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Case Study on Assessment of Radiological Environmental Impact from Normal Operation

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CASE STUDY ON ASSESSMENT OF RADIOLOGICAL ENVIRONMENTAL IMPACT FROM NORMAL OPERATION

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FOREWORD

The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) was launched on the basis of a resolution of the IAEA General Conference in 2000 (GC(44)/RES/21). INPRO's activities have since been continuously endorsed by resolutions of IAEA General Conferences.

INPRO intends to help ensure that nuclear energy is available in the twenty-first century in a sustainable manner. It seeks to bring together all interested Member States — both technology holders and technology users — to jointly consider actions to achieve desired nuclear energy innovations. INPRO supports developing countries with their specific nuclear energy needs.

To fulfil its objectives, INPRO has developed a set of basic principles, user requirements and criteria, and an assessment method which together comprise the INPRO methodology for the evaluation of the long term sustainability of nuclear energy systems. The INPRO methodology area of the environmental impact of stressors provides guidance for the sustainability assessment of criteria related to the environmental impact of radiological stressors from a nuclear energy system in normal operation and during anticipated operational occurrences.

INPRO aims to develop options for enhanced sustainability through the promotion of technical and institutional innovations in nuclear energy technology; through information exchange; and by bridging technology gaps through collaborative projects among the IAEA Member States. INPRO collaborative projects have been selected so that they complement other national and international research and development activities.

This publication documents the results of the INPRO collaborative project on Environmental Impact Benchmarking Applicable for a Nuclear Energy System under Normal Operation (ENV). The project was initiated in 2009 and included participants from Belarus, Brazil, France, India, Indonesia, the Republic of Korea, the Russian Federation and Ukraine.

The project was concluded in 2013 and an advanced draft of the publication was made ready. However, as a number of key IAEA publications on radiological environmental impact assessment were under development at that time, it was decided to revise the advanced draft to take into account these new publications, namely IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards; IAEA Safety Standards Series No. GSG-10, Prospective Radiological Environmental Impact Assessment for Facilities and Activities; and IAEA-TECDOC-1914, Case Study on Assessment of Radiological Environmental Impact from Potential Exposure.

The IAEA officers responsible for this publication were L. Meyer, J. Phillips and A. Korinny of the Division of Nuclear Power, D. Telleria of the Division of Radiation, Transport and Waste Safety, and M. Phaneuf of the Division of Physical and Chemical Sciences.

CONTENTS

1 INTRODUCTION

1.1 BACKGROUND

The concept of sustainable development was introduced in 1980s as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It is directly related to all environmentally sensitive areas of human activities including different types of energy production. Since then, the public awareness of environmental protection continues to increase, influencing politicians and decision makers. Protection of the environment is an important consideration in the governance processes for approving industrial activities in many countries and is a central theme within the concept of sustainable development.

The INPRO methodology is a tool for assessing the sustainability and sustainable development of a nuclear energy system, that was originally created in 2003 under the aegis of the IAEA using broad philosophical outlines of the concept of sustainable development. INPRO methodology comprises several sustainability related areas of the nuclear energy system development including economics, reactor safety, safety of nuclear fuel cycle facilities, waste management, infrastructure, proliferation resistance, resources and environmental stressors. The INPRO manual considering environmental stressors was revised and published in 2016 [1].

INPRO basic principle in the area of environmental impact of stressors aims at acceptability of expected adverse environmental effects and states that "the expected adverse environmental effects of a nuclear energy system should be well within the performance envelope of current nuclear energy systems delivering similar energy products" [1].

A nuclear energy system in INPRO may include the complete spectrum of the nuclear fuel cycle, i.e. mining, milling, conversion, enrichment of uranium and/or thorium, fuel fabrication, electricity generation or other energy products, reprocessing, storage of reprocessed fissile material, recycling of fissile materials, waste treatment and stabilization, waste repository and final end states for all wastes, and associated institutional arrangements.

The INPRO sustainability assessment in the area of environmental stressors described in Ref. [1] deals with normal operation, including infrequent events that are anticipated to occur during the life of the nuclear energy system components. Low frequency events (accidents) are dealt with by the INPRO sustainability assessment in the areas of reactor safety and safety of nuclear fuel cycle facilities[1]. INPRO assessment in the area of environmental stressors is limited to evaluate effects on members of the public and the environment. Assessment of impacts on workers is the subject of the INPRO manuals on sustainability assessment in the areas of safety.

The INPRO assessment utilizes the results obtained from an environmental analysis which should account for all relevant factors (sources, stressors, pathways, receptors and endpoints) for the proposed energy system. The INPRO assessment itself considers the stressors identified in that analysis. The performance of a proposed technology needs to be evaluated as an integrated whole by considering the likely environmental effects of the entire collection of processes, activities and facilities in the energy system at all stages of its life cycle.

[1] In 2012 the IAEA conceived the project on Environmental Impact of Potential Accidental Releases from Nuclear Energy Systems (ENV-PE) to study different approaches used in the Member States for evaluation of potential accidental releases from nuclear reactors. The final report of the ENV-PE was published as the IAEA-TECDOC-1914, Case Study on Assessment of Radiological Environmental Impact from Potential Exposures, (Vienna, 2020).

The IAEA/INPRO Collaborative Project on Environmental Impact Benchmarking Applicable for Nuclear Energy Systems under Normal Operation (ENV) was only focused on novel nuclear power plants (NPPs) as the nuclear energy system under consideration. This project aimed on studying different approaches used in the Member States for evaluation of environmental impact from a NPP under normal operation conditions. Eight institutions from the IAEA Member States took part in the project: Republican Scientific-Practical Centre of Hygiene (Belarus), the Nuclear and Engineering Institute, IPEN/CNEN (Brazil), the French Alternative Energies and Atomic Energy Commission, CEA (France), the Indira Gandhi Centre for Atomic Research, IGCAR (India), the National Nuclear Energy Agency, BATAN (Indonesia), the Korea Institute of Nuclear Safety, KINS (the Republic of Korea), the Russian Institute of Agricultural Radiology and AgroEcology, RIARAE (the Russian Federation), the Radiation Protection Institute (Ukraine)

This publication is the final report of the ENV summarising results developed under this project by the groups of national experts.

1.2 OBJECTIVE

This publication presents a set of examples of different approaches for estimating environmental impact from the NPPs under normal operation conditions in different countries based on participants' experience and considering the IAEA Safety Standard [2] on a generic framework for consideration of radiological environmental impact. It is further intended to provide necessary input for the development of common understanding in assessing releases from new NPPs and associated activities in terms of their radiation dose to members of the public.

This publication will contribute to further improvement and update of the INPRO methodology for sustainability assessment of nuclear energy systems and can help Member States applying the INPRO methodology to perform a nuclear energy system assessment in the area of environmental impact of stressors.

This publication is intended for use by organizations involved in development and deployment of nuclear energy systems including planning, design, modification, technical support and operation for nuclear power plants.

1.3 SCOPE

This publication is focused on the estimation of off-site consequences of the routine normal operation releases of radioactivity from an NPP to the environment. The hypothetical source terms used for the assessment were based on normal operation releases from actual nuclear power plants.

According to definitions in [3], protection of the environment includes the protection of living organisms other than humans and also the protection of natural resources, including land, forests, water and raw materials, together with a consideration of non-radiological environmental impacts from the NPP. However, this study is concerned only with the radiological impact on humans as the target group. Nonetheless, the same basic methodology may be applied to estimate radiation doses to other environmental components, such as flora and fauna, if required by applicable national or international regulations [2].

Assuming the nuclear energy system is an NPP, three release scenarios were evaluated by the participants:

- Gaseous and airborne releases into the atmosphere;
- Liquid releases into the sea;
- Liquid releases into a river.

Within each release scenario, every participant performed two or three case studies using the following options:

- All input parameters were pre-defined and fixed (e.g. meteorological data, transfer coefficients, exposure pathways, consumption rates);
- Atmospheric releases were studied using the same fixed parameters but varying only the meteorological data to see how local data would affect the ranking of radionuclides;
- All releases were studied considering diverse natural and cultural living conditions, varying transfer coefficients, country specific food chains, and breathing rates.

Assessments of radiological environmental impact were performed by the participants based on their own experience and considering the general framework for radiological environmental impact assessment established in the IAEA Safety Standards [2]. For the purpose of the studies, national experts could have used commercially available assessment tools, tools and methodologies developed in their countries, or published generic methods. All the approaches were applied to rank the radiological impact of different radionuclides in the given scenarios and to provide a radiological environmental assessment at a generic level. The comparison of the results of the different approaches may help to identify consistent environmental assessment methodologies which include the ranking of the radionuclides in terms of their potential human health related impact.

The methods and criteria presented in this report do not necessary represent the practices required in the national regulations of the participants and should be considered as a proposal of good practice by international experts for possible approaches to estimate prospectively off-site consequences of normal operation radioactive releases.

1.4 STRUCTURE

Following this introduction, Section 2 describes general considerations for assessing radiological impact on the public from normal operations of nuclear facilities and also gives an overview of the various models applied by the participants to make the radiological assessments. Information on the input data used, including description of the exposure scenarios evaluated in this exercise together with the influencing parameters and how they were applied is given in Section 3. Section 3 tabulates the source term data used to provide pre-defined fixed input for the three discharge scenarios, gives the meteorological data together with the Pasquill stability categories used to estimate the atmospheric dispersion and dilution of radionuclides downwind the release and provides the parameters that were fixed for all participants under Case A for each of the scenarios.

Section 4 presents a summary of the results obtained by the participants and recommendations for a generic ranked approach.

Annexes I to VII comprise national studies applying radiation dose assessment models to the different exposure scenarios covering atmospheric and aquatic releases. The exercises included common input data (to assess differences between models) as well as default parameterization. However, some site-specific input data and parameters were also used to allow their effect on the results to be assessed. The models and approaches used, the inputs provided, and the results derived by the participants as part of the exercise are presented in Annexes I to VII.

2 GENERAL CONSIDERATIONS FOR ASSESSING RADIOLOGICAL IMPACT TO THE PUBLIC FROM NORMAL OPERATIONS OF NUCLEAR FACILITIES

2.1 BASIS FOR CONSIDERATION OF RADIATION EXPOSURE TO PUBLIC

The use of radiation sources, including the operation of an NPP, may create two types of radiation exposure to the public which have to be considered prospectively at the time of design, site evaluation and authorization.

One type – potential exposure – is not expected to occur with certainty, but could result with a certain probability, e.g. from an accident or anticipated operational occurrences (AOOs) [3]. Potential exposures were studied in Ref. [4] and they are out of the scope of this publication.

Another type of public exposure at some limited level is expected to occur in normal operation conditions, for example the exposures resulting from the planned authorized discharges. This other type of exposures is considered further in this report.

Fundamental safety principle 6 of IAEA's Fundamental Safety Principles [5] requires that both the doses and the radiation risks be controlled within specified limits for ensuring the protection of the public and the environment from harmful effects of ionizing radiation.

Licensing of a facility or an activity, including licensing of an NPP, normally involves an appropriate prospective assessment made for radiological environmental impacts, commensurate with the radiation risks [2, 3]. Ref. [3] states:

> "3.122. Before authorization of a new or modified practice, the regulatory body shall require the submission of, and shall review, the safety assessments (…) and other design related documents from the responsible parties that address the optimization of protection and safety, the design criteria and the design features relating to the assessment of exposure and potential exposure of members of the public.
>
> 3.123. The regulatory body shall establish or approve operational limits and conditions relating to public exposure, including authorized limits for discharges. … "

The limited and controlled release of radionuclides to the atmospheric and aquatic environments is a practice which can be permitted under certain conditions [3, 5]. Ref. [6] provide guidance and recommendations for the process of evaluation and authorization of radioactive discharges from nuclear installations. Typically, controlled discharges of gaseous and airborne particulate material containing radionuclides are made through stacks, although for small facilities they may be made through discharge vents or working hoods, for example. Controlled liquid discharges are typically made via pipelines into rivers, lakes or the sea. An important and essential element in the control of the discharges is regular monitoring – both at the source of the discharge and in the receiving environment – to verify compliance with discharge limits and corroborate retrospectively the degree of protection of the public and the environment.

Currently the main contribution to radiological effects on human health from radionuclides discharged from the entire nuclear system is typically provided by the releases from uranium milling and spent fuel reprocessing facilities as well as from power plants. Although by any objective estimation the power plant operation is a relative minor contributor to adverse health outcomes, its consideration is prioritized by subjective elements, such as acceptance and risk perception by the public, which are very important elements for the social aspects of sustainability of nuclear power.

Rigorous regulatory mechanisms are already in place to restrict the release of radionuclides and, hence, their accumulation in the environment. Under the current system, environmental radiation protection is achieved through the restriction of discharges of radioactive substances into the environment, ensuring that members of the public receive radiation doses considerably below internationally established individual dose limits for humans. In doing so, it was previously assumed that, if human beings were adequately protected as the most vulnerable, other species were protected as well. However, more recently an increasing awareness of the vulnerability of the environment stipulated the need to be able to demonstrate explicitly (rather than assume) that it is protected against the effects of any industrial pollutants (including radioactive). This has been reflected in new and developing international policies, legal instruments and agreements. The strengthened needs for environmental protection have led to a review, including by the IAEA, of the ethical standpoint [7], the definitions of radiological protection of the environment [3], and the approaches for assessing and controlling the impact to flora and fauna of radionuclides in the environment, subject to national or international requirements [2].

On the more practical side, the IAEA has a long history of activities in the areas associated with the assessment of radiological impact to the environment. The IAEA promotes environmental / food-chain model validations and inter-comparisons by a series of projects including the Validation of Environmental Model Predictions (VAMP) in 1988-2000 [8-13], Biosphere Modelling and Assessment Methods (BIOMASS) in 1998-2001, Environmental Modelling for Radiation Safety (EMRAS) in 2003-2007 [14] and EMRAS II in 2009-2012 [15-19]. As a follow-up to EMRAS II, the Modelling and Data for Radiological Impact Assessments (MODARIA) project was run in 2012-2015 providing a mechanism through which IAEA Member States could develop and maintain knowledge and competence in the areas of radioecology and environmental assessment. MODARIA was followed by MODARIA-II from 2016.

The IAEA published safety guides [2, 6, 20] a safety report [21] and technical reports [22, 23] for the assessment and control of the protection of the public and the environment against the effects of operational routine radioactive discharges. Moreover, releases to the environment are considered in other IAEA safety standards, e.g. in Ref. [24] in relation to the predisposal waste management considerations.

Policies, methods and approaches that specifically address impacts on environment as a part of multidisciplinary ‘holistic’ approach, including also economic, social and psychological factors, are now being developed by different international, national and regional organizations. The IAEA has developed the INPRO methodology for sustainability assessment of nuclear energy systems which covers several areas from economics to safety including the area of environmental stressors. Such a holistic approach is also important when discussing innovative nuclear systems.

2.2 BASIC STRUCTURE OF RADIOLOGICAL IMPACT ASSESSMENT

The general approach for radiation dose assessment to the public comprises a number of stages. The first stage is to characterize the source of radiation related to the exposures (i.e. the source term); in the second stage, dispersion of radionuclides in the environment and transfer within and between the environmental compartments, including the selected dietary items, are considered. Activity concentrations in a number of environmental media are then combined with relevant habit data to calculate intakes of radioactivity (internal exposure) or external radiation (external exposure) to a reference person. The representative person[2], that is the person representing those most likely to be more highly exposed, should be identified. Finally, intakes and external radiation are combined with dosimetry data[3] to calculate doses to the representative person for comparison with dose constraints or limits or other relevant criteria. Figure 1 (adapted from [2]) gives the components of an assessment of the radiological impact of a nuclear facility under normal operations for members of the public. The concept of representative person, and details of the identified components within the dose assessment model are further discussed in the following sections of this report.

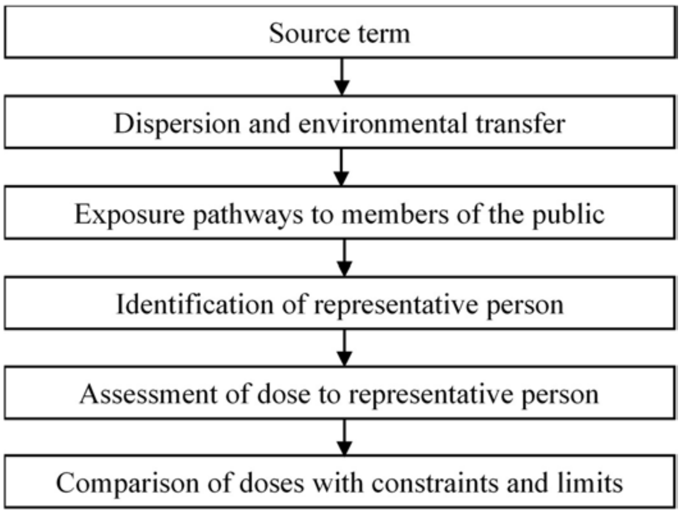

FIG. 1. Basic stages of assessment of radiological impact from a nuclear energy system (adapted from [2]).

To rank radionuclides on their relative relevance to contribution to the radiation dose to humans as a consequence of routine discharges during normal operation of a nuclear facility, one needs to assess which radionuclides may be emitted (i.e. the source term inventory), their activity concentrations or loads in the environmental compartments (estimated with dispersion and transfer models), and their means of exposure to the members of the public (i.e. the habit data and the dosimetry factors).

2.2.1 Source term

All relevant radionuclides which are expected to be released to the environment need to be identified and accompanied with details of processes leading to the release of these radionuclides which can be relevant for their characterization. Releases to the atmosphere, to the aquatic environment (marine, freshwater or sewage) and, if relevant, direct irradiation need to be considered. For prospective assessments, source terms can be estimated based on information from similar facilities already in operation or the inventory of the facility and the knowledge of the operational and technical characteristics.

Other information that may need to be considered, particularly for installations requiring complex assessments such as NPPs, includes the physical and chemical attributes of the

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[2] ICRP Publication 101 indicates that the dose to the representative person "is the equivalent of, and replaces, the mean dose in the 'critical group', and provides guidance on assessing doses to the representative person. The concept of critical group remains valid.

[3] Normally done with use of dose per unit intake.

radionuclides released and of the environmental transport media (such as chemical composition, size of the airborne particles and temperature of the effluents).

The total radioactive releases are expected to be available over the period required by the regulatory body – this is generally a year of operation – and need to give an indication of peak discharges over shorter periods, as necessary. However, an assessment of the radiological impact to the public will typically assume that the discharges are continuous and constant over a year. Where this is not the case and there is a significant variation in the discharges over a short time period (e.g. during special maintenance or refueling of a nuclear reactor) or if the site is affected by strong natural climatic impact (e.g. a long rainy season and a long dry season), then shorter term releases will need to be considered in the assessment.

The source term selected for an assessment of radiological impact has to be appropriate for the type of facility or activity being considered. Either conservative or more realistic options can be considered depending upon the rationale underpinning the need for the assessment. For example:

- Conservative source terms which predict maximal concentration of radionuclides in environment due to the nuclear energy system discharges can be used to establish the design basis of plant processing systems for the purpose of defining maximal system capacity and shielding requirements;
- Realistic source terms for the purpose of evaluating the reasonably expected inventories and releases of radionuclides driven the annual radiological impact to the public under normal operating condition, including anticipated operational activities which might occasionally increase releases.

For an initial assessment of the impact of releases during normal operations, generic source terms for the proposed facility could be used, based on published data or on the experience from similar installations. Later, for instance in the authorization process, when the type of facility has been selected (e.g. the design and detailed characteristics of the nuclear power plant) and the possible sites have been identified or decided upon, the source term can be characterized more accurately [2].

2.2.2 Dispersion and transfer in the environment

Nuclear installations during normal operation conditions may release small amounts of radioactivity to the environment in the gaseous (including aerosols and other airborne particles) or liquid effluents form. Gaseous and airborne radionuclides are transported and dispersed by wind and other atmospheric processes, and affected by radioactive decay, chemical reactions, absorption and deposition. The transport and dilution of radioactive materials released to the atmosphere in the form of aerosols, vapors, or gases are the function of atmospheric conditions along the plume path, the terrain topography, and the characteristics of the effluents themselves.

Radionuclides may be discharged together with the liquid effluents to a freshwater, estuarine or marine environment. Discharge of radionuclides to the sewerage system from some small facilities is another possibility. Radionuclides discharged to water bodies are transported and dispersed by water movements (currents and turbulence), and affected by chemical reactions, particle adsorption and sedimentation processes.

When radionuclides are continuously discharged, they accumulate in the environment up to the point where close to equilibrium conditions are reached. For long-lived radionuclides this accumulation may need to be considered in the assessments for the entire lifetime of the facility[4].

A radionuclide may decay into a progeny that is also radioactive and this may need to be taken into account for dose assessment purposes, bearing in mind that the progeny are likely to behave differently from their parent in the environment. In some cases, the decay products may be more radiologically significant than the parent radionuclide and so it is important to consider their ingrowth. Examples of this are the uranium decay series and plutonium-241 which decays into americium-241.

Several different models and a considerable array of input data are normally required to estimate the dispersion and transfer of radionuclides through the environmental media and their disposition into various environmental compartments. The evaluations are necessary to allow for assessment of internal and external doses to the selected endpoints (i.e. the representative person). Activity concentrations in environmental media such as air, sediments, soil, water, animals and plants in the food chain will need to be estimated. Environmental models to assess dispersion and transfers of varying levels of complexity have been developed in several countries. The IAEA published generic methods for environmental dispersion modelling and environmental transfer values to be used for dose assessment. [21–23]

Factors that are important for determining the complexity of the radiological environmental impact assessment include the following: the expected source term, the expected doses, the characteristics of the activity or facility, the characteristics of the location, the national licensing regulations for the particular facility or activity, and the stage in the authorization process [2].

For facilities needing a simple assessment, a generic environmental screening methodology that takes account of basic dilution and dispersion of discharges into the environment could be applied. If warranted, assessments using models that take account of some site-specific data rather than generic assumptions could be necessary. An alternative is to use pre-calculated factors (generic or site-specific) which provide activity concentrations in environmental media for unit discharges.

For complex assessments (e.g. for NPPs) it is generally expected that detailed environmental dispersion and transfer models with site-specific data could be used to estimate activity concentrations in different environmental media, particularly at the later stages in the process of licensing. The complexity of the assessment to be used (including the level of details and realism of the models) needs to be commensurate with the complexity of the assessment required.

In general, the models need to be able to predict both spatial distribution and temporal variation of activity concentrations.

For the assessment of public exposure due to normal operation of a facility, the models should be able to simulate at least the following processes:

- Atmospheric dispersion;
- Deposition of radioactivity to the ground;
- Dispersion of radionuclides in surface water and ground water;
- Transfer of radioactivity to plants and animals in the food chain.

For installations requiring complex assessments (such as NPPs), the model used to predict activity concentrations in the air and on the ground following atmospheric dispersion should

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[4] For some radionuclides such as plutonium-239, which have long half-lives and are not chemically mobile it can take many decades before equilibrium is reached.

take account of, e.g. the physical-chemical properties of the radionuclides being released (such as chemical form, particle size, vertical velocity, temperature to assess the effective release height), the range of meteorological conditions that occur in the course of a year, effects of nearby natural and anthropogenic landscape features, wet and dry deposition as well as radioactive decay.

