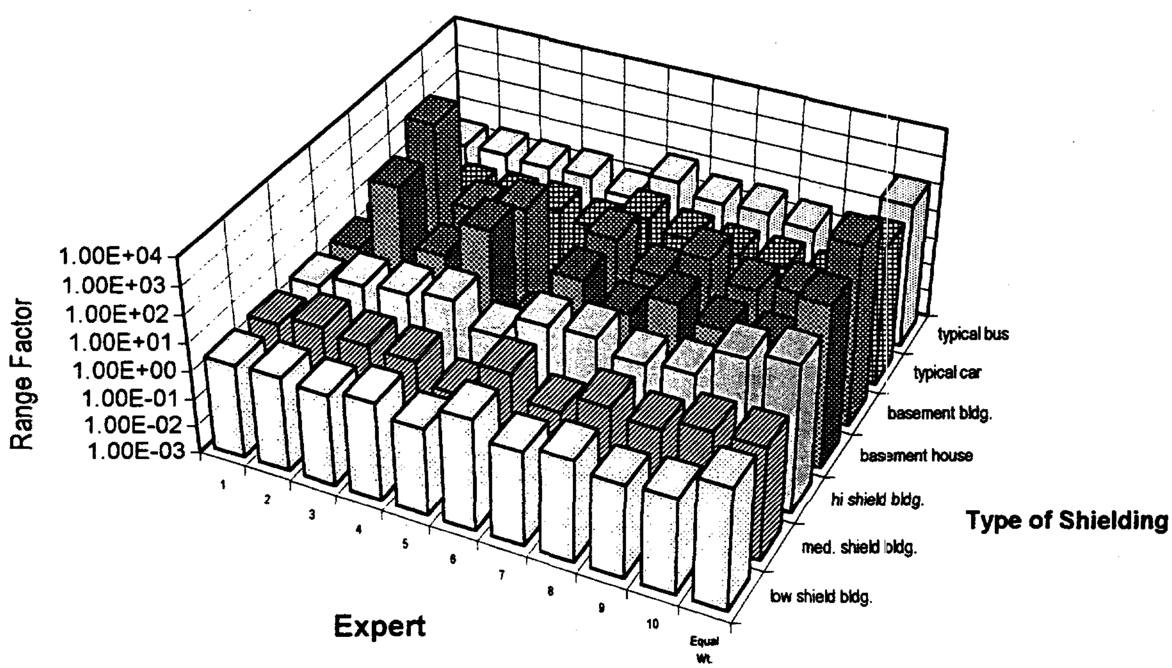

Figure E.34 Range factors (*ratio of 95th/5th percentile*) for the ratio of the effective dose received by an adult at several indoor locations to the effective dose received by an adult outdoors in an open lawned area one year after an initial uniform deposit of 1 Bq/m2 of ^{137}Cs to the lawned areas of the ground.