Meteorological data have a significant impact on uncertainties of dose assessment. Input data for atmospheric diffusion models include wind speed and direction, atmospheric stability, and airflow patterns in the region of interest. For simple assessments, the meteorological conditions could be of a generic character based on bibliography or national records. The meteorological conditions used for the complex assessments should be appropriate for the site in question and should preferably be averaged from several years of data. Such data may be available for the site itself or from nearby meteorological stations [2]. Several basic mathematical models have been developed for atmospheric dispersion. These models vary according to their consideration of the spatial and temporal changes of input data taking into account a variable trajectory or a constant mean wind direction. A commonly used model (particularly in the case of relative flat terrain) is the Gaussian plume model [21]. In this model, the wind speed and atmospheric stability at the release point are assumed to determine the atmospheric dispersion characteristics in the direction of the mean wind at all distances. The diffusion parameters used in the model incorporate the basic assumption that a plume spreads both laterally and vertically with a Gaussian distribution [21]. Gaussian dispersion of pollutants can be described as:

$$\chi(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u} \cdot exp\left(-\frac{y^2}{2\sigma_y^2}\right) \cdot \left(exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right)$$

Where χ *(x, y, z)* – time integrated concentration of a radionuclide at a point *x, y, z* downstream from the source at time *t* after the release; Q – quantity of material released (Bq); u – mean wind speed (m/s); H – height of the plume centerline, $\sigma_y\sigma_z$ – diffusion parameters (Gaussian distribution standard deviation on horizontal and vertical crosswind directions *y* and *z*) which are the functions of atmospheric stability characteristics and travel time (i.e. depend on *x*).

Traditionally the atmospheric stability characteristics are parametrized and considered in terms of discrete stability categories or classes. Several different parametrization schemes are broadly used. In Ref. [25] a scheme with two classes of atmospheric stability (Doury model) was defined comprising a normal diffusion class for convective (unstable and neutral) conditions, and low diffusion class for stable conditions [26]. In the Doury model, the diffusion parameters depend on transportation time. The rise of the plume due to convective buoyancy conditions is related to the temperature of the gaseous effluents and the atmospheric vertical temperature gradient, i.e $\gamma \leq -0.5$°C/100m for unstable conditions, and $\gamma > -0.5$°C/100m for stable conditions.. Rain wash-out of the radioactive plume and the subsequent deposition of radionuclides on ground can also be accounted. Pasquill-Gifford-Turner stability classification scheme [27] introduces several[5] dispersion stability classes ranging from A, very unstable, to F (or G), very stable. These categories are linked to the wind speed in combination with the solar insolation at daytime and the fraction of sky covered by clouds at nighttime.

Basic Gaussian models can be modified to account for various modes of effluent release and for effluent removal mechanisms. Other modifications and more complex dispersion models are also available [28, 29].

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[5] Six or seven classes can be used in different variations of this classification scheme.

Transport of the radionuclides discharged to water bodies depends strongly on the local characteristics of the receiving aquatic environment and it is not possible to have a totally generic model for these releases. For example, information is required, at least, on the size of a river and its flow rate.

In the aquatic release scenario, the activity concentrations in downstream water and in sediment are expected to be evaluated. Generic values for sediment-water partitioning of radionuclides are provided in Ref. [30] and water-biota transfer factors in Ref. [22]. Using this data, the activity concentrations in aquatic foods, such as fish, mollusks and crustaceans, can be estimated by applying generic or site-specific transfer factors and case specific assumptions[6].

For installations requiring complex assessment, an initial estimation of the dispersion and transfer to the environment can be done using simple cautious models and meteorological/hydrological data generic to the region (from published data or using records from the closest meteorological/hydrological stations, which may sometimes be located at tens to hundreds of kilometers from the sites) [2]. Later, data from measurements conducted on-site or very close to the plant location would be normally be available, as this is the regular practice during site survey and construction stages [2]. Information on the type and detail of data which should be available at the later stages of licensing process can be found in references [23, 31].

Transfer of radionuclides in the human food chain is normally evaluated with compartmental models where different steps of the transfer are represented as boxes connected via transfer functions.

Transfer (bioaccumulation) factors are used to assess activity concentrations in plants and animals in relation to environmental media concentrations. Transfer factors are not specific for an isotope but are characteristic for chemical elements. Transfer factor values for elements by plant groups or plant compartments are given in Ref. [22]. The range of values for an element (cesium for example) and a plant group (leafy vegetables for example) can be very important as they can vary over orders of magnitude (Table 17 of Ref. [22]). In the light of variability of these values, it is evident that differences in applied transfer factors have an effect on dose assessment and, as a result, on radionuclide ranking.

The different pathways for human impact studies typically involve consumption of vegetables directly contaminated (e.g. by aerosols deposition and rain fall) and indirectly contaminated (e.g. via root transfer) and consumption of meat and other food products from contaminated animals (such as milk and cheese). Figure 2 presents an example of simplified scheme of foods and products contamination from atmospheric releases. In some circumstances, it may only be possible to calculate doses for very general categories of food using generic values for the transfer parameters. For example, doses can only be calculated for ingestion of crops, without being able to specify which types of crops these are. However, if extensive surveys have been made close to the site then it may be appropriate to use site-specific values for those actual crops occurring in the region.

[6] For example, depending on the purpose of assessment the sediment-water partitioning can be omitted and special conditions for water intake regime can be introduced (for irrigation and drinking).

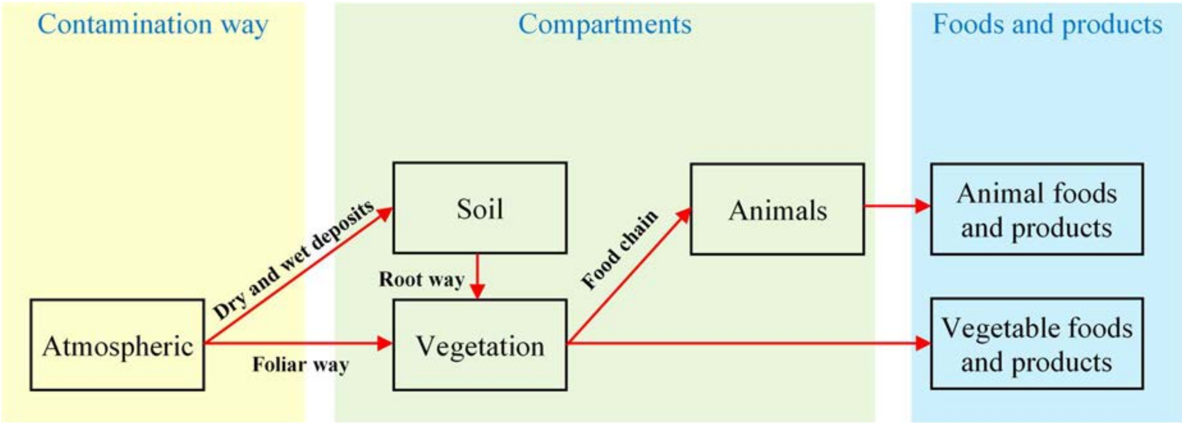

FIG. 2. Simplified scheme of foods and products contamination from atmospheric releases.

Input data required for environmental compartments models comprise transfer factors between different compartments such as 'soil to vegetation' and 'vegetation to animals'; translocation factors are also needed, such as from 'leaves to edible parts of the plant' and from 'entire animal to edible parts (milk or meat)'; radioactive, biological and migration half-times are also necessary. Other important information are soils, rain, dew and moisture characteristics. Finally, crop outputs, foliar class, rooting depths; harvest time and time to the final consumption are also necessary, depending on the complexity of the models.

2.2.3 Exposure pathways for members of the public

Doses need to be calculated for a number of exposure pathways which are considered relevant for the exposure situations associated with releases to the environment. An example (indicative list) of exposure pathways for both internal and external irradiation is given below based on Ref. [2].

For releases to atmosphere and surface waters (typically, for nuclear power plants):

- Inhalation of radioactivity in an atmospheric plume and/or resuspended by wind after surface deposition;
- Ingestion of crops, animal food products (milk, meat);
- Ingestion of drinking water;
- Ingestion of aquatic food (freshwater or seawater fish, algae, crustaceans, molluscs);
- External exposure to radioactivity in an atmospheric plume;
- External exposure to activity deposited on ground;
- External exposure to activity in water and sediments (e.g. from swimming, fishing etc.).

For releases to the sewerage system (possible, for small facilities or systems):

- Inhalation of resuspended sewage sludge;
- Ingestion of aquatic foods collected near the point of discharge of the sewage treatment system;
- External exposure to activity in sewage sludge;
- Ingestion of foods from crops grown on soils to which sewage sludge has been applied as an organic amendment.

Not all the exposure pathways listed in the paragraphs above may need to be included in the assessment [2]. Ref. [32] states that, for the generic assessment, assumptions can be made so that only the pathways that contribute substantially to the exposure are taken into account. The contribution of an exposure pathway to the overall dose depends on the radionuclides involved, the method of dispersion, the habit data and other characteristics of the population being considered. Therefore, some exposure pathways may be excluded from the assessment on the grounds that the doses associated with that pathway are negligible. Nonetheless, it is important that the dose to an individual includes appropriate contributions from all modes of exposure (e.g. atmospheric discharges, liquid discharges, and direct external exposure) [2].

It should also be noted that other exposure pathways may contribute to the dose received by individuals in particular circumstances, for example consumption of particular seafood for a short period of time or partaking of traditional regional practices or foods. Inclusion of some specific pathways into the assessment depends on the type of assessment, but the overall goal should be to ensure that no important pathway has been omitted [7]. The decision to exclude particular exposure pathways from consideration needs to be justified [2].

2.2.4 Representative person for normal operations

The effective dose is calculated using the organ or tissue equivalent doses which had been evaluated for a model of an idealized person named 'reference person'[7] [33]. An individual receiving a dose that is representative of the more highly exposed individuals in the population is a representative person [3]. Ref. [33] further clarifies:

> "The assessments of doses to the representative person are based on the dose coefficients provided by the ICRP for the reference persons of different ages. The parameters which are required for estimating the distribution of effective doses to members of the public in space and time (such as consumption of foodstuffs, outdoor/indoor time budget, etc.) define the representative person."

Ref. [3, 32] states that the dose to the representative person "is the equivalent of, and replaces, the mean dose in the 'critical group'." The concept of critical group remains valid.

Ref. [2, 32] gives guidance on the characteristics of the representative person. For a simple assessment, habit data of the representative person does not have to be those of a real individual but could be habits typical of the population living in the region where the facility is located or of the country at large.

For a complex assessment, the representative person can be a hypothetical person or group of persons in a conservative location from the point of view of the exposure (e.g. close to the fence or in the regions where the highest radionuclides deposition can be expected). Another option is to determine the characteristics of the representative person using data of real population. During the advanced stages of the decision-making, the characteristics of the representative person are expected to be defined according to the national regulations and through a systematic process involving the regulator, for example by means of local surveys if necessary.

2.2.5 Assessment of dose to representative person

An assessment of the radiological impact generally calculates individual effective doses to the representative person[8]. The effective dose is the sum of the committed effective dose from intakes of radioactivity (by ingestion and inhalation) and effective dose from external irradiation [3, 34]. Doses from internal irradiation are calculated using dose coefficients based

[7] International Commission on Radiological Protection (ICRP) uses six fixed ages of a reference person: 0, 1, 5, 10, 15 years and adults. In many cases the calculation of doses for 2–4 age groups may be considered as sufficient (e.g. 1-year old infants, 10-year-old children, adults).

[8] In some cases, equivalent dose for particular organs or tissues of interest may be required by the national regulatory body.

on the uptake and distribution amongst different tissues of radionuclides following intakes by ingestion and inhalation. These in turn provide committed effective doses to a reference individual per unit activity of intake (in Sv/Bq) for any radionuclide. Tabulated values of dose coefficients applicable for members of the public are available in Refs [3, 35-37]. Dose coefficients used by the national experts in this study are taken from Ref. [3].

Habit data used in an assessment of the radiological impact to the public can be obtained from statistics collected at national, regional or international level or, where possible, from surveys carried out at or near the location where the facility will operate. Habit data include consumption rates of food and drinking water, inhalation rates, location where people live and obtain their food (e.g. distance and direction from the point of release), fraction of the food consumed that is of local origin, occupancy times (time spent at different locations) and time spent outdoors and indoors [2]. Account needs to be taken of factors reducing the level of exposure, such as the degree of shielding or filtering offered by the buildings assumed to be inhabited.

If there are factors that may result in a particular age group being more highly exposed than others, then these should be considered.

2.2.6 Dose constraint and limits for members of the public

When assessing doses to the representative person from normal operations of a single source one of the criteria is the dose constraint[9], which is a fraction of the annual dose limit of 1 mSv established for members of the public [3, 6, 38]. The values of the dose constraints are normally established by the national regulatory body. Ref. [6] discusses the definition and use of a dose constraint within the range of 0.1 to <1 mSv in a year.

Sufficient caution should be retained in the assessments to provide confidence that actual doses received by members of the public will be below the dose limit. The regulatory body may determine what additional restrictions, if considered necessary, are required to ensure that the dose limits for the public in planned exposure situations are not exceeded through possible combinations of doses from exposures due to different authorized practices.

A generic dose constraint (for example, dose constraints for all nuclear fuel cycle facilities), which is normally defined by the national regulatory body, can be used as part of a governmental decision-making process or at an early stage of authorization process [2, 6]. After that the specific dose constraint defined by the regulatory body for the facility or activity under consideration needs to be used for the radiological environmental impact assessment. The specific dose constraint can be the dose corresponding to an optimized discharge level with a margin for flexibility of operations [6].

Ref. [2] provides the following recommendation on the consideration of transboundary radiological impacts to the public:

> "5.42. When considering transboundary impacts, the criteria used for the assessment of the level of protection in other States should be in line with the criteria set out in this Safety Guide and should be the same as those used for the State in which the facility or activity is located."

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[9] For public exposure, dose constraints are a source related value established or approved by the government or the regulatory body, with account taken of the doses from planned operations of all sources under control. The dose constraint for each particular source is intended, among other things, to ensure that the sum of doses from planned operations for all sources under control remains within the dose limit.

2.3 TOOLS APPLIED FOR EVALUATION OF THE ENVIRONMENTAL IMPACT

The methods used by the participants to evaluate the radiological environmental impact from a nuclear facility under normal operation conditions are briefly described in this section. More detailed description of the factors considered within each of the models are provided in the following Sections.

2.3.1 Generic models for use in assessing the impact of discharges of radioactive substances

Generic models for use in assessing the impact of discharges of radioactive substances have been published as the IAEA Safety Report Series [21][10]. This method comprises generic models for use in assessing the impact of discharges of radioactive substances to the environment. Ref. [21] provides simple spreadsheet-based methods for calculating doses arising from radioactive discharges into the environment.

For generic assessments, a Gaussian plume model is applied considering the frequency of the wind direction to assess the dispersion of annual atmospheric releases. Removal from the plume by radioactive decay and depletion by dry and wet deposition is considered. It also calculates ground deposition and resuspension of deposited radionuclides.

For aquatic releases, the generic methodology is based on analytical solutions to advection–diffusion equations describing radionuclides transport and dilution in surface waters with steady-state, uniform, flow conditions. A ‘box model’ is used to estimate dilution for small lakes and reservoirs.

To consider the exposures due to ingestion of radionuclides, terrestrial and aquatic food chain models are used to estimate activity concentrations in various foodstuff, i.e. human food crops and animal produce, including milk and meat. A ‘compartments model’ is used to estimate concentrations in linked compartments.

The estimation of total individual doses needs dosimetry factors, habits and other data as input. The estimation includes external doses from gaseous and airborne radionuclides and from deposited activity, and intake due to inhalation and ingestion of radionuclides.

Using Ref. [21], it is possible to calculate atmospheric and aquatic transport for C-14 and H-3 radionuclides. However, Ref. [21] does not give default transfer factors for C-14 and H-3 that are needed for calculation of transport through food chains. Hence, using the default Ref. [21] model for atmospheric discharge of C-14 and H-3 calculates only an external exposure from plume immersion and internal exposure from inhalation whilst computing zero doses from C-14 and H-3 via the ingestion pathway. At the same time, Ref. [21] states that ingestion of C-14 resulting from atmospheric depositions is the primary mode of exposure and that all other pathways will contribute less than 1% of the total dose. This means that, using only Ref. [21] the total doses from C-14 and H-3 are substantially underestimated when using the default form of the model: the dose from H-3 is almost 30 times less than the dose calculated with the special consideration for ingested H-3; the dose from C-14 is about 6000 times less than the dose obtained when applying ingestion under special considerations.

[10] A revision of Ref. [22] is in preparation and will cover generic assessments of public exposure, generic models and parameters for use in assessing the impact of radioactive discharges, and generic models and parameters for assessing exposures of flora and fauna due to radioactive discharges from facilities and activities.

Ref. [21] proposes the use of additional models for dose assessments from discharges of C-14 and H-3. Given that both radionuclides are long-lived and therefore transport time is usually inconsequential for them, these models are based on the reasonable assumption that steady state equilibrium has been attained between the environment and the exposed individuals, so that the ratio between the radionuclide and its stable counterpart is fixed. Such models can be called 'screening' models, because they are considered to give conservative dose estimates when an individual is assumed to be in complete equilibrium with maximum levels of environmental specific activity of C-14 and H-3.

For the sake of consistency, the default approach was agreed for use by participants applying Ref. [21] methodology. One exception was that the participant from India used the same basic Ref. [21] methodology as the others and an additional model for C-14 and H-3, because the requirement of special consideration for C-14 and H-3 is included in their national guidelines. The participant from Ukraine provided the comparison of rankings obtained without and with the special consideration for H-3 and C-14 in all atmospheric cases A, B and C based on the relative contribution from each radionuclide and pathway to the total adult dose from all pathways combined.

2.3.2 Consequences of Releases to the Environment: Assessment Methodology Code

The tool 'Consequences of Releases to the Environment: Assessment Methodology' (PC-CREAM 08) [39] is a commercial suite of codes developed by the United Kingdom Health Protection Agency[11] for the assessment of consequences from the normal operation radioactive discharges. This complex tool is divided into two parts, 'Models' and 'Assessor'. The Models part comprise a series of mathematical models that evaluate the transfer of radionuclides through the environment and provide estimates of activity concentrations in various environmental media following a continuous release. These activity concentrations are used as input to the dose assessment part of the program, Assessor. PC-CREAM 08 is capable of modelling discharges to the atmosphere, coastal waters (with special databases for Europeans seas) and rivers to determine both individual and collective doses [39].

The atmospheric dispersion models from the code include: a Gaussian plume model (to calculate activity concentrations in air, deposition rates and cloud gamma dose rates for specified release rate); a compartmental model for soil, vegetation and animals (that is used to calculate activity concentrations in foods per unit deposition rate); a compartmental model for soil and gamma dose, based on an infinite plane (to calculate time integrated ground gamma dose per unit deposition rate over one year); and a 'Garland model' [40] for radionuclide resuspension with dust (to calculate time integrated activity concentration in air per unit deposition rate over one year).

Exposure pathways considered in PC-CREAM 08 for atmospheric release are: inhalation of the plume; external gamma and beta from air; external gamma and beta from the ground inhalation of resuspended material; and ingestion of foodstuffs (cow meat, cow liver, cow milk, sheep meat, sheep liver, green vegetables, root vegetables, fruit and grain).

PC-CREAM 08 includes two additional models for the dispersion calculation of radionuclides released into rivers [39]. The Screening Model is a simple dilution model which assumes instantaneous equilibrium between the water and river sediments and can be used as a screening tool. It can be used in three modes depending on the amount of input data available. These are: the Simple Screening Model; the Extended Screening Model with complete mixing; and the

[11] Now Public Health England

Extended Screening Model with incomplete mixing. For more detailed assessments the Dynamic Model can be used. This is a time-dependent compartment model and it requires a greater amount of input data to run.

The marine dispersion model used in PC-CREAM 08 is based closely on the MARINA II Project aquatic models [39, 41, 42]. The model can be used to evaluate the activity concentrations in sea water, sediments and marine food for user-defined discharge rates. These activity concentrations are input to Assessor which scales them by the actual discharge rate and combines them with habit data to calculate doses from ingestion of marine foods, external exposure to beach sediments and inhalation of sea spray.

2.3.3 Integrated Dose Assessment Code

The 'Integrated Dose Assessment Code' (INDAC) [43] is a regulatory-authorized computer code to calculate radiation dose to the public due to exposures from nuclear facilities during normal operation. It was developed by Korea Institute of Nuclear Safety using the GASPAR-II/LADTAP-II codes [44, 45] of the US Nuclear Regulatory Commission. Those codes were supplemented by inclusion of food-chain components such as rice, green vegetables used to make kimchi[12] and seaweed unique to Korea and upgraded to incorporate concepts based on ICRP Publication 60 [38].

For atmospheric releases, the code considers external exposure from noble gas radionuclides in the plume and from contaminated ground, inhalation of airborne and gases and ingestion of farm products grown in contaminated soil. The code also considers aquatic exposure pathways such as from potable water, aquatic foods, shoreline deposits, swimming, boating, and irrigated foods. The radiation doses for both the most exposed individual and the general population are calculated as a function of age group and pathway. The dose estimates are for body organs and total effective dose.

The maximally exposed individual concept is applied to the calculation of the individual exposure dose. The maximally exposed individual has characteristics of ingestion, activities, physiology and metabolism, which surpass those of the common individual, leading to higher exposure in the dose calculation and hence, to a conservative evaluation.

The dose coefficients of the inhalation and ingestion pathways are those presented in Refs [35–37, 46]. The dose coefficients for external exposures, including submersion in noble gases, radioactive deposits on ground surfaces, and sea-shore activities (e.g. swimming and on-the-seashore activities) are taken from the DFEXT code [47].

2.3.4 CERES platform

The 'CERES platform' was developed by the Commissariat à l'énergie atomique et aux énergies alternatives (CEA) in France. The code platform is authorized in France as a procedure to evaluate the consequences of the emissions of radionuclides into the environment [28]. The pathways for human exposure include inhalation, immersion, ingestion and external exposure from contaminated ground. CERES consists of environmental dispersion and radiological impact models. The dispersion models comprise the GASCON code for atmospheric dispersion and the ABRICOT code for riverine releases. The impact model, EA, assesses transfers in the food chain.

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[12] A Korean national food.

The GASCON code is based on a Gaussian dispersion of pollutants model. The Gaussian parameters are calibrated for flat terrain, without buildings or topographic obstacles. The meteorological conditions parametrization can use either Doury scheme or Turner scheme. The Doury scheme was used for this exercise, considering two classes of atmospheric stability within the boundary layer (unstable conditions and stable conditions). Rain deposition can also be accounted for in the unstable condition.

The ABRICOT code for aquatic releases can assess and quantify radionuclides transfers in the environment as well as estimates their health impact. This model assumes instantaneous dilution of pollutants in the river (using the ratio between the river flow rate and the liquid effluent flow rate). Because this model was developed for human impact studies, the partitioning of pollutants onto sediments is not taken into account. This is an upper bound method, where water is used directly for irrigation and drinking, and provides external exposure due to soil contamination.

The EA code computes radionuclide transfer in food chains using a compartments model applying transfer coefficients.

CERES includes a model considering tritium (H-3). In this model an immersion in plume leads to internal exposure from tritium through inhalation and skin transfer. Direct external exposure from tritium in the plume and surfaces deposition of tritium are considered insignificant. No tritium accumulation in soil is assumed. Foliar translocation is considered only for the HTO (tritiated water) form and root transfer – only for tritium gas (after transformation by the soil microorganisms). After getting into plants, 40% of the HTO is converted into OBT (organically bound tritium).