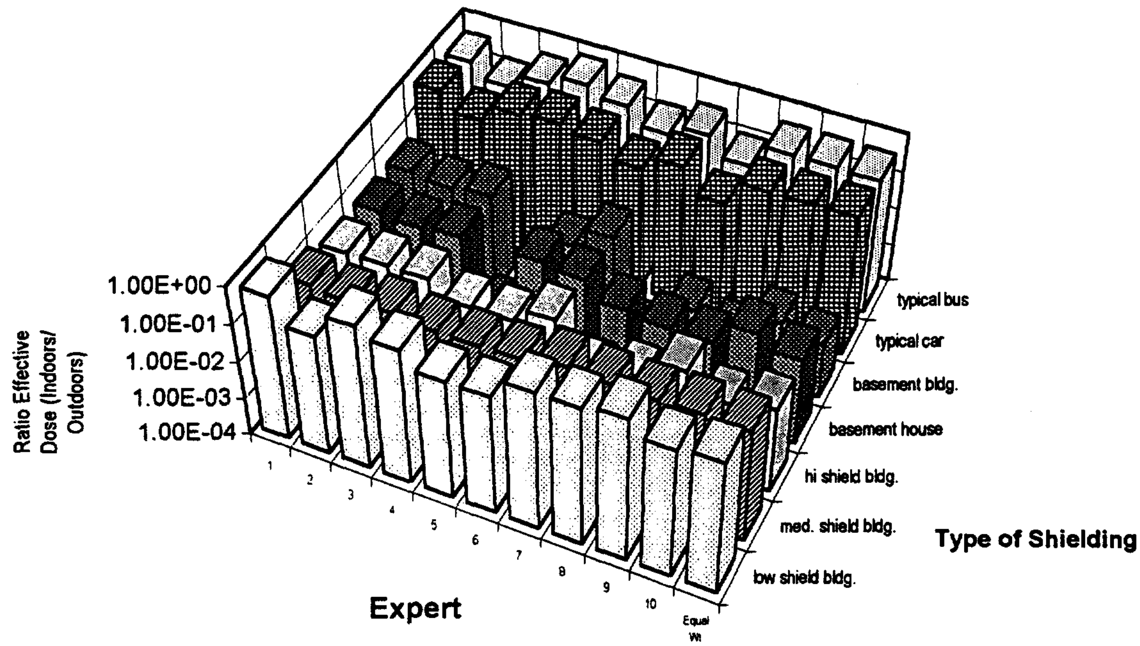

Figure E.35 Median results for the ratio of the effective dose received by an adult at several indoor locations to the effective dose received by an adult outdoors in an open lawned area shortly after an initial uniform dry deposit of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

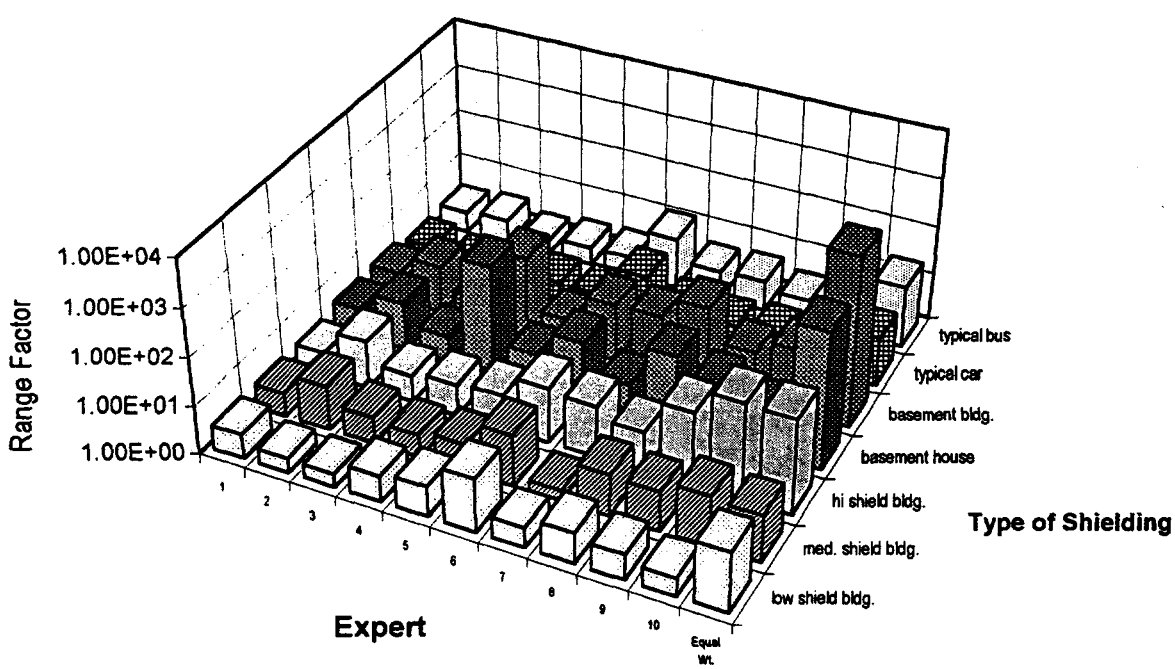

Figure E.36 Range factors (ratio of 95th/5th percentile) for the ratio of the effective dose received by an adult at several indoor locations to the effective dose received by an adult outdoors in an open lawned area shortly after an initial uniform dry deposit of 1 Bq/m^2 of ^{137}Cs to the lawned areas of the ground.

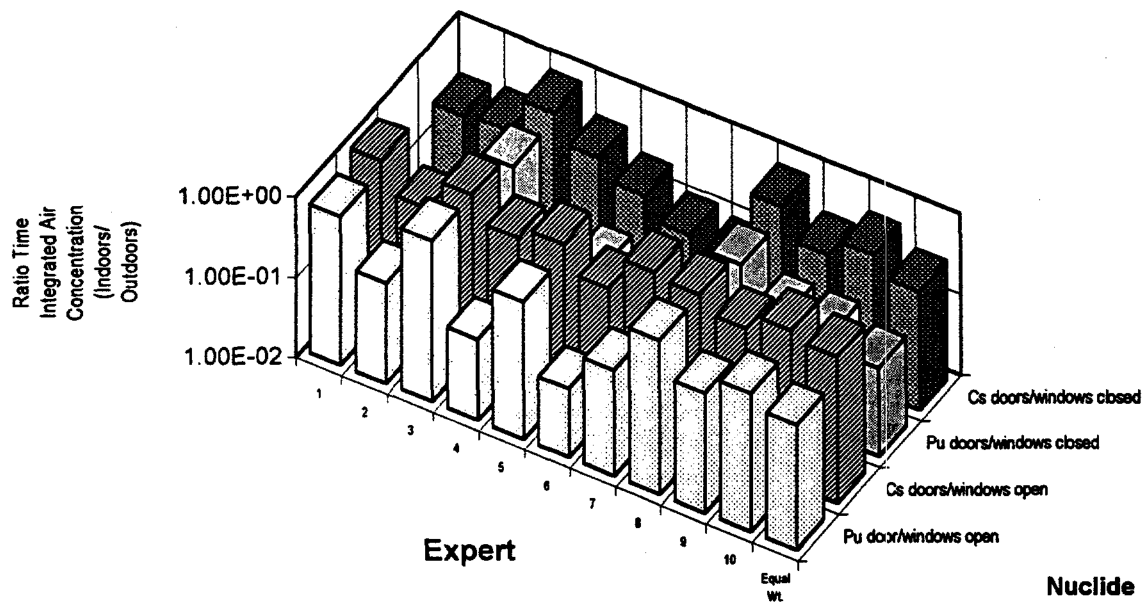

Figure E.37 Median results for the ratio of the time integrated air concentration (TIAC) indoors to that outdoors given an initial concentration of (1 Bq s)/m^3 for four different nuclides with the doors normally open.

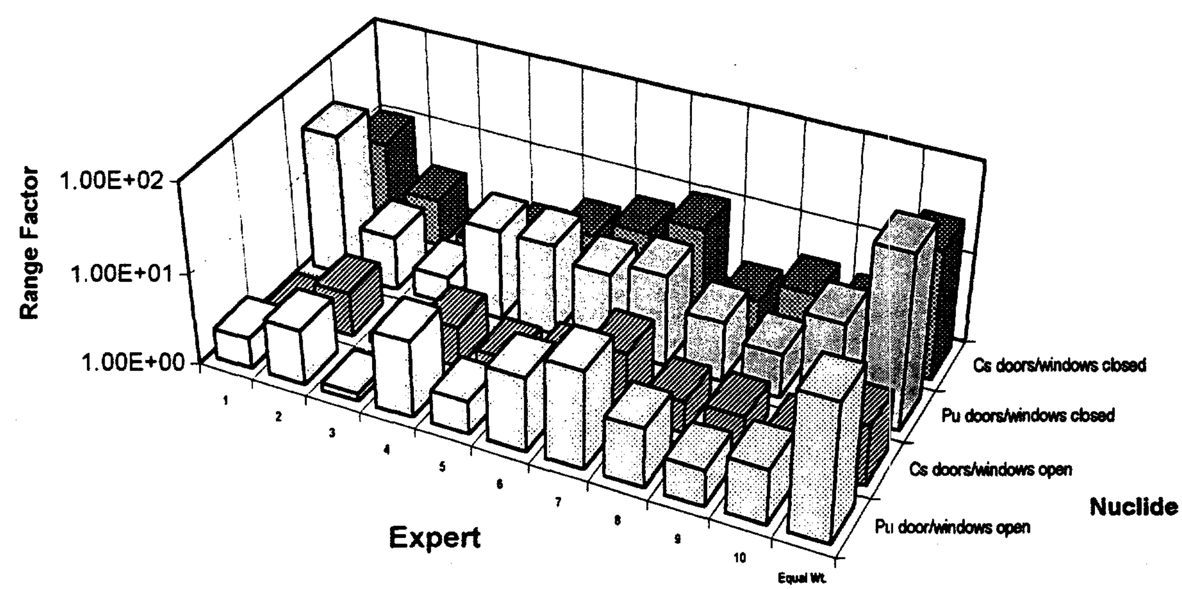

Figure E.38 Range factors (ratio of 95th/5th percentile) for the ratio of the time integrated air concentration (TIAC) indoors to that outdoors given an initial concentration of (1 Bq s)/m^3 for four different nuclides with the doors normally open.