2.3.5 AERB/NF/SG/S-5 tool

For India calculation in the present study, dose assessment methodology is applied in line with the regulatory guide AERB/NF/SG/S-5 [29]. This regulatory guide essentially follows the advice given in Ref. [21]. However, in contrast to the default parameters used in Ref. [21] (which were applied by the other participants of this study), the Indian approach includes special estimation of doses due to C-14 and H-3. Dose conversion values (based on a ‘specific activity model’) were used. The atmospheric exposure pathways considered for C-14 and H-3 were inhalation and ingestion (of food crops, milk and meat). The external dose contributions due to immersion in the plume and external exposure from activity deposited on ground from these two radionuclides are negligible and, hence, were not estimated. The use of the specific activity model values resulted in conservative estimates.

For atmospheric releases (other than C-14 and H-3) assessments, the guide refers to Ref. [48], whereby a Gaussian model assuming a flat terrain was used to estimate the downwind activity concentration. From that concentration, the consequent effective doses due to all the major exposure pathways were calculated using defaults from Ref. [21] or as adjusted based on data from Ref. [22]. Pathways included are: inhalation; external gamma from immersion in the plume; ingestion of selected food matrices (milk, meat and vegetables); and external exposure from the ground deposited activity. The latter two approaches were also applied for the aquatic release scenarios.

3 EXERCISE ON ASSESSMENT OF RADIOLOGICAL ENVIRONMENTAL IMPACT FROM NORMAL OPERATION

This section provides information on the input data for the various exposure routes considered in the exercise including meteorological data, source terms, release characteristics and consideration of terrain effects.

3.1 BASIC CONDITIONS FOR EXPOSURE SCENARIO

Under normal operation, NPPs release radionuclides under a regulatory authorization, at acceptably low concentrations to the environment fulfilling dose constraints and limits. These routine discharges will usually be either atmospheric or aquatic (marine, lacustrine, riverine). Scenarios covering atmospheric and aquatic dispersion pathways have been evaluated in this exercise using the radiological dose estimation tools presented in Section 2. This section gives an overview of the radiation exposure scenarios including the details on the source terms and the parameters applied, together with instructions provided to the participants about the choices that should, or could, be made with regard to the various case studies being assessed.

One of the tasks in this exercise was to rank the radionuclides in the source term data based on their relative importance in the contribution to adult individual doses, via each of the main exposure pathways (atmospheric, marine and/or riverine). Towards implementing this task, the calculation schemes were identified, and several common parameters were predefined across all scenarios considered. These predefined inputs were named ‘fixed parameters’. The approach applied facilitates the comparison of results obtained with different modelling approaches and makes possible objective ranking of radionuclides importance.

In addition, as different assessment tools with different models were applied to one case for atmospheric releases and two cases for aquatic releases (i.e. marine and riverine releases), some parameters were not predefined but could be varied by the individual participants, so as to evaluate the influence of site-specific conditions. These inputs were named ‘variable parameters’.

The parameters that were likely to cause large variations in the outcomes of the calculations and the parameters that are likely to change from country to country were duly considered when categorizing the fixed and the variable parameters. These mentioned parameters are discussed in more detail in the next sections. Any other input parameters that could be applied by the modellers were used at their discretion and would illustrate the intrinsic variability of the modelling approaches, particularly in circumstances where identical approaches were applied.

For the atmospheric releases, radiation annual dose estimation for an adult (considering annual discharges and assuming continuous routine operation of a nuclear facility over a 50 year period in order to take into account the build up in the environment of long lived radionuclides) were carried out by all participants. Three cases named A, B and C were considered. In case A, all parameters and data, such as radionuclide concentrations, meteorological data, environmental data and radiological data used in the estimation, were fixed. Only the type of model used by participants for the analysis varied.

To study the influence of the use of regional meteorological data versus local data, local meteorological data were used in the calculations for atmospheric case B (as defined by each participant). If necessary, the local data were adapted to fit the agreed release conditions (see Section 3.2) but all other input remained consistent.

For atmospheric case C, and case B for the aquatic release scenarios, the standard source terms were applied but participants were asked to use site-specific data (adult breathing rate, transfer coefficient values, plant interception factors and adult ingestion rates) to assess the influence of different environmental factors on radiological dose. The dose conversion factors used in all cases were fixed[13]. The transfer coefficients given as input for the atmospheric exercise are defined for dry weight tissues and hence local vegetable consumption was converted to a dry weight basis using agreed standard values.

The categorization of parameters (fixed versus variable) used in the calculations of dose to the public in the atmospheric release scenario is presented in Table 1 for each of the three cases (A, B and C).

TABLE 1. PARAMETERS FOR CALCULATION OF DOSE VIA THE ATMOSPHERIC PATHWAY

Parameters	Case A	Case B	Case C
Dose coefficient	Fixed	Fixed	Fixed
Source term	Fixed	Fixed	Fixed
Meteorological data	Fixed	Variable	Fixed
Breathing rate	Fixed	Fixed	Variable
Transfer coefficients	Fixed	Fixed	Variable
Consumption	Fixed	Fixed	Variable

Two cases were considered for estimating adult human dose from either the marine or riverine pathway. In case A all parameters were fixed. Case B used the same fixed dose conversion coefficients, source term and radionuclide concentrations but applied site-specific consumption rates and bioaccumulation factor values (assuming fresh weight). The transfer coefficients for the aquatic releases were on a wet weight basis. The considered parameters are listed in Table 2.

TABLE 2. PARAMETERS FOR CALCULATION OF DOSE VIA THE AQUATIC PATHWAYS

Parameters	Case A	Case B
Dose coefficient	Fixed	Fixed
Source term	Fixed	Fixed
Radionuclide concentrations in water at the fishing point	Fixed	Fixed
Radionuclide concentrations in water at the water extraction point[a]	Fixed	Fixed
Transfer coefficients	Fixed	Variable
Fish consumption	Fixed	Variable
Water consumption[a]	Fixed	Variable

a – these parameters refer only to the riverine scenario.

A complete set of tables comprising the data and parameters used is provided in this Section 3.

3.1.1 Meteorological data

Atmospheric dispersion models require meteorological data inputs (e.g. wind direction and speed, air temperature, atmospheric stability and mixing layer heights) from the region of

[13] Evaluation of the dose coefficients for inhalation of radionuclides normally involves assumptions on the human breathing rate. Using these dose coefficients with different breathing rates may theoretically require evaluation of impact on the result accuracy and justification of such an approach. However, in some countries national requirements and guides admit the combinations of dose coefficients published in the international safety publications and local data on breathing. Similar approach was discussed in ICRP Publication 101.

interest. The data agreed to be used in this exercise were provided by Nuclear and Energy Research Institute (São Paulo, Brazil) in the form of dilution factors for various wind directions and distances. These data were collected hourly (8760 hours per annum) from a 100 m tall meteorological tower and included the temperature difference (°C/100 m) between two different height levels, together with wind speed and wind direction at two different levels. The Pasquill stability classes were defined for each of 16 wind directions and 10 wind speed categories.

The standard meteorological data set proposed for the exercise was used for Case A and Case C calculations, while site specific meteorological data were used for calculations as defined by the participating experts under Case B. The standard data are provided in Tables 3 to 9. These data include the quantities of events of a given wind speed and direction at 10 m height which are divided into stability classes[14] associated with temperature difference between 80 m and 10 m. Values inside the parentheses show the wind speed average over the specific wind speed class. In total 7 years of meteorological data are considered, total hourly events in the period are equal to 61368. Valid hourly events comprise 87.57% of total number (53740 of 61368). Missing hourly events amount 7628 (12.43 %). Total events of calms in all classes amount 7929 (14.75 %).

TABLE 3. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS ‘A’ (DT/DZ ≤ −1.9°C/100m) OVER THE PERIOD 2002 TO 2008

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector N	12	39	142	202	498	266	4	0	0	0	1163
	(0.55)	(0.80)	(1.27)	(1.81)	(2.56)	(3.61)	(5.20)	-	-	-	(2.44)
Sector NNE	13	43	172	150	291	239	19	0	0	0	927
	(0.56)	(0.80)	(1.28)	(1.81)	(2.54)	(3.70)	(5.52)	-	-	-	(2.44)
Sector NE	16	26	95	64	88	34	2	1	0	0	326
	(0.56)	(0.79)	(1.28)	(1.77)	(2.50)	(3.71)	(6.00)	(9.50)	-	-	(1.95)
Sector ENE	11	30	53	40	43	7	0	0	0	0	184
	(0.55)	(0.79)	(1.25)	(1.78)	(2.48)	(3.30)	-	-	-	-	(1.62)
Sector E	6	18	51	44	67	46	4	0	0	0	236
	(0.55)	(0.84)	(1.28)	(1.82)	(2.54)	(3.74)	(5.55)	-	-	-	(2.24)
Sector ESE	7	14	48	72	132	191	30	0	0	0	494
	(0.54)	(0.77)	(1.25)	(1.78)	(2.54)	(3.80)	(5.74)	-	-	-	(2.91)
Sector SE	9	21	68	61	115	227	152	7	0	0	660
	(0.57)	(0.80)	(1.26)	(1.82)	(2.61)	(4.02)	(5.99)	(8.43)	-	-	(3.64)
Sector SSE	10	29	72	79	141	297	242	3	0	0	873
	(0.55)	(0.82)	(1.25)	(1.78)	(2.54)	(4.10)	(5.95)	(8.30)	-	-	(3.79)
Sector S	10	19	43	46	95	208	129	6	0	0	556
	(0.57)	(0.78)	(1.23)	(1.80)	(2.55)	(4.08)	(6.14)	(8.70)	-	-	(3.77)
Sector SSW	4	12	27	22	23	34	20	1	0	0	143
	(0.55)	(0.78)	(1.28)	(1.81)	(2.57)	(3.73)	(6.10)	(8.60)	-	-	(2.84)
Sector SW	4	8	34	28	31	12	2	0	0	0	119
	(0.58)	(0.83)	(1.26)	(1.80)	(2.47)	(3.77)	(5.40)	-	-	-	(2.00)

[14] Standard data in this exercise are specific for atmospheric dispersion models using Pasquill stability classes.

TABLE 3. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS 'A' (DT/DZ ≤ −1.9°C/100m) OVER THE PERIOD 2002 TO 2008 (cont.)

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector WSW	4	16	43	35	42	9	2	1	0	0	152
	(0.50)	(0.79)	(1.25)	(1.78)	(2.50)	(3.61)	(5.70)	(8.70)	-	-	(1.91)
Sector W	8	16	59	57	52	18	0	0	0	0	210
	(0.54)	(0.83)	(1.29)	(1.75)	(2.37)	(3.52)	-	-	-	-	(1.82)
Sector WNW	7	21	108	108	126	55	1	0	0	0	426
	(0.56)	(0.81)	(1.27)	(1.80)	(2.50)	(3.64)	(5.70)	-	-	-	(2.06)
Sector NW	9	16	136	131	213	132	5	0	0	0	642
	(0.59)	(0.78)	(1.30)	(1.78)	(2.52)	(3.57)	(5.36)	-	-	-	(2.28)
Sector NNW	11	26	125	204	345	141	3	0	0	0	855
	(0.55)	(0.85)	(1.29)	(1.80)	(2.50)	(3.54)	(5.37)	-	-	-	(2.27)
Total [a]	141	354	1276	1343	2302	1916	615	19	0	0	7966

a - Events of calms in this stability class: 147 (0.27 %).

TABLE 4. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS 'B' (−1.9< DT/DZ ≤ −1.7°C/100m) OVER THE PERIOD 2002 TO 2008

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector N	7	18	93	98	154	50	0	0	0	0	420
	(0.57)	(0.81)	(1.30)	(1.79)	(2.52)	(3.48)	-	-	-	-	(2.09)
Sector NNE	8	32	86	91	193	93	8	0	0	0	511
	(0.56)	(0.82)	(1.29)	(1.82)	(2.48)	(3.62)	(5.51)	-	-	-	(2.29)
Sector NE	9	13	54	31	37	10	0	0	0	0	154
	(0.57)	(0.80)	(1.28)	(1.76)	(2.47)	(3.85)	-	-	-	-	(1.76)
Sector ENE	9	10	41	22	10	2	0	0	0	0	94
	(0.53)	(0.78)	(1.23)	(1.76)	(2.47)	(3.30)	-	-	-	-	(1.44)
Sector E	9	13	38	37	25	14	0	0	0	0	136
	(0.56)	(0.84)	(1.22)	(1.77)	(2.44)	(3.75)	-	-	-	-	(1.79)
Sector ESE	6	14	33	35	75	141	19	0	0	0	323
	(0.55)	(0.82)	(1.23)	(1.80)	(2.56)	(3.93)	(5.56)	-	-	-	(3.01)
Sector SE	8	14	42	38	92	205	143	2	0	0	544
	(0.56)	(0.81)	(1.21)	(1.81)	(2.59)	(4.09)	(5.92)	(8.30)	-	-	(3.82)
Sector SSE	6	12	46	40	118	315	221	1	0	0	759
	(0.58)	(0.81)	(1.26)	(1.80)	(2.54)	(4.05)	(6.00)	(8.10)	-	-	(4.03)
Sector S	6	18	41	29	76	180	132	3	0	0	485
	(0.57)	(0.79)	(1.29)	(1.79)	(2.54)	(4.03)	(6.04)	(8.67)	-	-	(3.85)
Sector SSW	2	3	16	14	16	25	17	0	1	0	94
	(0.60)	(0.83)	(1.23)	(1.84)	(2.57)	(3.72)	(6.32)	-	(11.30)	-	(3.25)
Sector SW	3	4	8	13	14	11	3	0	0	0	56
	(0.50)	(0.85)	(1.29)	(1.74)	(2.57)	(3.75)	(6.77)	-	-	-	(2.48)
Sector WSW	4	6	14	15	15	8	0	0	0	0	62
	(0.60)	(0.78)	(1.29)	(1.80)	(2.39)	(3.80)	-	-	-	-	(1.95)
Sector W	6	8	23	12	13	3	0	0	0	0	65
	(0.57)	(0.83)	(1.28)	(1.83)	(2.45)	(3.67)	-	-	-	-	(1.64)
Sector WNW	3	10	27	23	21	6	0	0	0	0	90
	(0.57)	(0.82)	(1.24)	(1.75)	(2.44)	(3.38)	-	-	-	-	(1.74)

TABLE 4. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS 'B' (−1.9< DT/DZ ≤ −1.7°C/100m) OVER THE PERIOD 2002 TO 2008 (cont.)

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector NW	9	12	59	53	72	36	1	0	0	0	242
	(0.53)	(0.83)	(1.26)	(1.82)	(2.56)	(3.54)	(5.10)	-	-	-	(2.08)
Sector NNW	8	14	73	64	111	34	0	0	0	0	304
	(0.54)	(0.81)	(1.25)	(1.77)	(2.48)	(3.42)	-	-	-	-	(2.02)
Total [a]	103	201	694	615	1042	1133	544	6	1	0	4339

a - Events of calms in this stability class: 121 (0.23 %)

TABLE 5. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS 'C' (−1.7< DT/DZ ≤ −1.5°C/100m) OVER THE PERIOD 2002 TO 2008

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector N	10	12	39	43	64	17	0	0	0	0	185
	(0.56)	(0.79)	(1.26)	(1.80)	(2.49)	(3.55)	-	-	-	-	(1.95)
Sector NNE	12	24	59	53	76	33	2	0	0	0	259
	(0.53)	(0.80)	(1.28)	(1.78)	(2.49)	(3.64)	(5.20)	-	-	-	(2.00)
Sector NE	5	22	32	26	29	8	0	0	0	0	122
	(0.54)	(0.85)	(1.21)	(1.80)	(2.52)	(3.58)	-	-	-	-	(1.73)
Sector ENE	7	13	18	8	3	0	0	0	0	0	49
	(0.56)	(0.82)	(1.24)	(1.85)	(2.37)	-	-	.-	-	-	(1.24)
Sector E	5	6	15	11	8	2	0	0	0	0	47
	(0.58)	(0.80)	(1.31)	(1.77)	(2.34)	(4.25)	-	-	-	-	(1.60)
Sector ESE	9	13	26	22	40	39	14	0	0	0	163
	(0.51)	(0.80)	(1.32)	(1.77)	(2.51)	(3.87)	(5.61)	-	-	-	(2.57)
Sector SE	4	7	30	24	54	136	76	0	0	0	331
	(0.60)	(0.81)	(1.26)	(1.80)	(2.57)	(4.00)	(5.85)	-	-	-	(3.68)
Sector SSE	3	10	35	30	70	198	113	3	0	0	462
Sector S	6	9	16	12	49	119	68	0	0	0	279
	(0.53)	(0.79)	(1.21)	(1.83)	(2.58)	(4.03)	(6.20)	-	-	-	(3.88)
Sector SSW	4	7	13	7	18	23	13	0	0	0	85
	(0.53)	(0.83)	(1.22)	(1.80)	(2.49)	(3.87)	(5.50)	-	-	-	(2.89)
Sector SW	5	2	9	6	10	2	0	1	0	0	35
	(0.56)	(0.80)	(1.33)	(1.72)	(2.57)	(3.90)	-	(8.60)	-	-	(2.05)
Sector WSW	3	4	10	3	4	2	1	0	0	0	27
	(0.57)	(0.83)	(1.32)	(1.70)	(2.53)	(3.35)	(5.50)	-	-	-	(1.76)
Sector W	3	8	14	2	3	1	0	0	0	0	31
	(0.60)	(0.79)	(1.24)	(1.70)	(2.33)	(3.30)	-	-	-	-	(1.32)
Sector WNW	2	6	19	8	7	6	0	0	0	0	48
	(0.60)	(0.80)	(1.24)	(1.84)	(2.34)	(3.25)	-	-	-	-	(1.70)
Sector NW	4	8	23	27	38	9	0	0	0	0	109
	(0.50)	(0.80)	(1.21)	(1.81)	(2.53)	(3.46)	-	-	-	-	(1.97)
Sector NNW	3	14	34	27	29	10	0	0	0	0	117
	(0.53)	(0.82)	(1.25)	(1.82)	(2.63)	(3.47)	-	-	-	-	(1.86)
Total [a]	85	165	392	309	502	605	287	4	0	0	2349

a - Events of calms in this stability class: 95 (0.18 %)

TABLE 6. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS ‘D’ (−1.5< DT/DZ ≤ −0.5°C/100m) OVER THE PERIOD 2002 TO 2008

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector N	39	65	226	177	203	66	1	0	0	0	777
	(0.55)	(0.81)	(1.27)	(1.80)	(2.48)	(3.56)	(5.30)	-	-	-	(1.83)
Sector NNE	67	111	249	231	280	96	1	0	0	0	1035
	(0.56)	(0.80)	(1.26)	(1.80)	(2.48)	(3.60)	(5.20)	-	-	-	(1.84)
Sector NE	56	101	179	99	95	39	1	0	0	0	570
	(0.54)	(0.81)	(1.26)	(1.76)	(2.46)	(3.66)	(7.00)	-	-	-	(1.57)
Sector ENE	32	58	63	39	26	13	1	0	0	0	232
	(0.55)	(0.82)	(1.23)	(1.79)	(2.45)	(3.42)	(5.20)	-	-	-	(1.41)
Sector E	31	46	90	30	54	32	5	0	0	0	288
	(0.56)	(0.81)	(1.22)	(1.79)	(2.50)	(3.80)	(5.28)	-	-	-	(1.75)
Sector ESE	29	46	75	61	141	158	31	0	0	0	541
	(0.56)	(0.79)	(1.26)	(1.82)	(2.57)	(3.83)	(5.92)	-	-	-	(2.61)
Sector SE	42	70	170	158	309	650	254	0	0	0	1653
	(0.55)	(0.81)	(1.25)	(1.81)	(2.58)	(4.06)	(5.81)	-	-	-	(3.32)
Sector SSE	48	87	211	266	705	1320	589	3	0	0	3229
	(0.55)	(0.81)	(1.28)	(1.80)	(2.56)	(4.02)	(5.82)	(8.33)	-	-	(3.53)
Sector S	42	66	186	145	466	1078	407	7	0	0	2397
	(0.56)	(0.81)	(1.28)	(1.81)	(2.57)	(3.97)	(5.78)	(8.89)	-	-	(3.53)
Sector SSW	29	47	75	52	113	152	40	3	0	0	511
	(0.54)	(0.80)	(1.23)	(1.79)	(2.49)	(3.88)	(5.77)	(9.03)	-	-	(2.68)
Sector SW	17	25	56	37	42	22	2	0	0	0	201
	(0.56)	(0.78)	(1.25)	(1.78)	(2.49)	(3.80)	(6.25)	-	-	-	(1.83)
Sector WSW	15	20	52	42	46	21	1	0	0	0	197
	(0.54)	(0.80)	(1.24)	(1.78)	(2.46)	(4.06)	(5.40)	-	-	-	(1.87)
Sector W	7	23	33	42	44	16	0	0	0	0	165
	(0.56)	(0.79)	(1.24)	(1.76)	(2.38)	(3.83)	-	-	-	-	(1.85)
Sector WNW	18	22	82	46	43	17	1	0	0	0	229
	(0.55)	(0.77)	(1.28)	(1.82)	(2.40)	(3.52)	(5.30)	-	-	-	(1.69)
Sector NW	19	35	95	76	119	26	0	0	0	0	370
	(0.55)	(0.80)	(1.24)	(1.77)	(2.50)	(3.53)	-	-	-	-	(1.84)
Sector NNW	31	35	138	106	156	44	1	0	0	0	511
	(0.55)	(0.82)	(1.27)	(1.79)	(2.43)	(3.54)	(5.60)	-	-	-	(1.87)
Total [a]	522	857	1980	1607	2842	3750	1335	13	0	0	12906

a - Events of calms in this stability class: 900 (1.67 %)

TABLE 7. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS ‘E’ (−0.5< DT/DZ ≤ +1.5°C/100m) OVER THE PERIOD 2002 TO 2008

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector N	57	67	111	57	44	9	0	0	0	0	345
	(0.55)	(0.79)	(1.22)	(1.78)	(2.38)	(3.47)	-	-	-	-	(1.33)
Sector NNE	76	90	137	78	47	16	0	0	0	0	444
	(0.55)	(0.8)	(1.23)	(1.78)	(2.44)	(3.58)	-	-	-	-	(1.34)
Sector NE	40	38	56	15	22	7	0	0	0	0	178
	(0.54)	(0.79)	(1.18)	(1.8)	(2.52)	(3.56)	-	-	-	-	(1.27)

TABLE 7. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS ‘E’ (−0.5< DT/DZ ≤ +1.5°C/100m) OVER THE PERIOD 2002 TO 2008 (cont.)