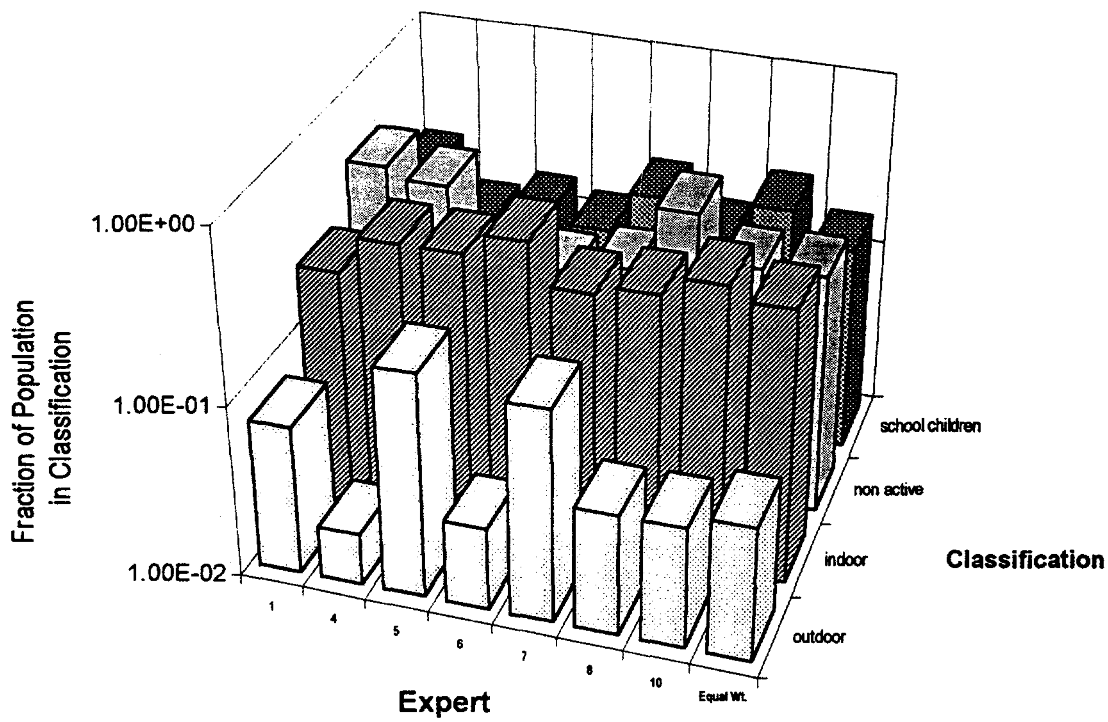

Figure E.39 Median results for the average population classed outdoor workers, indoor workers, nonactive adult population, or school children.

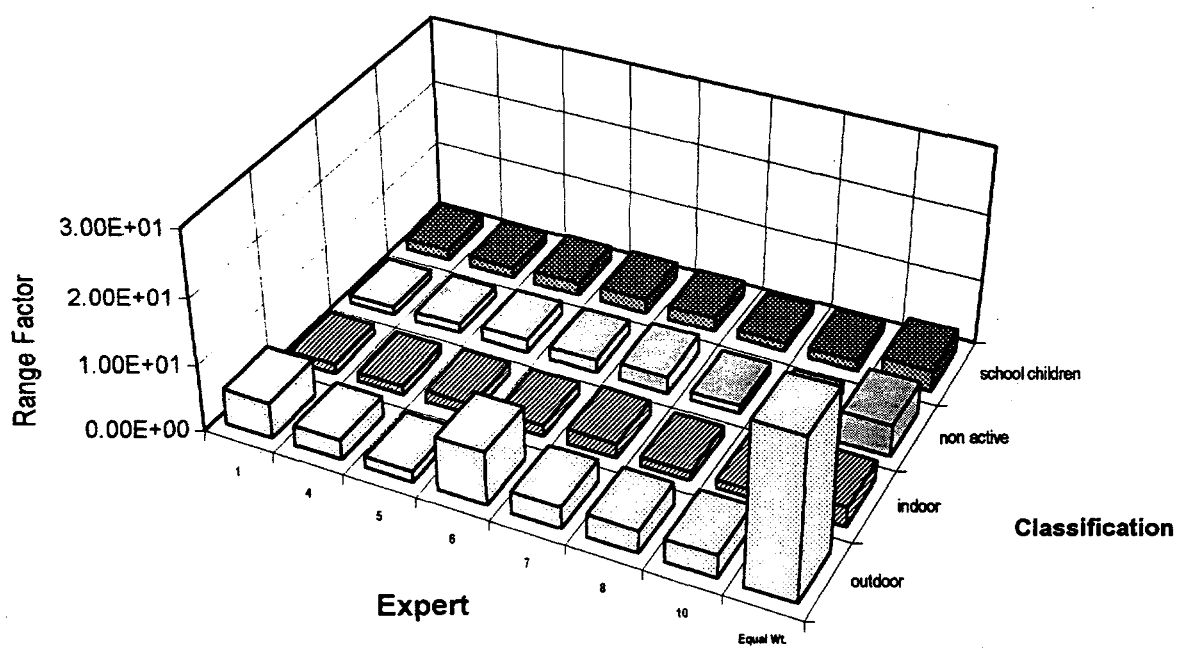

Figure E.40 Range factors (ratio of 95th/5th percentile) for the average population classed outdoor workers, indoor workers, nonactive adult population, or school children.

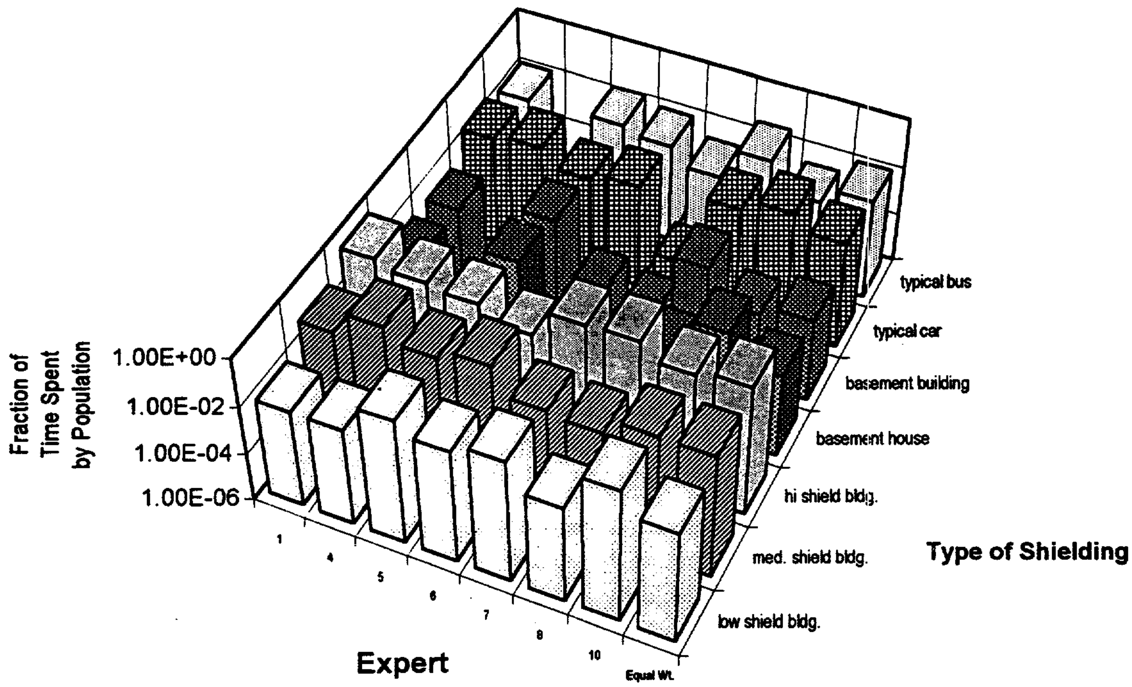

Figure E.41 Median annual average fraction of time that people working outdoors spend indoors in various types of housing or vehicles.