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector ENE	26	24	22	10	10	6	0	0	0	0	98
	(0.55)	(0.83)	(1.23)	(1.8)	(2.51)	(3.27)	-	-	-	-	(1.28)
Sector E	24	23	31	20	32	22	0	0	0	0	152
	(0.55)	(0.79)	(1.21)	(1.84)	(2.49)	(3.62)	-	-	-	-	(1.75)
Sector ESE	45	41	95	92	141	84	13	0	0	0	511
	(0.55)	(0.8)	(1.25)	(1.81)	(2.55)	(3.77)	(5.81)	-	-	-	(2.14)
Sector SE	66	119	390	393	670	423	38	0	0	0	2099
	(0.54)	(0.82)	(1.27)	(1.81)	(2.5)	(3.74)	(5.45)	-	-	-	(2.29)
Sector SSE	137	241	769	773	1469	915	38	0	0	0	4342
	(0.55)	(0.8)	(1.27)	(1.8)	(2.51)	(3.69)	(5.69)	-	-	-	(2.28)
Sector S	153	224	394	295	536	423	32	1	0	0	2058
	(0.55)	(0.8)	(1.24)	(1.79)	(2.56)	(3.73)	(5.74)	(8.3)	-	-	(2.15)
Sector SSW	132	150	157	33	62	39	15	0	0	0	588
	(0.55)	(0.78)	(1.21)	(1.77)	(2.54)	(3.83)	(6.05)	-	-	-	(1.42)
Sector SW	68	80	68	27	33	16	5	1	0	0	298
	(0.55)	(0.8)	(1.18)	(1.78)	(2.42)	(3.96)	(6.1)	(8.7)	-	-	(1.39)
Sector WSW	49	51	67	42	41	16	3	0	0	0	269
	(0.55)	(0.8)	(1.26)	(1.78)	(2.46)	(3.67)	(5.5)	-	-	-	(1.5)
Sector W	29	29	62	31	22	7	0	0	0	0	180
	(0.54)	(0.82)	(1.23)	(1.8)	(2.41)	(3.64)	-	-	-	-	(1.4)
Sector WNW	28	33	85	31	30	1	0	0	0	0	208
	(0.55)	(0.8)	(1.22)	(1.78)	(2.36)	(4.2)	-	-	-	-	(1.33)
Sector NW	34	31	70	36	15	3	0	0	0	0	189
	(0.54)	(0.78)	(1.24)	(1.79)	(2.35)	(3.47)	-	-	-	-	(1.28)
Sector NNW	38	55	87	46	48	7	0	0	0	0	281
	(0.55)	(0.81)	(1.24)	(1.77)	(2.47)	(3.7)	-	-	-	-	(1.43)
Total [a]	1002	1296	2601	1979	3222	1994	144	2	0	0	12240

a - Events of calms in this stability class: 2473 (4.60 %)

TABLE 8. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS ‘F’ (+1.5< DT/DZ ≤ +4.0°C/100m) OVER THE PERIOD 2002 TO 2008

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector N	21	25	22	4	0	1	0	0	0	0	73
	(0.56)	(0.83)	(1.20)	(1.78)	-	(4.50)	-	-	-	-	(0.96)
Sector NNE	30	36	14	5	3	0	0	0	0	0	88
	(0.54)	(0.77)	(1.19)	(1.66)	(2.27)	-	-	-	-	-	(0.87)
Sector NE	7	13	3	0	0	1	0	0	0	0	24
	(0.54)	(0.82)	(1.27)	-	-	(3.40)	-	-	-	-	(0.94)
Sector ENE	5	3	2	0	0	0	0	0	0	0	10
	(0.54)	(0.90)	(1.35)	-	-	-	-	-	-	-	(0.90)
Sector E	12	9	14	5	2	0	0	0	0	0	42
	(0.55)	(0.81)	(1.14)	(1.84)	(2.35)	-	-	-	-	-	(1.06)
Sector ESE	11	22	70	73	36	2	0	0	0	0	214
	(0.54)	(0.83)	(1.26)	(1.79)	(2.39)	(3.10)	-	-	-	-	(1.57)
Sector SE	40	70	183	130	105	6	0	0	0	0	534
	(0.54)	(0.77)	(1.26)	(1.79)	(2.42)	(3.80)	-	-	-	-	(1.53)

TABLE 8. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS ‘F’ (+1.5< DT/DZ ≤ +4.0°C/100m) OVER THE PERIOD 2002 TO 2008 (cont.)

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector	123	179	481	293	224	17	1	0	0	0	1318
SSE	(0.55)	(0.80)	(1.27)	(1.78)	(2.39)	(3.62)	(5.30)	-	-	-	(1.48)
Sector S	214	291	219	81	75	7	2	0	0	0	889
	(0.55)	(0.80)	(1.19)	(1.79)	(2.43)	(3.51)	(6.05)	-	-	-	(1.10)
Sector	205	216	86	7	7	2	0	0	0	0	523
SSW	(0.56)	(0.78)	(1.12)	(1.74)	(2.40)	(3.30)	-	-	-	-	(0.79)
Sector SW	70	57	39	8	3	2	0	0	0	0	179
	(0.54)	(0.78)	(1.13)	(1.86)	(2.63)	(3.55)	-	-	-	-	(0.88)
Sector	10	9	17	4	3	0	0	0	0	0	43
WSW	(0.55)	(0.82)	(1.20)	(1.83)	(2.37)	-	-	-	-	-	(1.13)
Sector W	6	6	5	5	1	3	0	0	0	0	26
	(0.53)	(0.78)	(1.22)	(1.78)	(2.70)	(3.93)	-	-	-	-	(1.48)
Sector	8	7	11	3	0	1	0	0	0	0	30
WNW	(0.53)	(0.74)	(1.15)	(1.83)	-	(4.80)	-	-	-	-	(1.13)
Sector NW	8	7	5	1	0	0	0	0	0	0	21
	(0.55)	(0.77)	(1.28)	(1.60)	-	-	-	-	-	-	(0.90)
Sector	15	11	15	2	0	0	0	0	0	0	43
NNW	(0.53)	(0.80)	(1.15)	(1.80)	-	-	-	-	-	-	(0.90)
Total [a]	785	961	1186	621	459	42	3	0	0	0	4057

a - Events of calms in this stability class: 2307 (4.29 %)

TABLE 9. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS ‘G’ (DT/DZ > 4.0°C/100m) OVER THE PERIOD 2002 TO 2008

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector N	13	11	4	1	0	0	0	0	0	0	29
	(0.55)	(0.80)	(1.23)	(1.60)	-	-	-	-	-	-	(0.78)
Sector	18	10	3	2	0	0	0	0	0	0	33
NNE	(0.54)	(0.79)	(1.10)	(1.70)	-	-	-	-	-	-	(0.76)
Sector NE	4	3	0	0	0	0	0	0	0	0	7
	(0.55)	(0.77)	-	-	-	-	-	-	-	-	(0.75)
Sector	0	0	0	0	0	0	0	0	0	0	0
ENE	-	-	-	-	-	-	-	-	-	-	-
Sector E	2	0	0	0	0	0	0	0	0	0	2
	(0.50)	-	-	-	-	-	-	-	-	-	(0.50)
Sector	1	4	3	3	0	0	0	0	0	0	11
ESE	(0.60)	(0.75)	(1.17)	(1.67)	-	-	-	-	-	-	(1.15)
Sector SE	24	21	14	3	1	0	0	0	0	0	63
	(0.54)	(0.79)	(1.09)	(1.73)	(2.20)	-	-	-	-	-	(0.85)
Sector	82	108	63	9	4	1	0	0	0	0	267
SSE	(0.56)	(0.79)	(1.20)	(1.78)	(2.25)	(3.30)	-	-	-	-	(0.89)
Sector S	263	345	195	5	2	2	0	0	0	0	812
	(0.55)	(0.80)	(1.11)	(1.76)	(2.45)	(4.25)	-	-	-	-	(0.81)
Sector	222	273	122	2	0	0	0	0	0	0	619
SSW	(0.55)	(0.79)	(1.12)	(1.75)	-	-	-	-	-	-	(0.77)
Sector SW	30	34	19	0	0	0	0	0	0	0	83
	(0.54)	(0.79)	(1.17)	-	-	-	-	-	-	-	(0.79)

TABLE 9. NUMBER OF EVENTS OF PASQUILL STABILITY CLASS 'G' (DT/DZ > 4.0°C/100m) OVER THE PERIOD 2002 TO 2008 (cont.)

Wind speed, m/s	0.46-0.60	0.61-0.90	0.91-1.50	1.51-2.00	2.01-3.00	3.01-5.00	5.01-8.00	8.01-11.0	11.1-15.0	>15.0	Total
Sector WSW	4	1	3	3	0	0	0	0	0	0	11
	(0.55)	(0.70)	(1.07)	(1.90)	-	-	-	-	-	-	(1.14)
Sector W	1	3	0	0	0	0	0	0	0	0	4
	(0.50)	(0.83)	-	-	-	-	-	-	-	-	(1.04)
Sector WNW	0	0	0	1	1	0	0	0	0	0	2
	-	-	-	(1.60)	(3.00)	-	-	-	-	-	(2.82)
Sector NW	2	1	0	0	0	0	0	0	0	0	3
	(0.50)	(0.70)	-	-	-	-	-	-	-	-	(1.51)
Sector NNW	3	2	1	1	1	0	0	0	0	0	8
	(0.53)	(0.75)	(1.00)	(1.70)	(2.10)	-	-	-	-	-	(1.18)
Total [a]	669	816	427	30	9	3	0	0	0	0	1954

a - Events of calms in this stability class: 1886 (3.51 %)

A statistical probability was evaluated for each paired wind direction/wind speed vector. The dilution factors have been defined[15] for all 16 directions for various distances from the release point. To simplify the exercise, the minimum dilution value ($4.705 \cdot 10^{-8}$ s/m^3) corresponding to the distance of 10 km from the source is used by all national experts for cases A and C. National 'site-specific' meteorological data (and respective dilution values for a measurement point 10 km downwind) are used in case B.

3.1.2 Release characteristics, consideration of terrain and radionuclides removal mechanisms

As it was mentioned above, the characteristics of the releases of radionuclides relevant for the calculation of dilution and dispersion in the atmosphere and aquatic media were agreed (fixed or variable) and then used in the dose evaluations performed by the different participants.

Modelling of radionuclides dilution and dispersion in the atmosphere was performed with the following conditions:

- The releases of radionuclides to the atmosphere are assumed to be uniform and continuous from a 100 m tall stack. The effective release height is assumed to be 100 m (plume rise is not considered). For atmospheric case B, the participants were requested to adjust the meteorological data if their local stack height was different from 100 m.
- The release rate is deduced from the annual release quantities given as part of the source term. Plume rise or stack downwash are not considered in the calculation for any case. Terrain is assumed to be flat and plain with no significant surface undulations. Hence, turbulence (wakes) introduced by buildings or other vertical elements are not considered in the calculations while estimating the downstream concentrations and subsequent doses. However, corrections due to dry deposition, ingrowth and radioactive decay during plume transport and dispersion were included. Doses are estimated at 10 km downwind.
- Radionuclide concentrations may undergo change due to radioactive decay during plume dispersion. The fraction could be significant if the half-life of the radionuclide is relatively short and the distances under consideration are far from the release point. For atmospheric dispersion, the transit time was deduced from the downwind distance under consideration

[15] A single method to evaluate the dilution and dispersion of the effluent plume was applied to give the radionuclides concentrations in air at the point of assessment to be used by all participants.

and the mean wind speed. For cases A and C these values were 10 km and 2 m/s respectively. For case B, the distance was retained but the wind speed was provided by local meteorological data. The time thus deduced was used for the correction of radionuclide concentrations at the receptor point.

- Particulate radionuclides also undergo the deposition process while they are dispersing in the atmosphere, resulting in reduced downwind concentrations and consequent ground deposited activity. Depletion due to dry deposition was based on an agreed default value for the settling rate suggested for the exercise. A typical deposition velocity of 1000 m/d is used in the calculation for all the radionuclides, except for noble gases, tritium and carbon. This approach is adopted for all three atmospheric cases in the exercise.

In the case of marine releases, the source term was given as annual radionuclide activity discharges in Bq/a (Bq in a year) and for both cases (A and B) activity concentrations (Bq/m^3) at 1 km from the release point were calculated using dispersion characteristics agreed by participants for the study.

In the case of riverine releases, the annual source term was used to calculate with models the radionuclide activity concentrations (Bq/l) in the water medium at the location determined for dose assessment (agreed to be at 1 km downstream from the release). The models used the sea or river characteristics as an input, such as depth, flow rate and dilution factors. The temperature of the effluents was assumed to be near ambient.

Some participants did not calculate aquatic dispersions. They were provided with estimations of activity concentrations at the receptor locations (1 km downstream) calculated by the other participants.

3.1.3 Habit data, dose conversion and transfer coefficients

For the purpose of the study, only individual adults were selected as the representative person for dose calculation. The parameters influenced by this choice include physiological parameters such as breathing rate and ingestion rates of water, milk, meat, vegetable and fish.

The occupancy factor considered for the calculation of doses due to plume immersion and ground shine for the atmospheric scenario is 1.0. Occupancy is not considered for the aquatic exposure pathways.

The food items used for the estimation of doses (in both atmospheric and aquatic scenarios) were limited for better comparison of the calculation results. In the cases allowing variability of input parameters, several participants included food types specific to their region.

The normalized dose conversion coefficients for inhalation and immersion, and dose conversion factors for the ground deposited activity are taken from Ref. [21]. Dose coefficients for ingestion are taken from Ref. [3] and other necessary data were supplemented from Ref. [37].

The environmental transfer coefficients (terrestrial uptake) and the bioaccumulation factors (aquatic uptake) used in the exercise were taken from Refs [22, 30]. The transfer coefficient values given for vegetables are for dry weight and were corrected for wet weight, as required, using standard procedures and the wet/dry ratios provided with the data (for green vegetables, roots and fruit) as it was agreed by the participants. Bioaccumulation factors for aquatic biota were on a fresh weight basis. These factors are fixed for case A in all release scenarios and for atmospheric case B. For atmospheric case C, and for the aquatic scenarios case B, site-specific input values were used by participants, if available.

For atmospheric dispersion, in addition to soil-to-crop transfer of ground deposited radioactivity there are factors to estimate interception onto leaves and, if another part in the plant is the edible, translocation to the dietary component from Ref. [21] were used. For the soil-pasture-animal flesh/milk transfer, ingestion rates for livestock were provided from Refs [21, 22].

The site-specific values in the parameters used in the models applied by the various participants when variability was allowed are provided in Annexes I-VII.

3.1.4 Time delay between production and consumption and effect of food preparation

In more realistic dose estimations, a time delay between the sampling/production and the consumption of any food is considered. Typical delay times used in the calculation of dose from atmospheric releases are 1 day for milk, 14 days for vegetables and up to 20 days for meat. However, for consistency, in this study it was agreed that no time delay is used except in cases where default values were applied within the individual models used.

Usual processes related to food production and preparation (such as washing, peeling, drying and heating) can reduce the amount of radioactivity consumed compared with the total activity in the basic food when it is collected. Despite that, the participants applied a conservative approach and avoided discrepancies due to differential dietary habits by applying no correction factors for food processing in these exercises.

3.2 SOURCE TERMS

This section provides information on the source terms for the release routes considered in the exercises.

3.2.1 Source term for atmospheric discharge

The source term data used for assessing radiation dose from an atmospheric release in this study was provided by the participant from Korea.

TABLE 10. ANNUAL ATMOSPHERIC RELEASE OF RADIONUCLIDES

Radionuclide	*Q*, Bq/a	Radionuclide	*Q*, Bq/a	Radionuclide	*Q*, Bq/a
H-3	3.44E+13	Kr-88	4.07E+11	Xe-135m	1.48E+11
C-14 (CO_2)	2.70E+11	Sr-89	5.92E+06	Xe-138	1.11E+11
Ar-41	1.26E+12	Sr-90	2.33E+06	I-131	1.37E+09
Cr-51	3.59E+06	Zr-95	3.70E+05	I-132	5.92E+09
Mn-54	2.11E+06	Nb-95	1.55E+06	I-133	4.07E+09
Fe-59	1.04E+06	Ru-103	6.29E+05	I-134	9.62E+09
Co-57	3.03E+05	Ru-106	2.89E+04	I-135	7.40E+09
Co-58	1.78E+07	Sb-125	2.26E+04	Cs-134	1.78E+06
Co-60	4.07E+06	Xe-131m	2.11E+13	Cs-136	1.22E+06
Kr-85	1.81E+14	Xe-133	3.00E+13	Cs-137	3.33E+06
Kr-85m	2.22E+11	Xe-133m	3.70E+11	Ba-140	1.55E+05
Kr-87	1.48E+11	Xe-135	1.59E+12	Ce-141	4.81E+05

Information on the radionuclides that would be released or discharged from the reactor was obtained from the analysis of normal operation conditions of APR-1400 which was performed using a mathematical code PWR-GALE [23] and data provided in ANSI/ANS-18.1-1984 [49]. From this, a dataset of annual releases for 36 radionuclides was derived as a source term for the atmospheric exposure pathway. The estimated activity values (Q, Bq/a) for the annual release of radionuclides via the stack of APR-1400 are provided in Table 10. This data set was used to estimate annual adult individual radiation dose via immersion, ground exposure, inhalation and ingestion of local food.

3.2.2 Source term for marine discharges

The source term data used in this study for assessing radiation dose from a release to the sea was provided by the participant from Korea. Information on the radionuclides that would be released or discharged in liquid form from the APR-1400 reactor at the normal operation conditions was obtained from analysis performed using PWR-GALE code [23] and data provided in ANSI/ANS-18.1-1984 [49]. Annual releases of 54 radionuclides were defined as a source term for the marine exposure pathway. The estimated activity values (Q, Bq/a) for the annual release of radionuclides from the APR-1400 reactor to the sea are provided in Table 11.

Activity concentrations at the point where dose is evaluated (1 km downstream from the release) are given in Section 3.3.

TABLE 11. ANNUAL MARINE RELEASE OF RADIONUCLIDES

Radionuclide	Q, Bq/a	Radionuclide	Q, Bq/a	Radionuclide	Q, Bq/a
H-3(HTO)	2.41E+13	Y-91	3.70E+06	I-131	7.03E+09
Na-24	3.00E+08	Y-93	1.55E+07	I-132	3.15E+08
P-32	6.66E+06	Zr-95	7.40E+07	I-133	3.70E+09
Cr-51	4.44E+08	Nb-95	9.62E+07	I-134	7.03E+07
Mn-54	2.85E+08	Mo-99	2.22E+08	I-135	1.63E+09
Fe-55	3.70E+08	Tc-99m	2.00E+08	Cs-134	1.26E+09
Fe-59	1.07E+08	Ru-103	6.29E+08	Cs-136	7.77E+07
Co-58	7.03E+08	Ru-106	8.51E+09	Cs-137	1.74E+09
Co-60	5.55E+08	Rh-103m	6.29E+08	Ba-135m	1.07E+09
Ni-63	6.29E+07	Rh-106m	8.14E+09	Ba-140	9.62E+08
Zn-65	4.44E+07	Ag-110	1.52E+07	La-140	1.22E+09
Br-84	1.33E+06	Ag-110m	1.59E+08	Ce-141	2.07E+07
Rb-88	1.04E+06	Sb-124	1.59E+07	Ce-143	4.81E+07
Sr-89	1.52E+07	Te-129m	1.59E+07	Ce-144	4.81E+08
Sr-90	1.55E+06	Te-129	1.26E+07	Pr-143	1.30E+07
Sr-91	3.44E+06	Te-131	4.07E+06	Pr-144	3.52E+08
Y-90	6.29E+05	Te-131m	2.29E+07	W-187	2.92E+07
Y-91m	2.04E+06	Te-132	6.66E+07	Np-239	6.66E+07

This data set was used to estimate annual doses to an adult member of the public from the consumption of marine fish and shellfish[16]. The biota was assumed to be collected at the point where does is evaluated (1 km downstream from the release).

3.2.3 Source term for riverine discharges

A typical data set for radionuclides released into a river was provided by the participant from Ukraine as a source term for dose estimation. Annual liquid discharge rates to a river were derived from the available data on liquid discharges from 11 pressurized light water cooled

[16] It was agreed that only dose from the consumption of marine fish and shellfish would be calculated.

reactors operated in Ukraine[17]. The measured liquid discharges were normalized (averaged) to an assumption of a single 1 GW power unit. This normalization provided the generic values of annual liquid discharge of radionuclides to a river.

Annual releases of 16 radionuclides were defined as a source term for the riverine exposure pathway. The estimated activity values (*Q*, Bq/a) for the annual release of radionuclides from a 1 GW pressurized light water cooled reactor to a river are provided in Table 12.

Activity concentrations at the point where doses are evaluated are given in Section 3.3.

TABLE 12. ANNUAL RELEASE OF RADIONUCLIDES TO A RIVER

Radionuclide	*Q*, Bq/a	Radionuclide	*Q*, Bq/a
H-3	1.4E+12	Zr-95	8.3E+06
Cr-51	2.1E+07	Nb-95	5.4E+06
Mn-54	2.9E+06	Ru-106	3.7E+07
Fe-59	5.1E+06	Ag-110m	4.3E+06
Co-58	2.8E+06	I-131	4.3E+07
Co-60	6.1E+06	Cs-134	6.8E+06
Zn-65	9.8E+06	Cs-137	1.1E+07
Sr-90	1.1E+07	Ce-144	1.5E+07

For the riverine scenario, dose from the consumption of fish was used. The fish was assumed to be caught at the point where dose was estimated (1 km downstream from the release).

3.3 FIXED PARAMETERS USED FOR CALCULATION OF CASE A

In addition to the source term presented above the same set of predefined input data and modelling parameters has been used by all national experts for ‘case A’ calculations in this exercise. Input data and modelling parameters used for case A are presented below in this Section, for atmospheric releases and aquatic (marine and riverine) releases.

The modelling parameters and input data have been proposed, discussed and agreed among the participants of this study or taken from Ref. [21], unless otherwise indicated in the tables below. Several parameters (noted below) in the models were updated using data from Refs [14, 22, 30].

3.3.1 Atmospheric discharges

Input data used for modelling of atmospheric transport and deposition of radionuclides are presented in Table 13, including the long term (1 year) atmospheric diffusion coefficient (minimum dilution value, $4.705\cdot10^{-8}$ s/m^3, at 10 km from the source). Crop and soil exposure periods, food and forage parameters, human inhalation and consumption rates are provided in Table 14. Consumption rates of vegetables is provided according to Ref. [21] and shares of different types of vegetables were evaluated according to [31]. Element specific concentration factors for uptake of the radionuclide from soil by edible parts of crops and uptake factors from feed to milk and meat are provided in Table 15 [22]. Effective dose coefficients for different radionuclides for the cloud immersion, surface deposits, inhalation and ingestion scenarios are provided in Table 16.

[17] Ukraine operates 15 VVER type reactors (PWRs of Russian design) at 4 different sites. Data from the Rivne NPP operating 4 reactors have not been considered because 2 of these reactors have lower installed capacity.