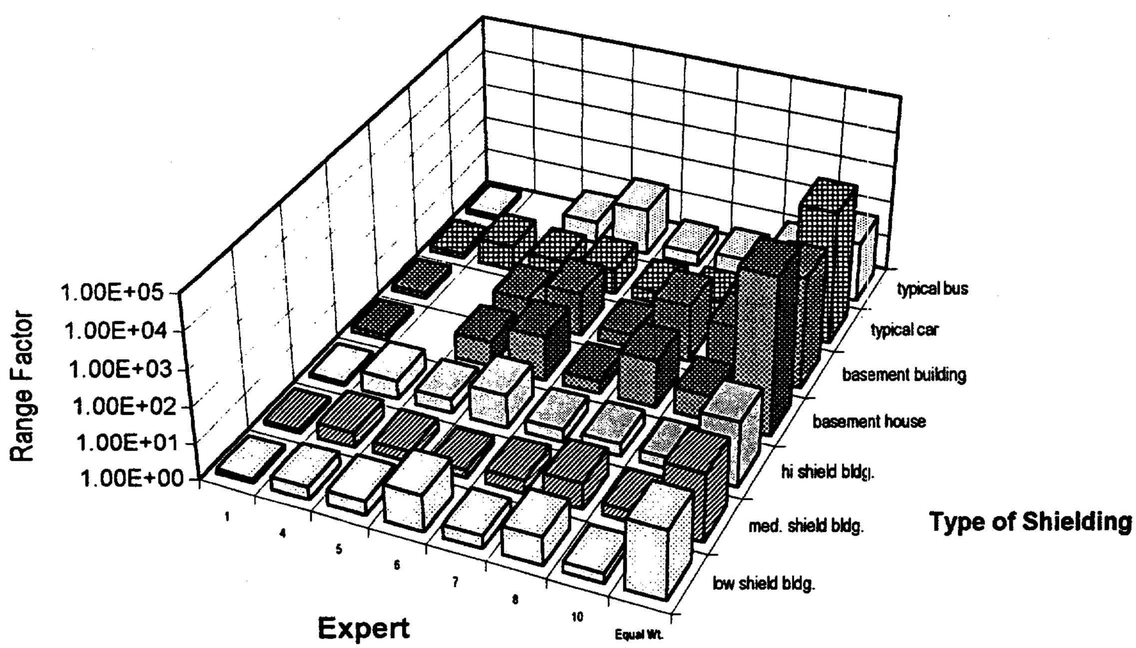

Figure E.42 Range factors (ratio of 95th/5th percentile) for annual average fraction of time that people working outdoors spend indoors in various types of housing or vehicles.

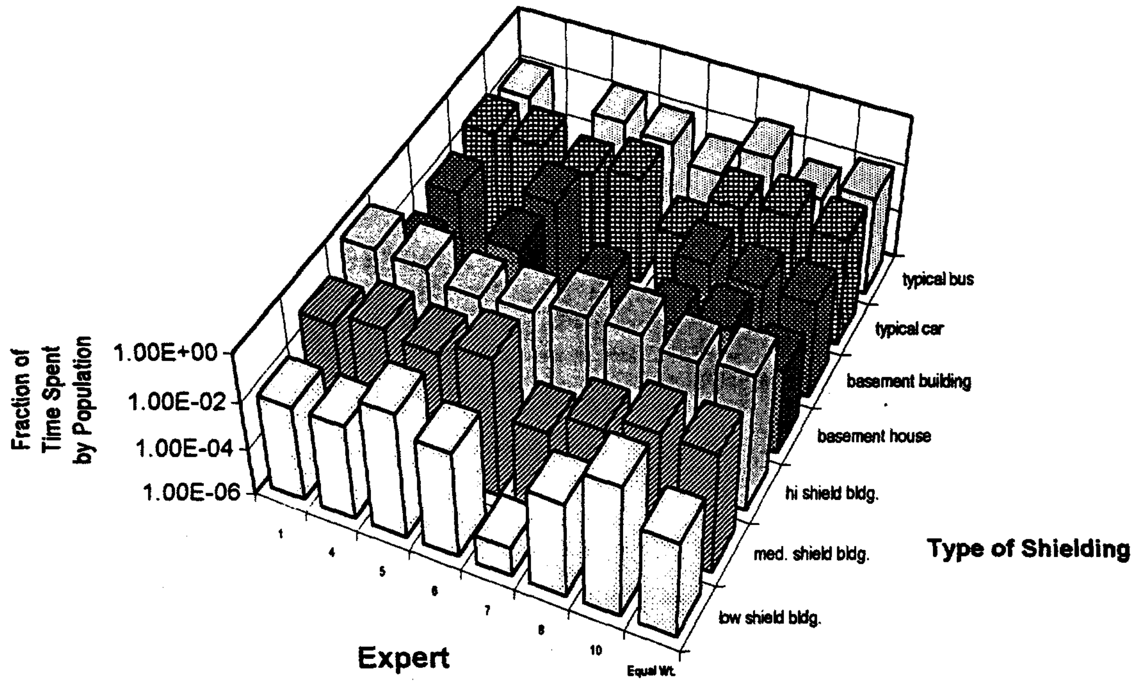

Figure E.43 Median annual average fraction of time that people working indoors spend indoors in various types of housing or vehicles.