TABLE 13. ATMOSPHERIC TRANSPORT AND DEPOSITION

Characteristics		Values
Total duration of the discharge of radioactive material (for build up), a		50
Wind speed, m/s		2
Distance to receptor location, km		10
Transport time, s		500
Long term atmospheric diffusion coefficient (χ/Q), s/m^3		4.705E-08
Deposition coefficient (for aerosols only), m/d		1000
Dry soil density, kg/m^3		1300
Depth of top mixed soil layer (pasture), m		0.1
Fraction of deposited activity intercepted by the edible portion of vegetation, m^2/kg	Forage vegetation (dry weight)	3
	Food crops (wet weight)	0.3
Environmental removal rate for all plant surfaces, 1/d		0.05

TABLE 14. CROP AND SOIL EXPOSURE PERIODS, VEGETABLE PARAMETERS, INHALATION AND CONSUMPTION RATES

Characteristics		Values
Time period that crops are exposed to contamination during the growing season, d	Forage grasses	30
	Food crops	60
Average dry matter content, %/100	Green vegetables	0.076
	Root vegetables	0.143
	Domestic fruits	0.135
Amount of feed (dry matter) consumed by the animal, kg/d	Sheep	1.6
	Milk cow [22]	16
Human consumption rate	Milk (cow), l/a	250
	Meat (cow), kg/a	100
	Green vegetables, kg/a	115
	Root vegetables, kg/a	187
	Domestic fruits, kg/a	108
Human inhalation rate, m^3/a		8400

TABLE 15. CONCENTRATION FACTORS FOR UPTAKE OF RADIONUCLIDES FROM SOIL BY CROPS AND UPTAKE FACTORS FROM FEED TO MILK AND MEAT [22]

Element	Soil-to-plant transfer coefficients (Bq/kg dry weight) per (Bq/kg dry soil)			Fraction of the animal's daily intake of the radionuclide	
	leafy vegetables	non-leafy vegetables	root vegetables	In milk at equilibrium, d/l	In flesh at equilibrium or at slaughter, d/kg
Cr	1.0E-03	1.0E-03	1.0E-03	4.3E-04	9.0E-02
Mn	4.1E-01	3.1E-01	4.2E-01	4.1E-05	6.0E-04
Fe	1.0E-03	1.0E-03	1.0E-03	3.5E-05	1.4E-02
Co	1.7E-01	1.4E-01	1.1E-01	1.1E-04	4.3E-04
Sr	7.6E-01	3.6E-01	7.2E-01	1.3E-03	1.3E-03
Zr	4.0E-03	4.0E-03	4.0E-03	3.6E-06	1.2E-06
Nb	1.7E-02	8.0E-03	1.7E-02	4.1E-07	2.6E-07
Ru	9.0E-02	2.0E-02	1.0E-02	9.4E-06	3.3E-03
Sb	9.4E-05	1.3E-04	6.2E-04	3.8E-05	1.2E-03
I	6.5E-03	1.0E-01	7.7E-03	5.4E-03	6.7E-03
Cs	6.0E-02	2.1E-02	4.2E-02	4.6E-03	2.2E-02
Ba	5.0E-03	5.0E-03	5.0E-03	1.6E-04	1.4E-04
Ce	6.0E-03	n/a	6.0E-03	2.0E-05	2.0E-04 [21]

TABLE 16. EFFECTIVE DOSE COEFFICIENTS FOR RADIONUCLIDES

Radionuclide	Cloud immersion, Sv/a per Bq/m^3	Surface deposits, Sv/a per Bq/m^2	Inhalation, Sv/Bq	Ingestion, Sv/Bq
H-3	n/a	0	1.8E-11 [37]	1.8E-11 [37]
C-14	n/a	0	6.2E-12 [37]	5.8E-10 [37]
Cr-51	4.8E-8 [22]	9.8E-10 [22]	3.7E-11	3.8E-11
Mn-54	1.3E-6 [22]	2.6E-8 [22]	1.5E-9	7.1E-10
Fe-59	1.9E-6 [22]	3.6E-8 [22]	4.0E-9	1.8E-9
Co-57	n/a	n/a	1.0E-9 [37]	2.1E-10 [37]
Co-58	1.5E-6 [22]	3.0E-8 [22]	2.1E-9	7.4E-10
Co-60	4.5E-6 [22]	7.5E-8 [22]	3.1E-8	3.4E-9
Sr-89	1.4E-8 [22]	2.2E-9 [22]	7.9E-9	2.6E-9
Sr-90	3.1E-9 [22]	3.5E-9 [22]	1.6E-7	2.8E-8
Zr-95	1.1E-6 [22]	4.7E-8 [22]	5.9E-9	9.5E-10
Nb-95	1.2E-6 [22]	2.4E-8 [22]	1.8E-9	5.8E-10
Ru-103	7.2E-7 [22]	1.5E-8 [22]	3.0E-9	7.3E-10
Ru-106	3.6E-7 [22]	1.1E-8 [22]	6.6E-8	7.0E-9
Sb-125	6.5E-7 [22]	1.4E-8 [22]	1.2E-8	1.1E-9
I-131	5.8E-7 [22]	1.2E-8 [22]	7.4E-9	2.2E-8
I-132	3.6E-6 [22]	7.2E-8 [22]	9.4E-11 [37]	2.9E-10
I-133	9.5E-7 [22]	2.0E-8 [22]	1.5E-9	4.3E-9
I-134	4.2E-6 [22]	8.3E-8 [22]	4.5E-11	1.1E-10
I-135	2.6E-6 [22]	4.8E-8 [22]	3.2E-10	9.3E-10
Cs-134	2.4E-6 [22]	4.9E-8 [22]	6.6E-9	1.9E-8
Cs-136	3.4E-6 [22]	6.7E-8 [22]	1.2E-9	3.0E-9
Cs-137	8.7E-7 [22]	1.8E-8 [22]	4.6E-9	1.3E-8
Ba-140	n/a	0 [39]	5.1E-9 [37]	2.6E-9 [37]
Ce-141	n/a	2.4E-9 [22]	3.8E-9	7.1E-10
Ar-41	1.9E-6	n/a	n/a	n/a
Kr-85	8.0E-9	n/a	n/a	n/a
Kr-85m	2.2E-7	n/a	n/a	n/a
Kr-87	1.2E-6	n/a	n/a	n/a
Kr-88	3.1E-6	n/a	n/a	n/a
Xe-131m	1.2E-8	n/a	n/a	n/a
Xe-133	4.4E-8	n/a	n/a	n/a
Xe-133m	4.0E-8	n/a	n/a	n/a
Xe-135	3.5E-7	n/a	n/a	n/a
Xe-135m	5.8E-7	n/a	n/a	n/a
Xe-138	1.7E-6	n/a	n/a	n/a

ICRP Publication 72 [37] gives inhalation dose coefficients for three lung absorption classes – F, M, and S (Fast, Moderate, and Slow absorption of deposited material from the respiratory tract into the blood) – for most nuclides. The values in Table 16 are for Type S which is usually the most conservative.

3.3.2 Marine discharges

The annual marine discharges defined in the source term were used to calculate activity concentrations (Bq/m^3) in seawater at 1 km from the point of release. The results of calculation are provided in Table 17. The estimates of activity concentration were based on a discharge flow rate of 2.14E+09 m^3/a, dilution factor of 31.4 and travel time of 1.4 hours allowing for radioactive decay correction based on the half-lives of the radionuclides (see Table 17).

The input data used for the marine scenario are given as activity concentrations calculated at the point of interest for assessing the doses. Removal mechanisms are not considered.

TABLE 17. ESTIMATED AVERAGE ACTIVITY CONCENTRATIONS IN WATER AT 1 KM FROM RELEASE

Radionuclide	Half-life, s	Activity concentr., Bq/m^3	Radionuclide	Half-life, s	Activity concentr., Bq/m^3
H-3 (HTO)	3.90E+08	3.59E+02	Rh-106m	1.27E+05	1.18E-01
Na-24	5.40E+04	4.19E-03	Ag-110	2.46E+01	4.95E-66
P-32	1.24E+06	9.91E-05	Ag-110m	2.16E+07	2.37E-03
Cr-51	2.39E+06	6.61E-03	Sb-124	5.20E+06	2.37E-04
Mn-54	2.70E+07	4.25E-03	Te-129m	2.90E+06	2.37E-04
Fe-55	8.52E+07	5.52E-03	Te-129	4.18E+03	8.14E-05
Fe-59	3.85E+06	1.59E-03	Te-131	1.50E+03	5.93E-06
Co-58	6.12E+06	1.05E-02	Te-131m	1.08E+05	3.31E-04
Co-60	1.66E+08	8.28E-03	Te-132	2.82E+05	9.81E-04
Ni-63	3.03E+09	9.38E-04	I-131	6.95E+05	1.04E-01
Zn-65	2.11E+07	6.62E-04	I-132	8.28E+03	3.08E-03
Br-84	1.91E+03	3.18E-06	I-133	7.49E+04	5.27E-02
Rb-88	1.00E+03	4.78E-07	I-134	3.15E+03	3.46E-04
Sr-89	4.36E+06	2.27E-04	I-135	2.38E+04	2.10E-02
Sr-90	9.18E+08	2.31E-05	Cs-134	6.50E+07	1.88E-02
Sr-91	3.42E+04	4.63E-05	Cs-136	1.13E+06	1.16E-03
Y-90	2.31E+05	9.24E-06	Cs-137	9.46E+08	2.60E-02
Y-91m	2.98E+03	9.43E-06	Ba-135m	1.53E+02	1.97E-12
Y-91	5.05E+06	5.52E-05	Ba-140	1.10E+06	1.43E-02
Y-93	3.64E+04	2.10E-04	La-140	1.45E+05	1.78E-02
Zr-95	5.53E+06	1.10E-03	Ce-141	2.81E+06	3.08E-04
Nb-95	3.03E+06	1.43E-03	Ce-143	1.19E+05	6.97E-04
Mo-99	2.38E+05	3.26E-03	Ce-144	2.45E+07	7.17E-03
Tc-99m	2.17E+04	2.54E-03	Pr-143	1.18E+06	1.93E-04
Ru-103	3.40E+06	9.37E-03	Pr-144	1.04E+03	1.81E-04
Ru-106	3.19E+07	1.27E-01	W-187	8.60E+04	4.18E-04
Rh-103m	1.79E+07	9.38E-03	Np-239	2.04E+05	9.77E-04

TABLE 18. EQUILIBRIUM RATIO OF THE CONCENTRATION OF RADIONUCLIDE IN AQUATIC FOOD TO ITS DISSOLVED CONCENTRATION IN SEAWATER

Element	Bioaccumulation factor, Bq/kg per Bq/l		Element	Bioaccumulation factor, Bq/kg per Bq/l		Element	Bioaccumulation factor, Bq/kg per Bq/l	
	Fish	Shellfish		Fish	Shellfish		Fish	Shellfish
H	0	0	Rb	100	20	Sb	400	400
Na	0.1	0.3	Sr	2	2	Te	30	1000
P	30000	20000	Y	20	1000	I	10	10
Cr	200	800	Zr	20	5000	Cs	100	30
Mn	400	5000	Nb	30	1000	Ba	10	1
Fe	3000	33000	Mo	10	100	La	0	0
Co	1000	5000	Tc	30	1000	Ce	50	5000
Ni	1000	2000	Ru	2	2000	Pr	0	0
Zn	1000	50000	Rh	100	1000	W	0	0
Br	3	10	Ag	500	10000	Np	10	400

It was agreed that only dose from the consumption of marine fish and shellfish would be calculated. The biota was assumed to be collected at the point of dose evaluation. The bioaccumulation factors for the various radionuclides into fish and shellfish [22] are given in Table 18. Information on adult consumption rates and other relevant food parameters [21, 22] are given in Table 19; it was assumed that there was no delay between collection and consumption and that no radioactivity was increased by concentration or lost during the process of food preparation. Dose coefficients for ingestion from Ref. [3], were used to estimate annual adult dose from fish and shellfish consumption (Table 20).

TABLE 19. CONSUMPTION RATES AND OTHER FOOD PARAMETERS

Parameter		Value
Consumption rate (fresh), kg/a	Fish	50
	Shellfish	15
Fraction of produce from contaminated source, %/100	Fish	1
	Shellfish	1
Modifying factor for food processing, %/100	Fish	1
	Shellfish	1

TABLE 20. COMMITTED EFFECTIVE DOSE COEFFICIENTS (DF) FOR INGESTION

Radionuclide	*DF*, Sv/Bq	Radionuclide	*DF*, Sv/Bq	Radionuclide	*DF*, Sv/Bq
H-3 (HTO)	1.80E-11	Y-91	2.40E-09	I-131	2.20E-08
Na-24	4.30E-10	Y-93	1.20E-09	I-132	2.90E-10
P-32	2.40E-09	Zr-95	9.50E-10	I-133	4.30E-09
Cr-51	3.80E-11	Nb-95	5.80E-10	I-134	1.10E-10
Mn-54	7.10E-10	Mo-99	6.00E-10	I-135	9.30E-10
Fe-55	3.30E-10	Tc-99m	2.20E-11	Cs-134	1.90E-08
Fe-59	1.80E-09	Ru-103	7.30E-10	Cs-136	3.00E-09
Co-58	7.40E-10	Ru-106	7.00E-09	Cs-137	1.30E-08
Co-60	3.40E-09	Rh-103m	3.80E-12	Ba-135m	4.30E-10
Ni-63	1.50E-10	Rh-106m	1.60E-10	Ba-140	2.60E-09
Zn-65	3.90E-09	Ag-110	0	La-140	2.00E-09
Br-84	8.80E-11	Ag-110m	2.80E-09	Ce-141	7.10E-10
Rb-88	9.00E-11	Sb-124	2.50E-09	Ce-143	1.10E-09
Sr-89	2.60E-09	Te-129m	3.00E-09	Ce-144	5.20E-09
Sr-90	2.80E-08	Te-129	6.30E-11	Pr-143	1.20E-09
Sr-91	6.50E-10	Te-131	8.70E-11	Pr-144	5.00E-11
Y-90	2.70E-09	Te-131m	1.90E-09	W-187	6.30E-10
Y-91m	1.10E-11	Te-132	3.80E-09	Np-239	8.00E-10

3.3.3 Riverine discharges

The total annual riverine discharges were used as the source term to estimate the radionuclide activity concentrations (Bq/l) in water at 1 km downstream from the release. Estimated average activity concentrations in filtered, i.e. bioavailable, river water (corrected for sediment-water partitioning using distribution coefficients [21] from Table 21) at the consumption location, 1 km downstream from the release, are provided in Table 22.

For the models calculating activity concentrations the basic river characteristics used are provided in Table 23. Partial mixing index (A) value was calculated as $A = 1.5 \cdot D \cdot x / B^2$, where D - river depth, x - longitudinal distance from the discharge point to a potential receptor location, B - river width. River partial mixing coefficient value was obtained from Table IV of Ref. [21] using a linear interpolation between precalculated values.

For the estimation of radiation dose from the fish consumption by adults the fish was assumed to be collected at the location where dose to the representative person is assessed (1 km downstream). The bioaccumulation factors (taken from Ref. [22]) provided in Table 21 can be used to estimate activity concentrations in the fish. The consumption data and other factors associated with the processing of food are presented in Table 23. Dose coefficients for ingestion from Ref. [3] were used to estimate annual adult dose from riverine fish consumption (see Table 24).

The input data used for the riverine scenario are given as activity concentrations at the point of interest for assessing the doses. Removal mechanisms are not considered.

TABLE 21. DISTRIBUTION COEFFICIENTS AND BIOACCUMULATION FACTORS

Element	Distribution coefficient, l/kg	Bioaccumulation factor, Bq/kg per Bq/l	Element	Distribution coefficient, l/kg	Bioaccumulation factor, Bq/kg per Bq/l
H	0	–	Zr	1 000	95
Cr	10 000	200	Nb	–	300
Mn	1 000	450	Ru	500	10
Fe	5 000	140	Ag	–	110
Co	5 000	400	I	10	650
Zn	500	4700	Cs	1 000	3000
Sr	1 000	190	Ce	10 000	12

TABLE 22. ACTIVITY CONCENTRATIONS IN FILTERED RIVER WATER AT 1 KM DOWNSTREAM FROM RELEASE

Radionuclide	Activity concentr., Bq/m^3	Radionuclide	Activity concentr., Bq/m^3	Radionuclide	Activity concentr., Bq/m^3
H-3	2.78E+03	Co-60	9.68E-03	Ru-106	7.16E-02
Cr-51	2.78E-02	Zn-65	1.90E-02	Ag-110m	8.53E-03
Mn-54	5.48E-03	Sr-90	2.08E-02	I-131	8.51E-02
Fe-59	8.09E-03	Zr-95	1.57E-02	Cs-134	1.28E-02
Co-58	4.44E-03	Nb-95	1.07E-02	Cs-137	2.08E-02
				Ce-144	1.98E-02

TABLE 23. BASIC RIVER CHARACTERISTICS, CONSUMPTION RATE AND OTHER FOOD PARAMETERS

Characteristics	Values
Mean annual river flow rate, m^3/a	1.25E+09
River depth, m	2
River width, m	50
Freshwater velocity, m/s	0.4
Longitudinal distance from the discharge point to a potential receptor location, m	1 000
Partial mixing index	1.2[a]
River partial mixing coefficient	2.48[b]
Water intake, m^3/a	0.6
Freshwater fish consumption (fresh), kg/a	30
Fraction of fish from contaminated source	1
Modifying factor for food processing	1

a - calculated as $A=1.5 \cdot D \cdot x/B^2$

b - linear interpolation of data provided in Ref. [21]

TABLE 24. COMMITTED EFFECTIVE DOSE COEFFICIENTS (DF) FOR INGESTION

Radionuclide	*DF*, Sv/Bq	Radionuclide	*DF*, Sv/Bq	Radionuclide	*DF*, Sv/Bq
H-3	1.8E-11	Co-60	3.4E-09	Ru-106	7.0E-09
Cr-51	3.8E-11	Zn-65	3.9E-09	Ag-110m	2.8E-09
Mn-54	7.1E-10	Sr-90	2.8E-08	I-131	2.2E-08
Fe-59	1.8E-09	Zr-95	9.5E-10	Cs-134	1.9E-08
Co-58	7.4E-10	Nb-95	5.8E-10	Cs-137	1.3E-08
				Ce-144	5.2E-09

3.4 RANKING OF RADIONUCLIDES

3.4.1 Basic ranking scheme

A mandatory requirement for every nuclear facility is to comply with the annual dose limits required by the national regulatory authority. Hence, it is also prudent to identify the key radionuclides that contribute to the total dose by ranking them on their relative dose contribution so as to prioritize management actions. Such an exercise would not only enable the operators to identify the exposure pathway that is resulting in higher doses but also aid in implementing nuclide-specific filtrations or removal systems, should they be required. As noted in 5.1.3, the exercise should consider all discharges via atmospheric, marine and river systems.

Discharges from any nuclear facility results in radiation dose to the general public through several pathways. For example, discharge of particulate radioactivity into the atmosphere results in doses through inhalation, ingestion, plume shine and ground shine from deposited activity. While noble gases contribute only through plume exposure, their contribution to the other pathways of exposure would be zero. Considering these differences, in this exercise it was decided to rank radionuclides based on their total dose contributions from all exposure pathways under any scenario.

The annual dose from each radionuclide under each pathway of exposure was estimated. The ranking of the radionuclides (from highest to lowest dose) was based on their relative contribution to the total dose. The exercise was undertaken for all three cases of atmospheric discharge and two cases each for marine and riverine discharges. In the case of atmospheric and riverine discharges, all the radionuclides considered in the release were included in the ranking exercise. In the case of marine discharges, since many of the radionuclides in the source term resulted in contributions of less than a hundredth of a percentage, it was decided to choose only the top ten radionuclides for the ranking exercise.

3.4.2 Alternative ranking scheme

Initial observations of the ranked radionuclides showed marked differences between results of different participants. However, much of this variability was due to differences in radionuclide dose contributions that were within a fraction of a percent of the total dose. Such small differences were mostly well within the uncertainties of the estimates. Hence an alternative method for ranking the radionuclides was also proposed. Under this method, it was decided that radionuclides whose relative contribution to the total dose is less than 0.5% were excluded. The remaining radionuclides were ranked into arbitrary class-sizes (based on % contribution to total dose) that evolved during the exercise (Table 25.).

TABLE 25. ALTERNATIVE RANKING SCHEME - RANGE SUGGESTED RANKING

Ranking notation	Range	Ranking notation	Range
A_{100}	100% to 75%	E_{25}	25% to 10%
B_{75}	75% to 50%	F_{10}	10% to 5%
C_{50}	50% to 33%	G_{5}	5% to 2%
D_{33}	33% to 25%	H_{2}	2% to 0.5%

Note: Radionuclides with contribution less than 0.5% of the total are not considered in the ranking.

4 COMPARISON OF MODELS RESULTS AND RADIONUCLIDE RANKING

This section provides a comparison of the major results from the modelling performed by each participant. Detailed information on the individual approaches, results obtained, and rankings performed, can be found in Annexes I-VII.

4.1 COMPARISON OF RESULTS FOR TOTAL DOSE

For each of the exposure scenarios, Table 26 provides the estimations of total dose (i.e. all exposure pathways combined) given by each of the seven participants. The results of case studies for each release scenario (i.e. 'Atm' for atmospheric; 'Mar' for marine; and 'Riv' for riverine) are presented adjacent to each other. Cases A represent the comparisons where major inputs were fixed and only the model differed.

TABLE 26. TOTAL DOSE ESTIMATES BY ALL PARTICIPANTS FOR EACH CASE (ATMOSPHERIC, MARINE AND RIVERINE EXPOSURES)

		Total dose ($\mu Sv \cdot a^{-1}$)						
	Model used	Atm A	Atm B	Atm C	Mar A	Mar B	Riv A	Riv B
1	PC CREAM	2.25E-02	2.51E-02	9.15E-03			3.99E-02	5.80E-03
2	AERB/NF/SG/S-5	1.05E-01	4.90E-02	5.77E-02	4.75E-02	1.54E-02	1.00E-01	3.55E-02
3	INDAC	1.40E-01	9.55E-02	1.73E-01	1.13E-01	6.10E-02		
4	SRS 19	1.76E-02	6.44E-03	1.88E-02	4.75E-02	1.85E-03	9.73E-02	1.55E-02
5	SRS 19	4.70E-02	1.90E-01	2.70E-02	2.90E-02	2.90E-02	9.70E-02	1.20E-02
6	CERES	1.00E-01	3.37E-02	1.15E-01			1.64E-02	3.27E-03
7	SRS 19	3.65E-02	4.90E-02	3.53E-02	4.75E-02	4.75E-02	1.00E-01	1.36E-02

The first important observation to note is that, even with realistic source terms (based on actual nuclear installations) and very conservative assumptions for the dose assessment, all the adult doses estimations are much lower (by orders of magnitude), than internationally recommended public dose limit of 1 mSv per year [3]. This result is generally observed for NPPs worldwide under normal operation.

For Case A, when the inputs and parameters were the same for all participants and only the type of model changed, it can be noted that the total dose estimates for the atmospheric scenario and the two aquatic scenarios have a variation within 1 order of magnitude.

Even when the participants were applying the same model set (such as those using the methodology in Ref. [21]) the results varied by up to a factor of 3. This points to the sensitivity of the models to 'user-effects' and reinforces the need to be always conservative in any human dose assessment for environmental releases.

The variability between models and the user-effects was analyzed using the radionuclides contributing more significantly to the total dose. Table 27 shows the top 10 radionuclides contributing to annual adult dose from atmospheric dispersion as estimated by each of the participants. Three participants found ^{14}C to be the major contributor whereas the others did not identify that radionuclide at all as an important contributor. This is a direct consequence of the model choice (as some models consider ^{14}C and others did not).

Apart from C-14 discrepancies, most of the participants identified ^{131}I as the next most significant contributor, followed by ^{3}H. Nonetheless, some models provided distinct contrasts. PC-CREAM inverted the order for ^{3}H and ^{131}I reached 6 other participants, and the INDAC model assigned ^{131}I as the 6th ranked radionuclide, contributing less than 1% of the total annual adult dose compared to others that had it providing almost 70% of the annual dose. Even for the 3 participants using the same methods in Ref. [21] the dose from ^{131}I was identified as the most substantial contributor in each case but the proportion of total dose due to that radionuclide ranged from 37% to 69%.

TABLE 27. RADIONUCLIDES CONTRIBUTING MOST TO THE TOTAL ADULT DOSE AND THEIR RELATIVE CONTRIBUTION, %. ATMOSPHERIC CASE A

	Rank									
	1	2	3	4	5	6	7	8	9	10
PC-CREAM	C-14 (47.46)	H-3 (43.03)	I-131 (3.68)	I-134 (0.78)	I-133 (0.75)	Kr-85 (0.74)	I-135 (0.71)	I-132 (0.58)	Ar-41 (0.44)	Xe-133 (0.41)
AERB/ NF/SG/ S-5	C-14 (51.29)	I-131 (20.66)	H-3 (17.77)	Kr-85 (2.07)	Ar-41 (1.99)	Xe-133 (1.85)	Kr-88 (1.26)	I-133 (1.02)	Xe-135 (0.71)	Xe-131m (0.35)
INDAC	C-14 (62.93)	H-3 (30.05)	Kr-85 (1.33)	Xe-133 (1.19)	Ar-41 (1.11)	I-131 (0.78)	Kr-88 (0.73)	Co-57 (0.63)	Xe-135 (0.45)	Xe-131m (0.23)
SRS 19	I-131 (69.1)	H-3 (7.67)	I-133 (7.67)	Ar-41 (3.53)	Kr-85 (2.14)	Xe-133 (1.94)	Kr-88 (1.84)	Co-60 (1.28)	I-135 (1.1)	Cs-137 (1.08)
SRS 19	I-131 (57.0)	H-3 (16.0)	Kr-85 (4.6)	Ar-41 (4.5)	Xe-133 (4.1)	Kr-88 (2.8)	Co-60 (2.0)	I-133 (1.6)	Xe-135 (1.6)	Cs-137 (1.5)
CERES	I-131 (58.2)	H-3 (10.4)	I-133 (6.6)	Co-60 (4.3)	Cs-137 (3.9)	Kr-85 (3.0)	Ar-41 (2.9)	Xe-133 (2.7)	Kr-88 (1.8)	I-135 (1.2)
SRS 19	I-131 (37.0)	H-3 (21.0)	Ar-41 (9.8)	Kr-85 (5.9)	Xe-133 (5.4)	Kr-88 (5.1)	Co-60 (3.6)	Xe-135 (2.3)	Cs-137 (1.83)	Sr-90 (1.3)

TABLE 28. RADIONUCLIDES CONTRIBUTING MOST TO THE TOTAL ADULT DOSE AND THEIR RELATIVE CONTRIBUTION, %. MARINE CASE A

	Rank									
	1	2	3	4	5	6	7	8	9	10
PC-CREAM[a]	-	-	-	-	-	-	-	-	-	-
AERB/ NF/SG/S-5	Ru-106 (56.4)	Co-60 (7.4)	Ce-144 (6.1)	Zn-65 (4.4)	Cs-134 (4.1)	Fe-59 (3.9)	Cs-137 (3.9)	I-131 (3.1)	Fe-55 (2.5)	Ag-110m (2.4)
INDAC	Ru-106 (56.9)	Co-60 (7.5)	Ce-144 (6.2)	Zn-65 (4.4)	Cs-134 (4.2)	Cs-137 (3.9)	Fe-59 (3.8)	I-131 (2.7)	Fe-55 (2.5)	Ag-110m (2.5)
SRS 19	Ru-106 (56.4)	Co-60 (7.4)	Ce-144 (6.1)	Zn-65 (4.4)	Cs-134 (4.1)	Fe-59 (3.9)	Cs-137 (3.9)	I-131 (3.1)	Fe-55 (2.5)	Ag-110m (2.5)
SRS 19	Ru-106 (66.0)	Cs-134 (6.4)	Cs-137 (6.1)	I-131 (5.1)	Zn-65 (4.2)	Ag-110m (3.6)	Co-60 (3.0)	P-32 (1.5)	Rh-106m (1.3)	Co-58 (0.84)
CERES[a]	-	-	-	-	-	-	-	-	-	-
SRS 19	Ru-106 (56.0)	Co-60 (7.4)	Ce-144 (6.1)	Zn-65 (4.4)	Cs-134 (4.1)	Fe-59 (3.9)	Cs-137 (3.9)	I-131 (3.1)	Fe-55 (2.5)	Ag-110m (2.4)

[a] - Participants 1 and 6 did not evaluate a marine scenario.

For the marine scenario (Table 28), ^{106}Ru provided most of the annual adult dose estimated by all participants using identical input data, due to its significant activity concentration together with its biological transfer coefficient. However, the proportion contributed by that radionuclide still ranged from 56% to 66%, even for modellers using the same approach in Ref. [21]. There was some variability between the other radionuclide contributions but, given the dominance of ^{106}Ru, those differences could be considered minor.

TABLE 29. RADIONUCLIDES CONTRIBUTING MOST TO THE TOTAL ADULT DOSE AND THEIR RELATIVE CONTRIBUTION, %. RIVERINE CASE A

	Rank									
	1	2	3	4	5	6	7	8	9	10
PC-CREAM	I-131 (36.8)	Cs-137 (24.6)	Cs-134 (22.2)	Zn-65 (10.6)	Sr-90 (3.4)	H-3 (1.5)	Co-60 (0.4)	Ru-106 (0.2)	Ag-110m (0.08)	Fe-59 (0.06)
AERB/ NF/SG/S-5	I-131 (36.4)	Cs-137 (25.4)	Cs-134 (23.0)	Zn-65 (10.7)	Sr-90 (3.5)	Co-60 (0.5)	Ru-106 (0.2)	Ag-110m (0.1)	Fe-59 (0.1)	Nb-95 (0.1)
INDAC[a]	-	-	-	-	-	-	-	-	-	-
SRS 19	I-131 (37.5)	Cs-137 (25.0)	Cs-134 (22.6)	Zn-65 (10.7)	Sr-90 (3.4)	Co-60 (0.41)	Ru-106 (0.16)	Fe-59 (0.06)	Mn-54 (0.05)	Zr-95 (0.04)
SRS 19	I-131 (37.0)	Cs-137 (25.0)	Cs-134 (23.0)	Zn-65 (11.0)	Sr-90 (3.4)	Co-60 (0.41)	Ru-106 (0.15)	Ag-110m (0.08)	Fe-59 (0.06)	Nb-95 (0.06)
CERES	Cs-137 (41.8)	Cs-134 (37.8)	Zn-65 (5.6)	I-131 (5.5)	H-3 (3.7)	Sr-90 (2.7)	Co-60 (0.9)	Ru-106 (0.4)	Zr-95 (0.4)	Ce-144 (0.3)
SRS 19	I-131 (36.0)	Cs-137 (25.0)	Cs-134 (23.0)	Zn-65 (11.0)	Sr-90 (3.5)	Co-60 (0.5)	Ru-106 (0.2)	Ag-110m (0.08)	Fe-59 (0.08)	Nb-95 (0.06)

[a] - Participant 3 did not evaluate a riverine scenario.

There was also variability under the riverine scenario (Table 29). Whilst all participants identified ^{131}I and the Cs radioisotopes as contributing more than 80% to the annual adult dose, the contribution estimated for ^{131}I by the Abricot CEA (CERES) model dropped from the most prominent (<40%) to the 4th position contributing <6%. A lowly-ranked contribution from ^{3}H was identified by 2 participants (using the PC-CREAM and Abricot CEA (CERES) models) but not by others.

4.2 ATMOSPHERIC DISCHARGES

4.2.1 Atmospheric case A

Figure 3 shows the results of for each participant for the total dose for all pathways for each nuclide and the overall total dose. There is a spread of about two orders of magnitude for most nuclides although the spread in the total dose is less than one order of magnitude. For C-14 the spread is over 4 orders of magnitude reflecting the differing approaches used for this nuclide by the participants. The Co-57 result from the participant from Republic of Korea is several orders of magnitude higher than those from the other participants but this nuclide does not make a significant contribution to the total result.

Figure 4 shows the breakdown of the total dose by pathway for each participant. For all participants apart from the one from Indonesia, ingestion is the pathway that makes the biggest contribution to the total. The participants from France, India, Indonesia, Republic of Korea have roughly similar doses for inhalation and immersion but different contributions for the ingestion pathways and external exposure; this suggests the differences between these participants might arise from differing treatments of deposition and transfer of radionuclides into the foodchain. The differences between the results from these participants (France, India, Indonesia, Republic of Korea) and those from the others (Belarus and Russian Federation) might arise from the atmospheric dispersion modelling since this will affect all pathways. The participant from the Republic of Korea has a much larger contribution from meat ingestion than the other participants and this is mainly responsible for the total dose from this participant being the highest overall.

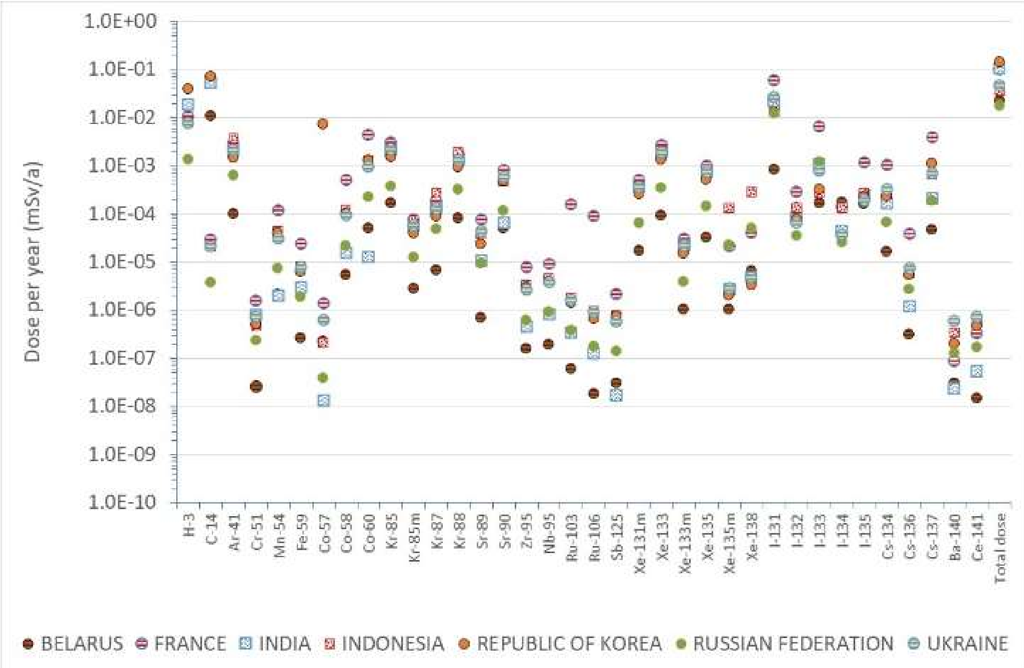

FIG. 3. Summary of results showing dose for each nuclide and the total dose for each participant (logarithmic scale). Atmospheric case A

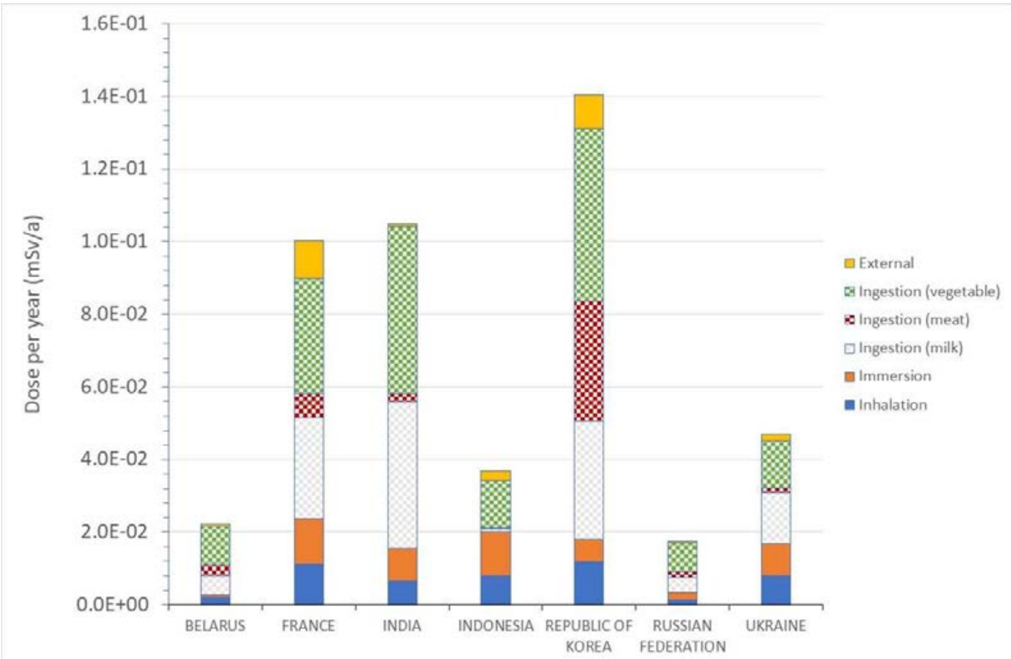

FIG. 4. Summary of results showing total dose for each participant broken down by pathway (linear scale). Atmospheric case A

Figure 5 shows the breakdown of the total dose by the main nuclides for each participant. There is a large variation between the participants in the contributions from C-14 and H-3 although I-131 seems to be a significant contributor for all participants apart from the one from Belarus.

To try and better understand where these differences are arising, the nuclide contributions for each pathway were examined. This is shown in Figures 6-11 for the six pathways.

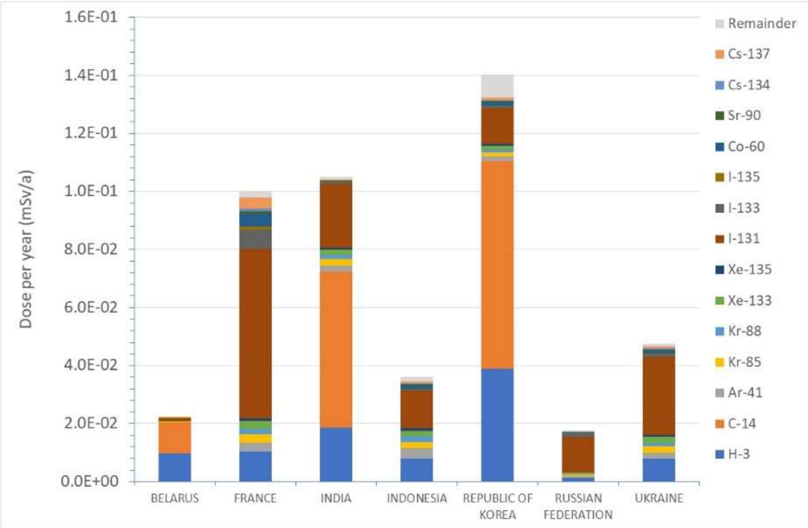

FIG. 5. Summary of results showing total dose for each participant broken down by nuclide (linear scale). Atmospheric case A

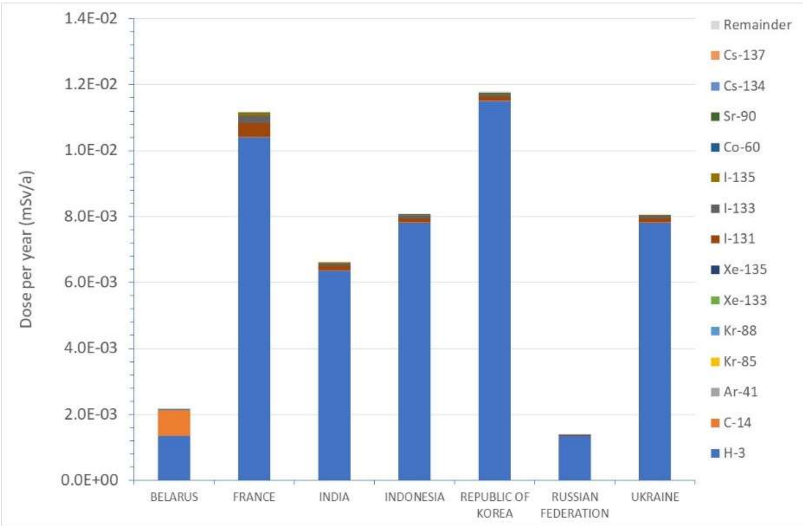

FIG. 6. Summary of results showing inhalation dose for each participant broken down by nuclide (linear scale). Atmospheric case A

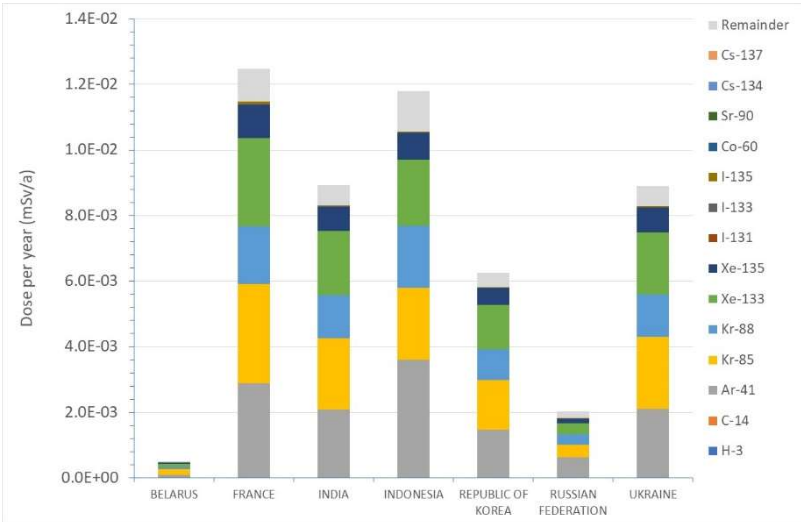

FIG. 7. Summary of results showing immersion dose for each participant broken down by nuclide (linear scale). Atmospheric case A

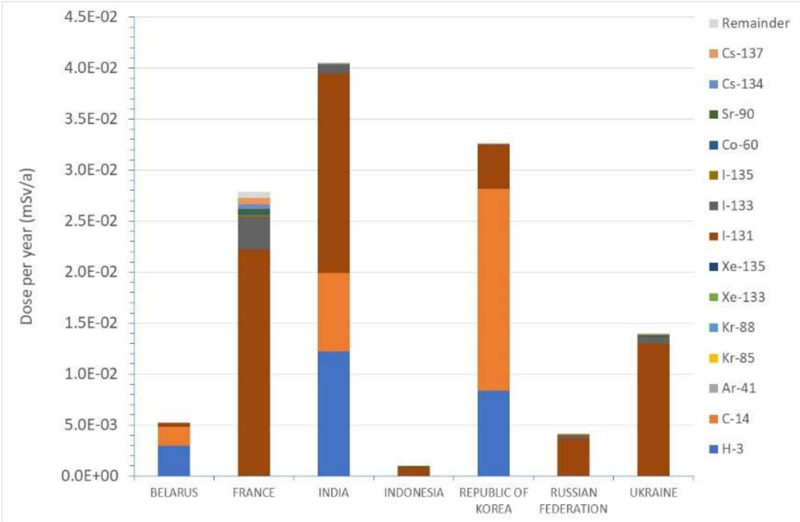

FIG. 8. Summary of results showing ingestion (milk) dose for each participant broken down by nuclide (linear scale). Atmospheric case A

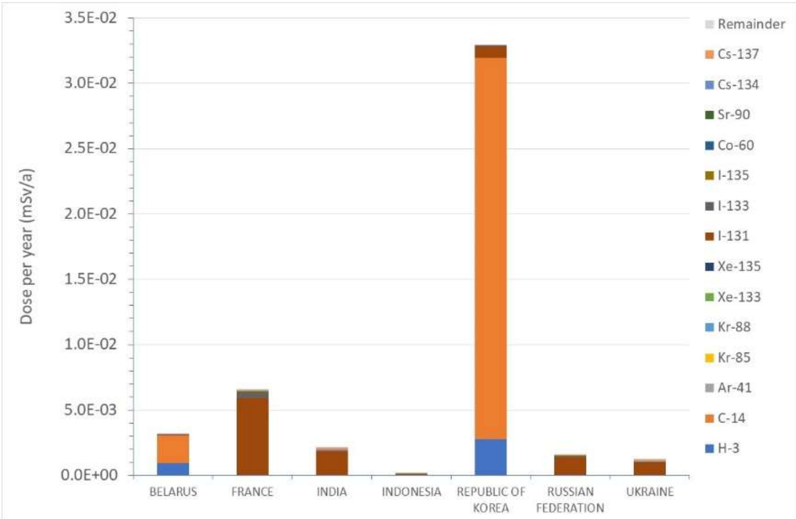

FIG. 9. Summary of results showing ingestion (meat) dose for each participant broken down by nuclide (linear scale). Atmospheric case A

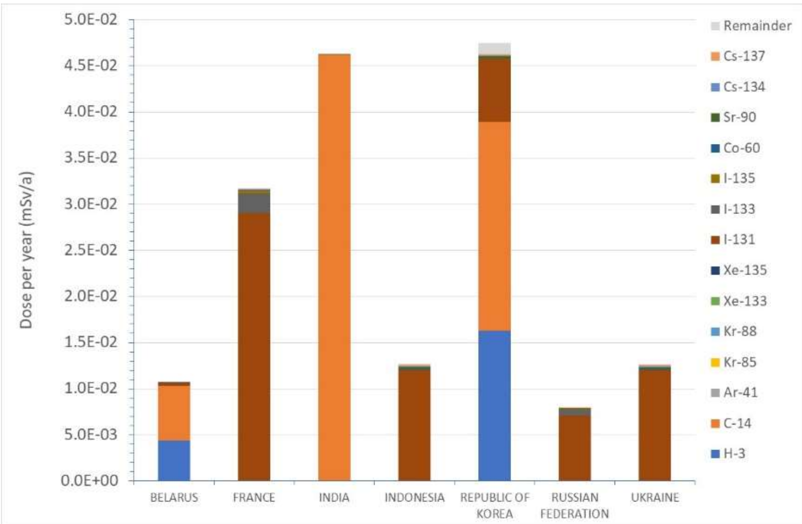

FIG. 10. Summary of results showing ingestion (vegetable) dose for each participant broken down by nuclide (linear scale). Atmospheric case A

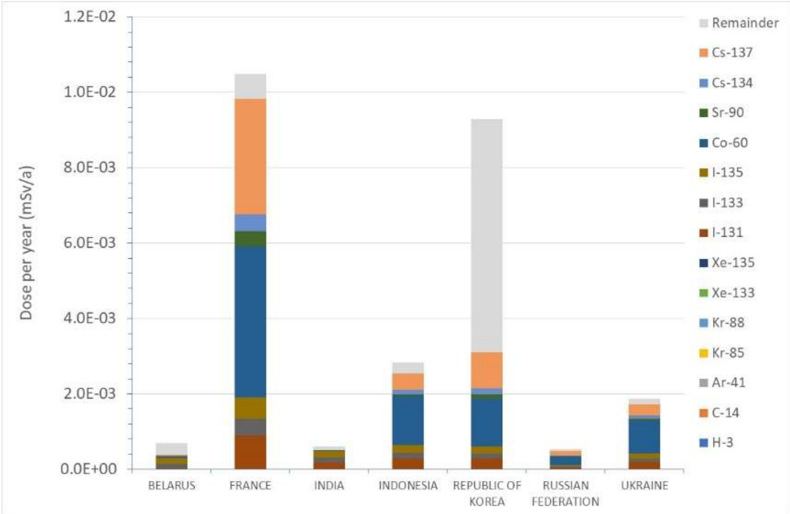

FIG. 11. Summary of results showing ingestion (external) dose for each participant broken down by nuclide (linear scale). Atmospheric case A

The simplest pathway should be immersion or cloudshine as the dose is determined by only the atmospheric dispersion and the effective dose coefficients which are fixed parameters for case A. This is shown in Figure 7 and it can be seen that the participants from France, India, Indonesia, Republic of Korea, and Ukraine have similar results spanning a factor of about 2. The results for the participants from Belarus and Russian Federation are somewhat lower. The results from all participants show a roughly similar pattern in the relative contributions from the main nuclides (Ar-41, Kr-85, Kr-88, Xe-133, and Xe-135); this suggests the differences arise from the dispersion modelling.