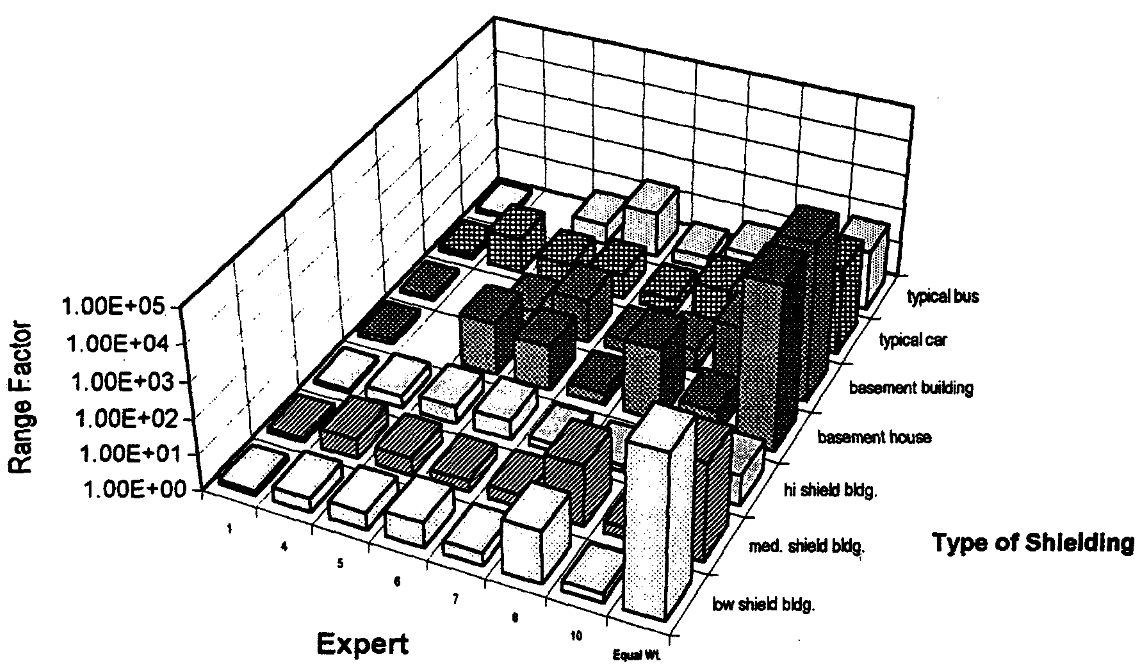

Figure E.44 Range factors (ratio of 95th/5th percentile) for annual average fraction of time that people working indoors spend indoors in various types of housing or vehicles.