Multiplying the annual atmospheric release for each nuclide in Table 10 by the fixed minimum dilution factor, and the effective dose coefficients from Table 16 gives a total dose from the immersion pathway of 1.17E-02 µSv/a with no account taken of any radioactive decay or removal by deposition. The different approaches to modelling the atmospheric dispersion are summarized briefly below for each participant. All the participants except those from France and Belarus state that they used the minimum dilution factor provided.

Annex I by Belarus states that it was not possible to use directly the fixed dilution factors (χ/Q values) provided from the Brazilian data as input to the PC-CREAM model. Instead, a new input file of meteorological data for the PC-CREAM model based on the Pasquill meteorological scheme was created using meteorological data provided by Brazil.

The fixed value for the dilution factor provided corresponded to minimum dilution (maximum value of χ/Q); this would correspond to stable conditions (category F) whereas the approach adopted by Belarus is equivalent to using an average value for the whole year. In other words, it is the difference between using a best estimate and a worst-case.

This could explain why the results are much lower than those from the other participants.

Annex II by France states that the meteorological data provided were converted to the Doury formalism. It is not clear what effect this would have but the results for France correspond very closely to the result obtained by multiplying the fixed parameters together as described above.

A possible explanation for the variations in the results for the other participants could be a result of applying radioactive decay during the passage of plume with different wind speed assumptions; however, the transport time of 500 s in the fixed data provided in Table 13 would not result in significant decay. The results for the participant from the Russian Federation look too low for this to be an explanation and the results for long-lived nuclides such as Kr-85 are also lower.

The differences introduced by the differing approaches to modelling the atmospheric dispersion described above will propagate through to the doses calculated from all the other pathways.

Figure 6 shows the results for the inhalation pathway. For all participants, H-3 is the predominant contributor with some contribution from I-131 and I-133. The results from Belarus also have a significant contribution from C-14.

Multiplying the annual atmospheric release for each nuclide in Table 10 by the fixed minimum dilution factor, and the effective dose coefficients from Table 16 gives a total dose from the immersion pathway of about 8.0E-03 μSv/a nearly all from H-3.

The absolute dose values for each of the participants show a similar pattern to that seen for the immersion pathway reflecting the fact that the difference in dispersion modelling is also affecting the results for inhalation as would be expected. Differences from this pattern are seen for Belarus which has a higher dose from H-3 and a contribution from C-14 as mentioned above and for Republic of Korea which now has the largest dose reflecting a high H-3 contribution. In the case of Belarus, the difference is probably a result of differences in the PC-CREAM modelling and parameters compared with those used by the other participants.

Figures 8-10 shows the results for the three ingestion pathways – milk (no results from the participant form France), meat, and vegetable consumptions. Very little consistency is seen in the results from the different participants reflecting the different treatments for H-3 and C-14; some participants did not include these nuclides at all whereas for other participants these nuclides can dominate the results. For example, for ingestion of vegetables, the results for the participant from India show the dose is virtually all from C-14 whereas for the participants from France, Indonesia Russia, Ukraine the results are dominated by I-131 with virtually no contribution from C-14 and for Belarus and Republic of Korea, H-3, C-14, and I-131 all make a contribution. If the contributions from H-3 and C-14 are ignored, the results for the participants look more similar with I-131 the dominant contributor although the I-131 results for India are much lower than the results for other participants.

Figure 11 shows the dose for the external exposure or groundshine pathway. The results for the Republic of Korea show a large contribution from Co-57 (included in 'remainder' in the figure) which the other participants do not include as Table 16 does not give a value for the dose coefficient of this nuclide for external exposure. The results from the participants from France, Indonesia, Republic of Korea (apart from Co-57 mentioned above), Russian Federation, and Ukraine show a similar nuclide contribution pattern with I-131, I-133, I-135, Co-60, Sr-90, Cs-134, and Cs-137 significant contributors. The results from Belarus have a smaller relative contribution from the longer-lived nuclides such Sr-90, Cs-134, and Cs-137 possibly reflecting the effect of the GRANIS model in PC-CREAM which models the transfer of radionuclides through the soil and takes into account the shielding properties of the soil possibly leading to lower doses in comparison.

4.2.2 Atmospheric cases B and C.

Figure 12 shows the doses from each nuclide and the total dose calculated by each participant for case B. Figures 13 and 14 show the breakdown of the total dose for each participant broken down by pathway and nuclide respectively for case B. Figures 15-17 show the equivalent plots for case C.

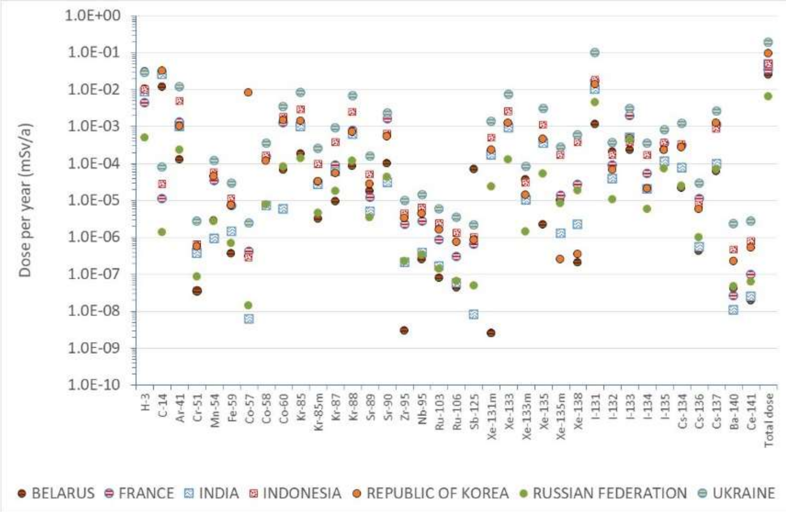

FIG. 12. Summary of results showing dose for each nuclide and the total dose for each participant (logarithmic scale). Atmospheric case B

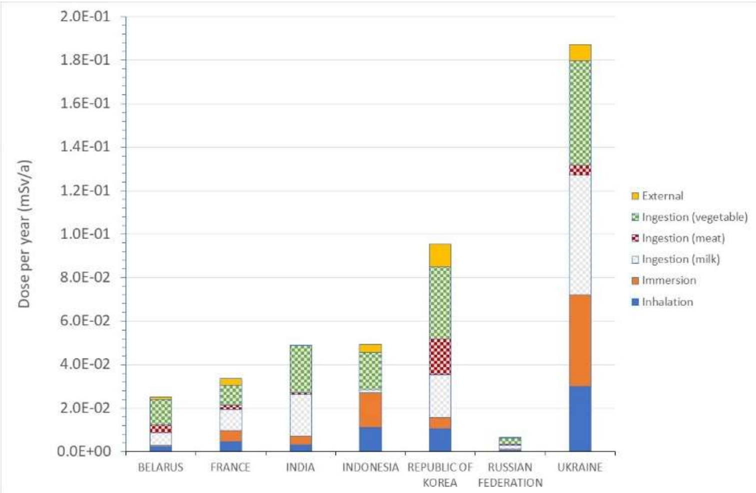

FIG. 13. Summary of results showing the total dose broken down by pathway for each participant (linear scale). Atmospheric case B

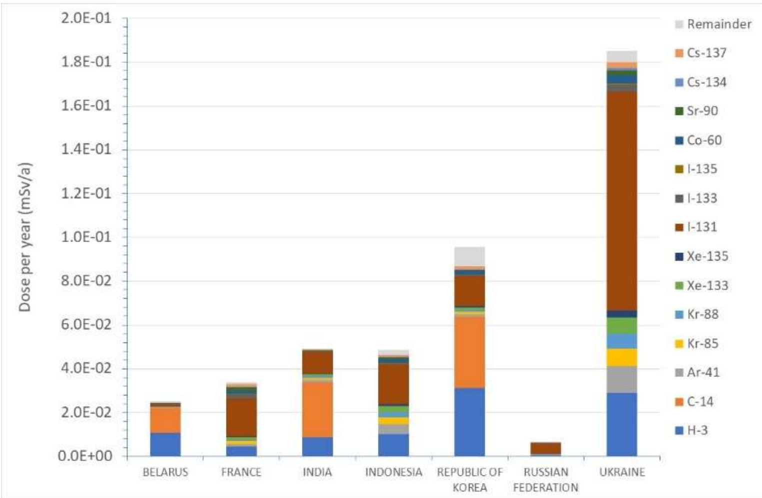

FIG. 14. Summary of results showing the total dose broken down by nuclide for each participant (linear scale). Atmospheric case B

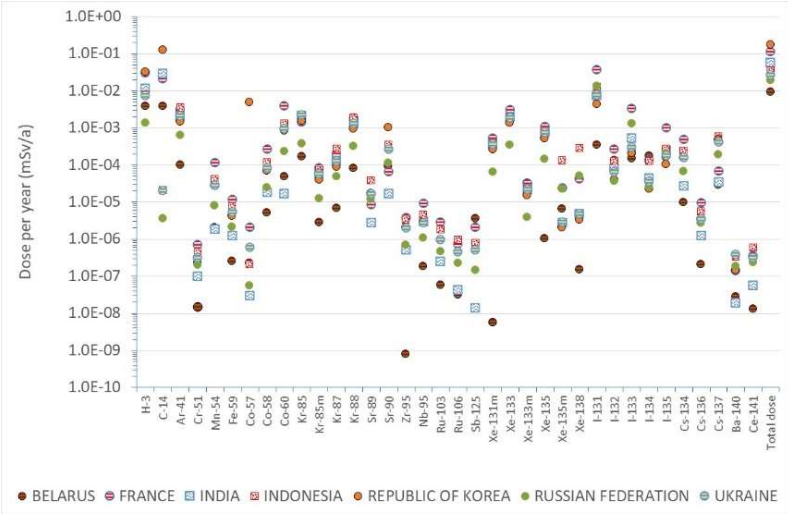

FIG. 15. Summary of results showing dose for each nuclide and the total dose for each participant (logarithmic scale). Atmospheric case C

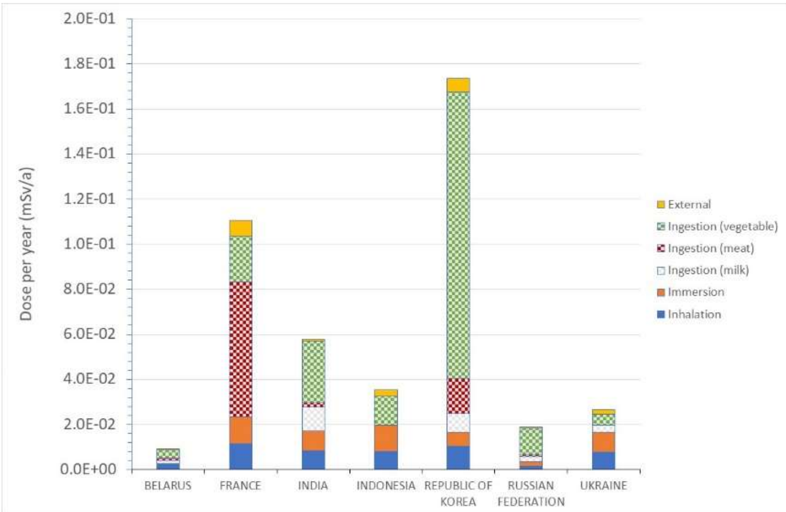

FIG. 16. Summary of results showing the total dose broken down by pathway for each participant (linear scale). Atmospheric case C

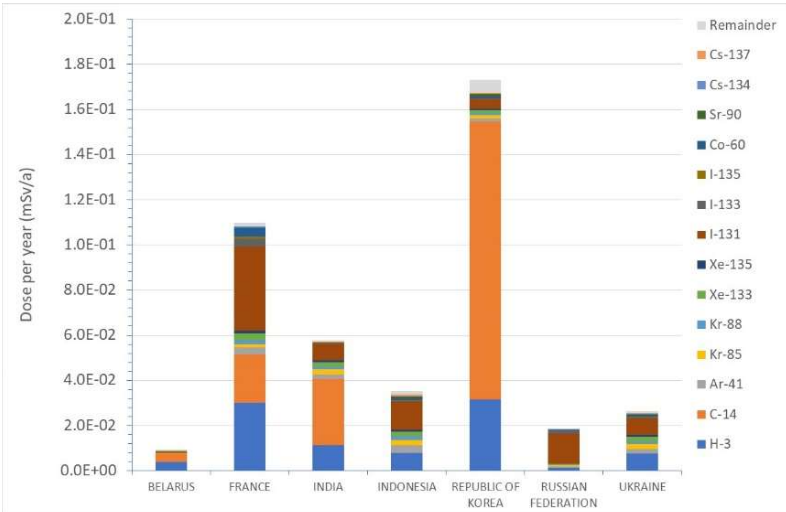

FIG. 17. Summary of results showing the total dose broken down by nuclide for each participant (linear scale). Atmospheric case C

Figures 18-24 show for each participant a comparison for the three cases with a breakdown of the total dose by pathway.

The difference between case A and B is the use of site-specific meteorology rather than the fixed provided meteorological parameters; this should affect the dose from all pathways and all nuclides more or less in proportion – radioactive decay and deposition during plume passage may differ slightly (for the very short-lived nuclides in the case of the former). Table VII–2 considers the effect of radioactive decay during plume transport for the short-lived nuclides; however, only the contributions of Ar-41 and Kr-88 to the total dose were non-negligible.

The difference between case A and C is the use of other site-specific data – breathing rates, ingestion rates for different food types, and bioaccumulation factors – but the same meteorological data. These site-specific factors should not affect the immersion and external pathways. The breathing rate assumed does not vary significantly among the participants and so the inhalation pathway should also not be significantly affected. The ingestion pathway will be the pathway most affected by the use of site-specific data.

Consequently, the discussion for case B will focus on the differences in the total dose from that in case A for each of the participants and the discussion for case C will focus on the differences in the ingestion doses from those in case A for each of the participants.

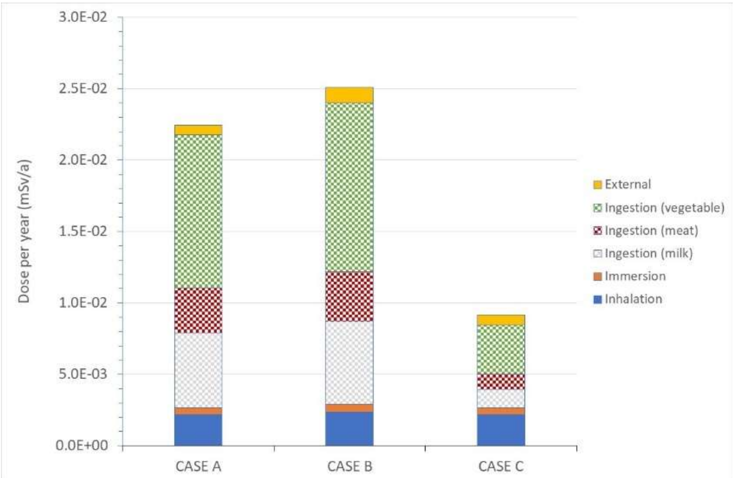

FIG. 18. Comparison of the results for each case showing the breakdown by pathway. Belarus

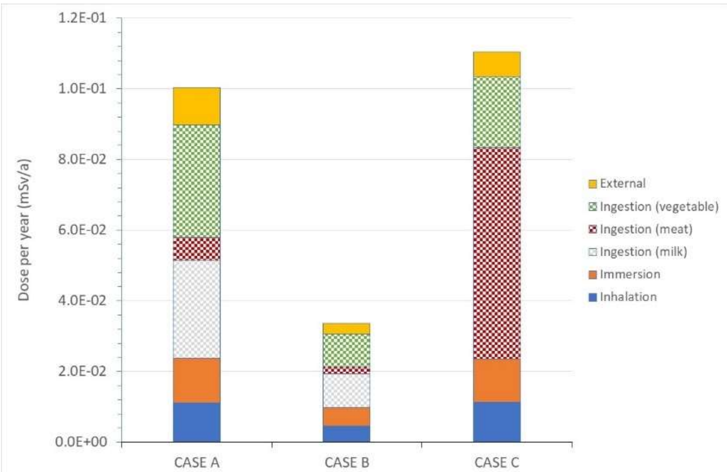

FIG. 19. Comparison of the results for each case showing the breakdown by pathway. France

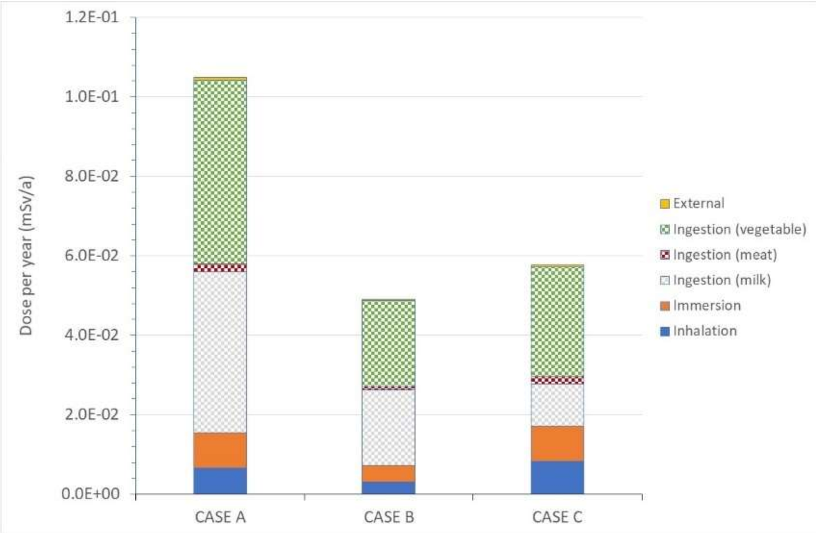

FIG. 20. Comparison of the results for each case showing the breakdown by pathway. India

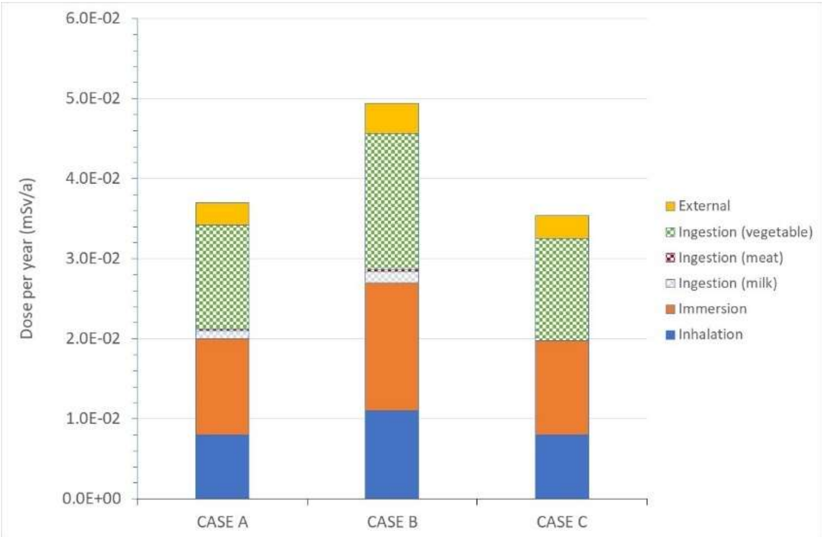

FIG. 21. Comparison of the results for each case showing the breakdown by pathway. Indonesia

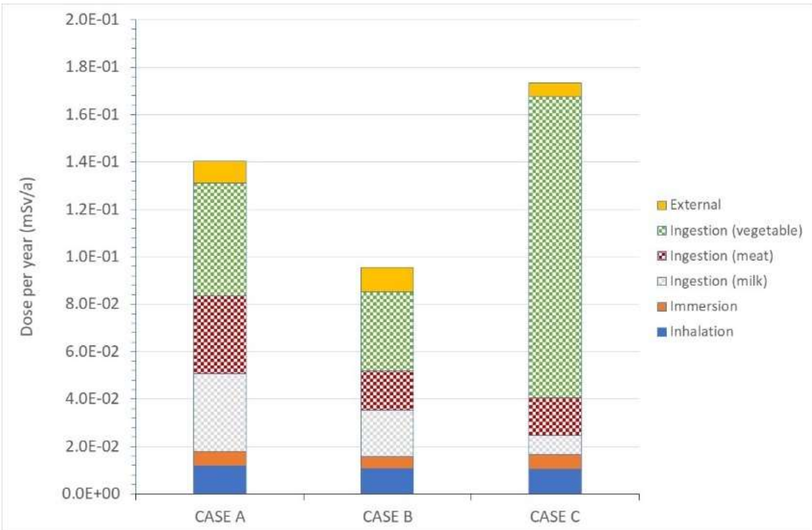

FIG. 22. Comparison of the results for each case showing the breakdown by pathway. Republic of Korea

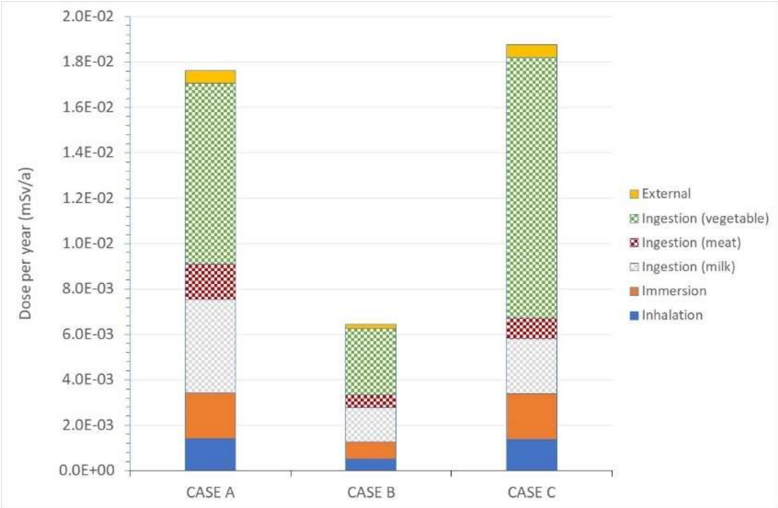

FIG. 23. Comparison of the results for each case showing the breakdown by pathway. Russian Federation

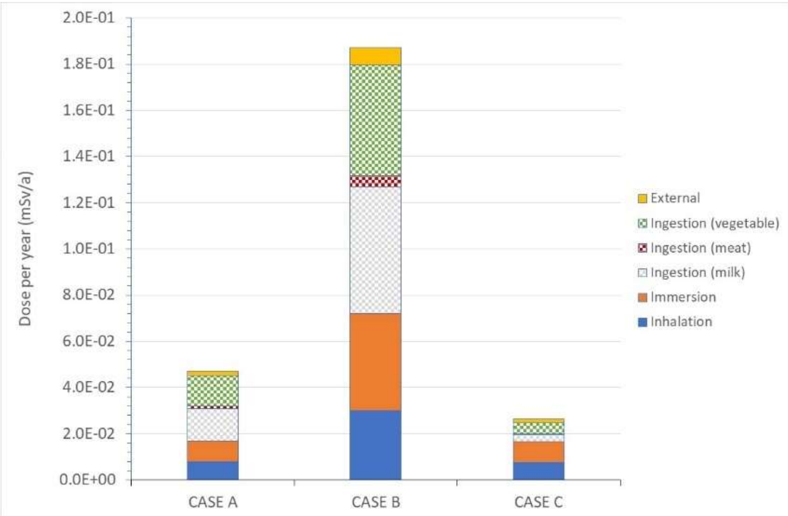

FIG. 24. Comparison of the results for each case showing the breakdown by pathway. Ukraine

Figure 18 shows the comparison of the three cases for the participant from Belarus. The case B total dose is about 12% higher than that for case A. For case B meteorological data for the Ostrovets site (54°45′42.8″N 26°7′11.5″E) near Grodno, Belarus were used in place of the data provided from a site in São Paulo, Brazil for case A. In both cases, hourly meteorological data were used in the PC-CREAM model rather than a fixed dilution parameter.