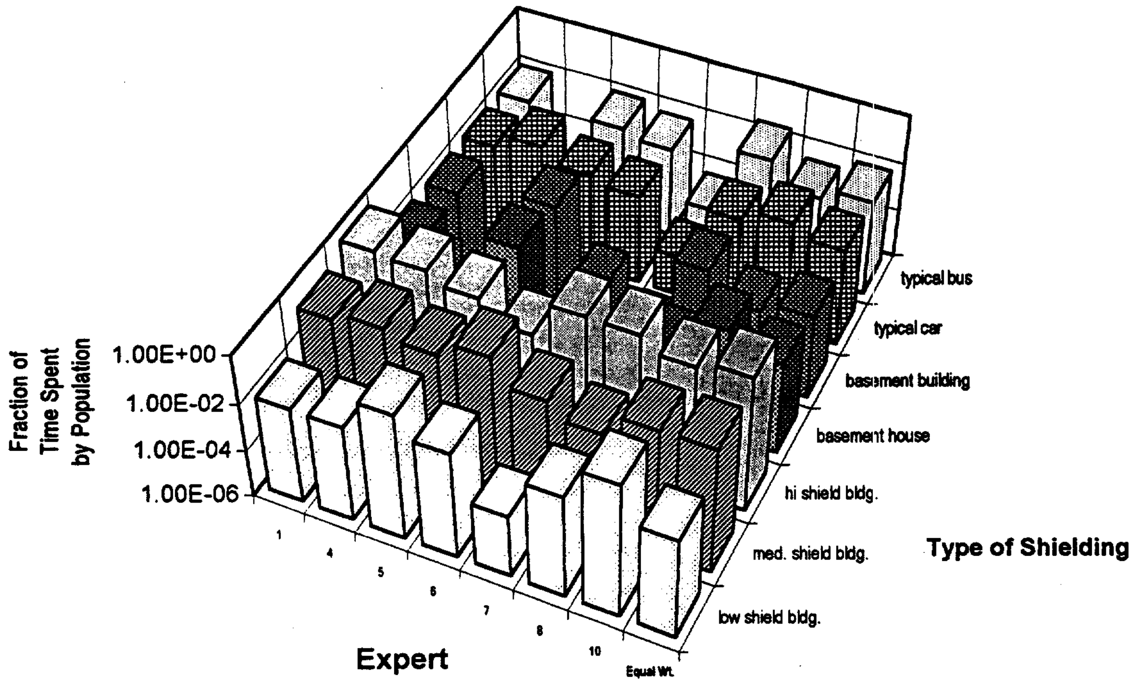

Figure E.45 Median annual average fraction of time that nonactive adult population spend indoors in various types of housing or vehicles.

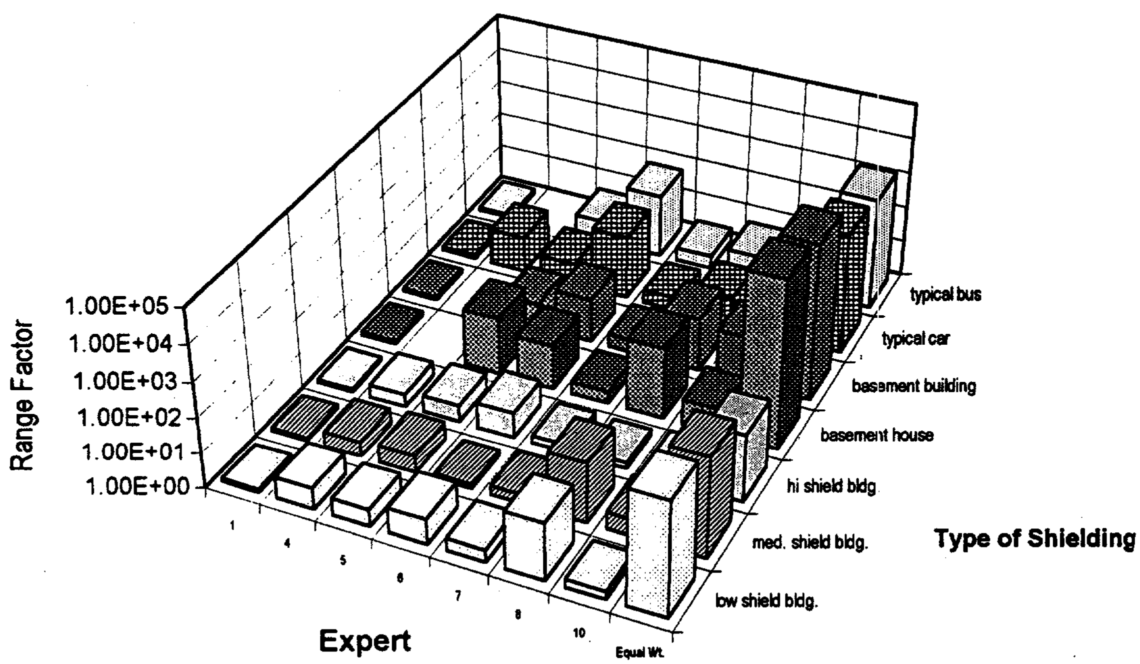

Figure E.46 Range factors (ratio of 95th/5th percentile) for annual average fraction of time that nonactive adult population spend indoors in various types of housing or vehicles.

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J. Randall, NRC Project Manager

11. ABSTRACT *(200 words or less)*

The development of two new probabilistic accident consequence codes, MACCS and COSYMA, was developed in 1990. These codes estimate the consequence from the accidental releases of radiological material from hypothesized accidents at nuclear installations. In 1991, the U.S. Nuclear Regulatory Commission and the Commission of the European Communities began cosponsoring a joint uncertainty analysis of the two codes. The ultimate objective of this joint effort was to systematically develop credible and traceable uncertainty distributions for the respective code input variables. A formal expert judgment elicitation and evaluation process was identified as the best technology available for developing a library of uncertainty distributions for these consequence parameters. This report focuses on the results of the study to develop distribution for variables related to the MACCS and COSYMA deposited material and external dose models.

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