Figure 19 shows the comparison of the three cases for the participant from France. The case B total dose is about 34% of that for case A. For case B, meteorological data for the Cadarache site and for both case A and B the meteorological data was converted into the Doury formalism.

Figure 20 shows the comparison of the three cases for the participant from India. The case B total dose is about half that for case A. For case B, the minimum atmospheric dilution factor value from the Kalpakkam site was used (7.72E-08 sm^{-3}) instead of the fixed minimum value for Brazil used in case A (4.705E-08 sm^{-3}); this would be expected to give a dose about 60% higher than case A not lower and, therefore, other differences in the modelling approach used must more than compensate for the differences in dilution factors.

Figure 21 shows the comparison of the three cases for the participant from Indonesia. The case B total dose is about 40% higher than that for case A. For case B, the minimum atmospheric dilution factor value from the Serpong site was used (6.31E-08 sm^{-3}) which is about 40% higher than the provided value for case A (4.705E-08 sm^{-3}).

Figure 22 shows the comparison of the three cases for the participant from the Republic of Korea. The case B total dose is about 70% that for case A. For case B, the minimum atmospheric dilution factor value from the Shin-Ulchin NPP site was used (4.286E-08 sm^{-3}); the atmospheric dilution factor is ~90% of the value used in case A so this explains some but not all of the difference seen.

Figure 23 shows the comparison of the three cases for the participant from the Russian Federation. The case B total dose is about 37% that for case A. For case B, the minimum atmospheric dilution factor value from the Rostov NPP site was used (1.2E-08 sm^{-3}); this is about 25% of the provided value for case A (4.705E-08 sm^{-3}) and so explains most of the difference seen.

Figure 24 shows the comparison of the three cases for the participant from Ukraine. The case B total dose is a factor of 4 higher than that for case A. For case B, the minimum atmospheric dilution factor value from the Rivne NPP site was used (1.78E07 sm^{-3}); this is about 4 times the value provided value for case A (4.705E-08 sm^{-3}). As well as different meteorological data, a closer distance to the release was used for case B – 2.5 km instead of 10 km – resulting in the much higher dilution factor used.

Figures 25, 26, and 27 show the comparison of the doses from milk, meat, and vegetable ingestion respectively broken down by nuclide for the participant from Belarus. For each ingestion pathway, case C shows a similar nuclide breakdown to that in case A (H-3, C-14, and I-131) but with a dose in proportion with the ratio of the food consumption rate as shown in Table 30 below. The PC-CREAM model was used for both case A and C and so there was no difference in transfer coefficients between the two cases.

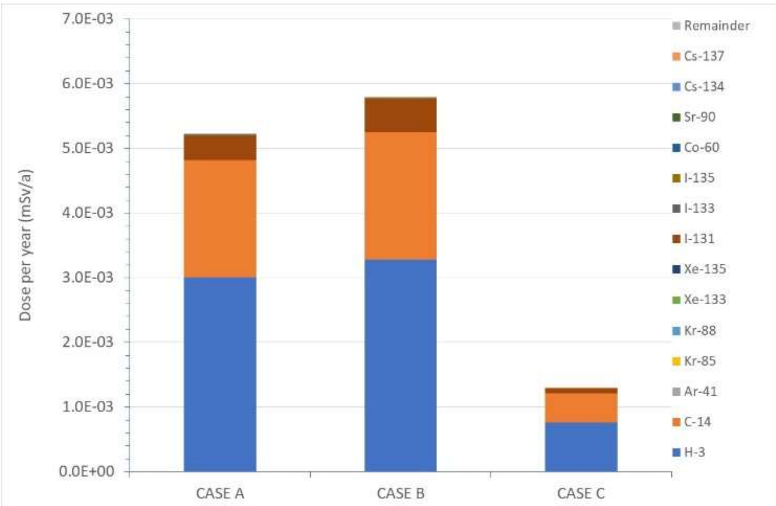

FIG. 25. Comparison of the results for each case showing the breakdown by nuclide (milk ingestion – Belarus)

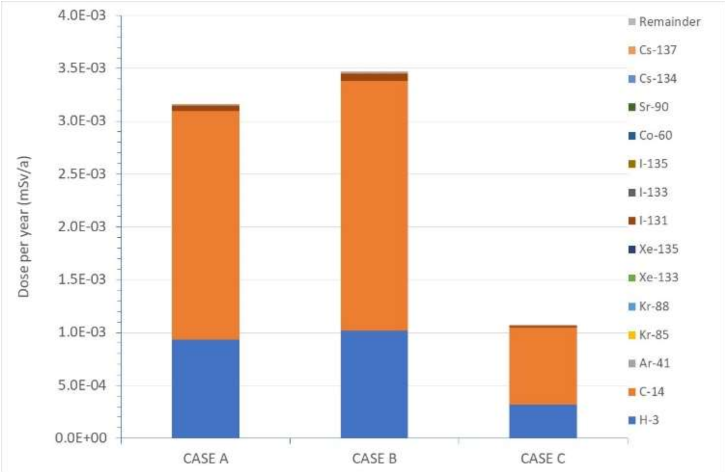

FIG. 26. Comparison of the results for each case showing the breakdown by nuclide (meat ingestion – Belarus)

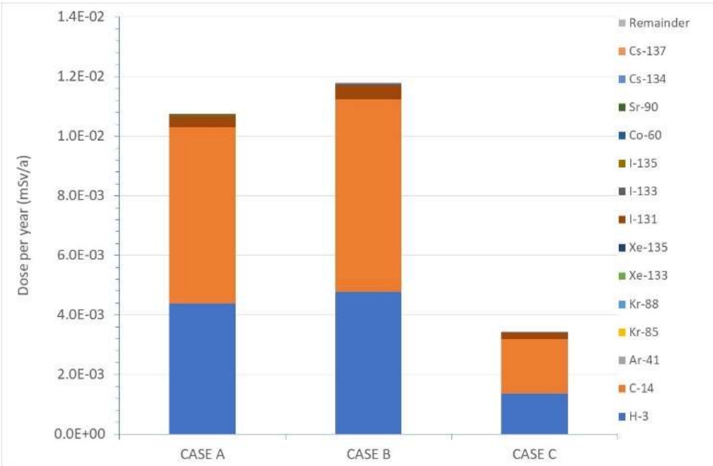

FIG. 27. Comparison of the results for each case showing the breakdown by nuclide (vegetable ingestion – Belarus)

TABLE 30. COMPARISON OF FOOD CONUMPTION RATES AND INGESTION DOSES. BELARUS, CASE A AND C

Food	Consumption rate (kg or l/a)		Ratio of consumption rate, case A:C	Ratio of ingestion dose, case A:C
	Case A	Case C		
Milk	250.00	62.99	0.25	0.25
Cow meat	-	33.82	-	-
Sheep meat	-	0.35	-	-
Total meat	100.00	34.17	0.34	0.34
Green vegetable	115.00	15.28	0.13	-
Root vegetable	187.00	82.03	0.44	-
Fruit	108.00	29.82	0.28	-
Total fruit & veg	410.00	127.13	0.31	0.32

Figures 28, 29, and 30 show the comparison of the doses from milk, meat, and vegetable ingestion respectively broken down by nuclide for the participant from France. Milk consumption was not considered in case C and H-3 and C-14 were included as nuclides in case C but not in case A. I-131 is the dominant nuclide for case A for both meat and vegetable consumption pathways. For vegetable consumption in case C, H-3 and C-14 make significant contributions with I-131 making up most of the remainder. For meat consumption in case C, I-131 is the major contributor with significant contributions from H-3 and C-14 and with some contribution from I-133. The differences between case A and case C are a result of including H-3 and C-14 in case C, different consumption rates, and different environmental transfer factors. Direct comparison of the results from case A with those from case C is difficult since the transfer of radionuclides in the food chain is evaluated by a box model where each box represents different environmental compartments – including many more food types than those considered in case C – connected by transfer functions rather than applying simple factors. Table 31 below shows a comparison of the ratios of the consumption rates and the ratio of the doses for cases A and C.

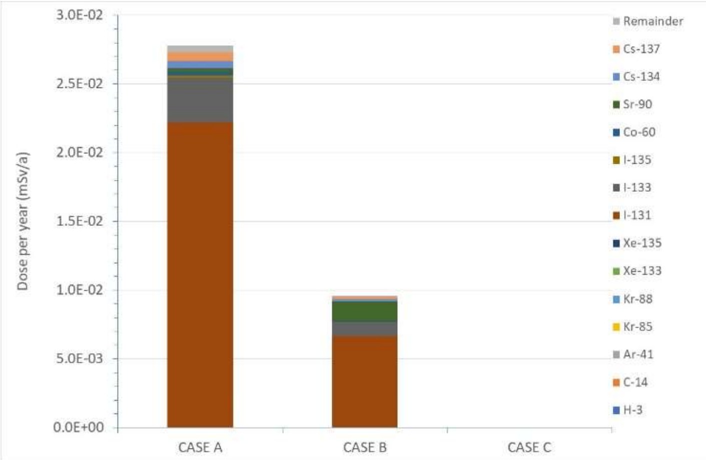

FIG. 28. Comparison of the results for each case showing the breakdown by nuclide (milk ingestion – France)

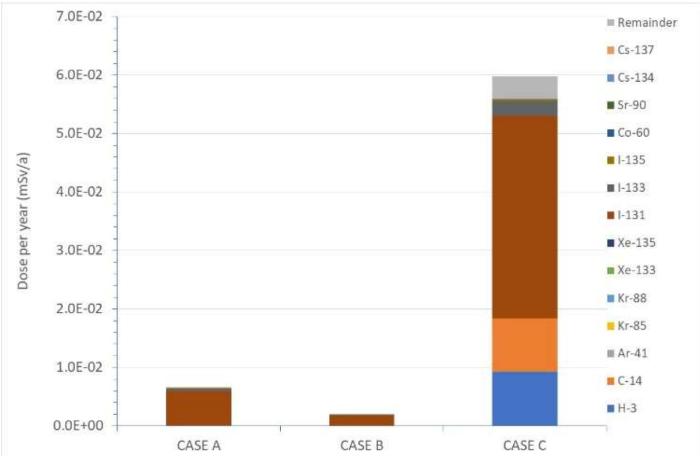

FIG. 29. Comparison of the results for each case showing the breakdown by nuclide (meat ingestion – France)

TABLE 31. COMPARISON OF FOOD CONUMPTION RATES AND INGESTION DOSES. FRANCE, CASE A AND C

Food	Consumption rate (kg or l/a)		Ratio of consumption rate, case A:C	Ratio of ingestion dose, case A:C
	Case A	Case C		
Milk	250.00	42.00	0.17	-
Total meat	100.00	14.00	0.14	9.13
Green vegetable	115.00	15.00	0.13	-
Root vegetable	187.00	25.00	0.13	-
Fruit	108.00	10.00	0.09	-
Apples	-	40.00	-	-
Total fruit & veg	410.00	90.00	0.22	0.63

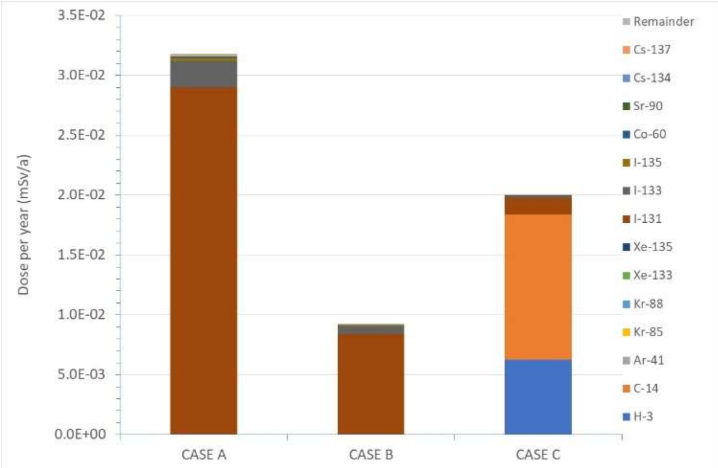

FIG. 30. Comparison of the results for each case showing the breakdown by nuclide (vegetable ingestion – France)

Figures 31, 32, and 33 show the comparison of the doses from milk, meat, and vegetable ingestion respectively broken down by nuclide for the participant from India. Table 32 below shows the ratio of food consumption rates and the ingestion doses for cases A and C. For milk consumption in case A, the main contributors are For meat consumption, the main contribution is from I-131 with smaller contributions from Cs-134 and Cs-137 but a negligible contribution from C-14 whereas for case C, C-14 is a dominant contributor with a smaller contribution from I-131 but negligible contributions from Cs-134 and Cs-137. For vegetable consumption, the dose is virtually all due to C-14 for both case A and C and the ratio in the dose is consistent with the ratio of the consumption rates.

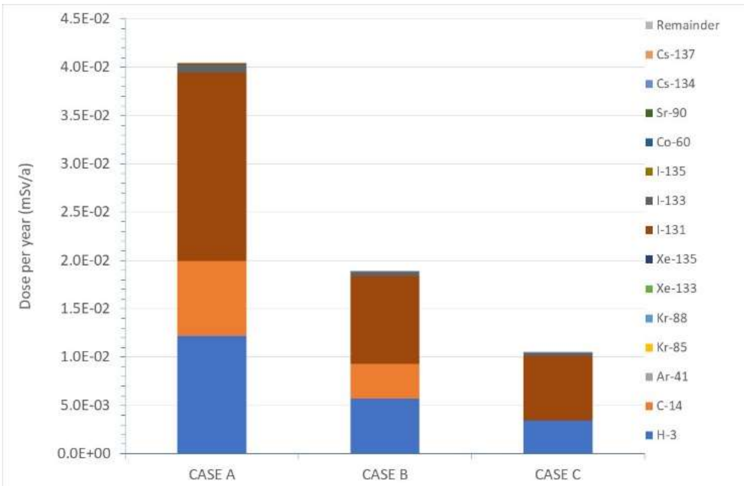

FIG. 31. Comparison of the results for each case showing the breakdown by nuclide (milk ingestion – India)

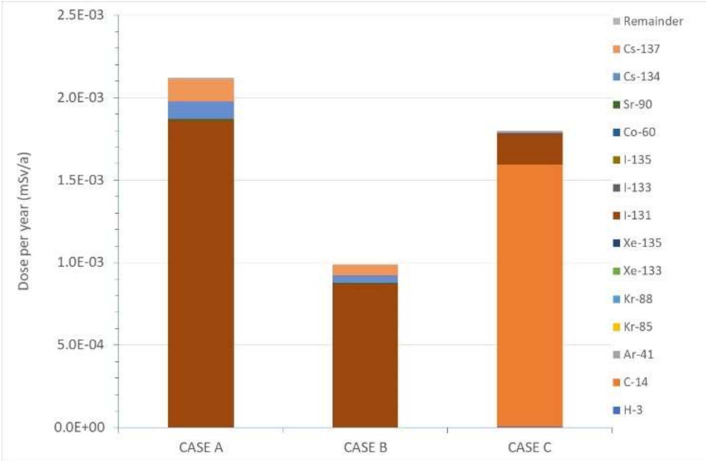

FIG. 32. Comparison of the results for each case showing the breakdown by nuclide (meat ingestion – India)

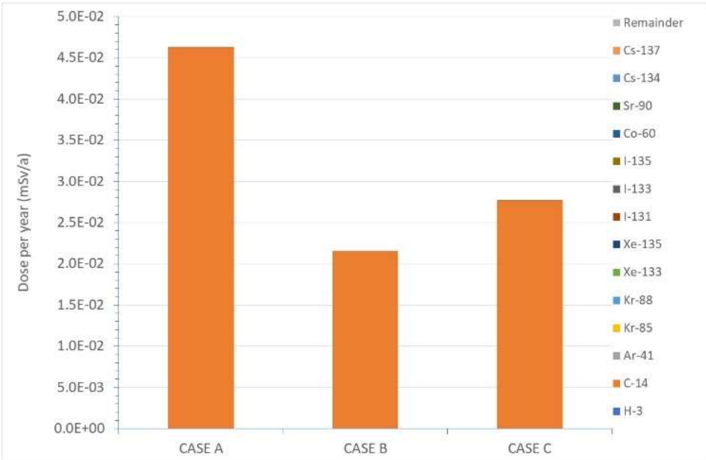

FIG. 33. Comparison of the results for each case showing the breakdown by nuclide (vegetable ingestion – India)

TABLE 32. COMPARISON OF FOOD CONUMPTION RATES AND INGESTION DOSES. INDIA, CASE A AND C

Food	Consumption rate (kg or l/a)		Ratio of consumption rate, case A:C	Ratio of ingestion dose, case A:C
	Case A	Case C		
Milk	250.00	70.00	0.28	0.26
Cow meat	100.00	16.00	0.16	0.85
Total fruit & veg	410.00	240.00	0.59	0.60

Figures 34, 35, and 36 show the comparison of the doses from milk, meat, and vegetable ingestion respectively broken down by nuclide for the participant from Indonesia. Table 33 below shows the ratio of food consumption rates and the ingestion doses for cases A and C. For milk consumption, the main contribution to the dose is from I-131 with smaller contributions from I-133, Sr-90, and Cs-137 for both case A and C although the dose for case C is much smaller. For meat consumption, the main contributions to the dose are from I-131, Sr-90, and Cs-137 with a smaller contribution from Cs-134 for both case A and C; the dose for case C is smaller reflecting the lower meat consumption in Indonesia. For vegetable consumption, the dose is dominated by I-131 with small contributions from Sr-90, Cs-134, and Cs-137 for both case A and C which both have a very similar dose for this pathway; the consumption rates differ for the different types of vegetable between case A and C but only the total vegetable dose is provided.

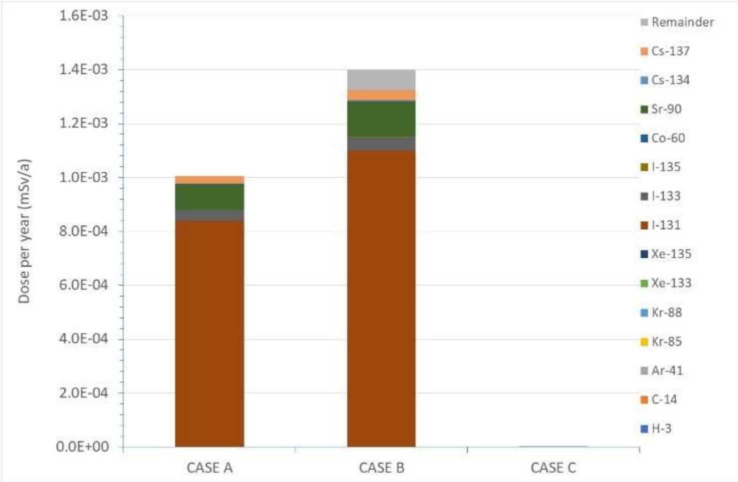

FIG. 34. Comparison of the results for each case showing the breakdown by nuclide (milk ingestion – Indonesia)

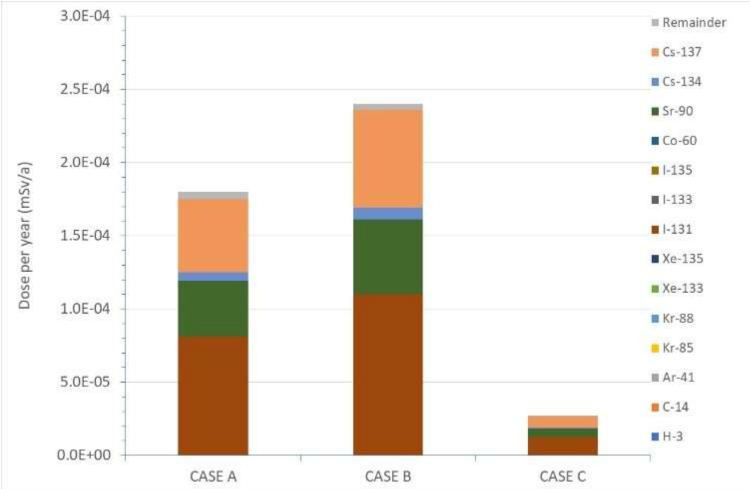

FIG. 35. Comparison of the results for each case showing the breakdown by nuclide (meat ingestion – Indonesia)

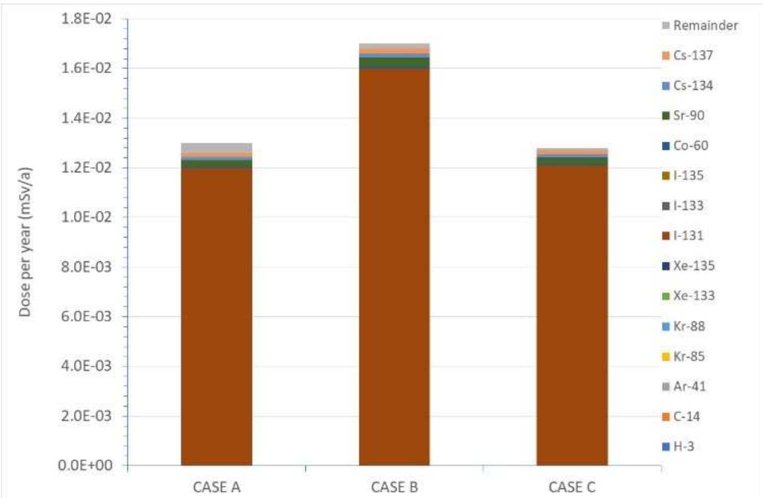

FIG. 36. Comparison of the results for each case showing the breakdown by nuclide (vegetable ingestion – Indonesia)

TABLE 33. COMPARISON OF FOOD CONUMPTION RATES AND INGESTION DOSES. INDONESIA, CASE A AND C

Food	Consumption rate (kg or l/a)		Ratio of consumption rate, case A:C	Ratio of ingestion dose, case A:C
	Case A	Case C		
Milk	250.00	0.16	6.57E-04	6.60E-04
Total meat	100.00	15.26	0.15	0.15
Green vegetable	115.00	17.25	0.15	
Root vegetable	187.00	10.84	0.06	
Fruit	108.00	142.77	1.32	
Total fruit & veg	410.00	170.87	0.42	0.98

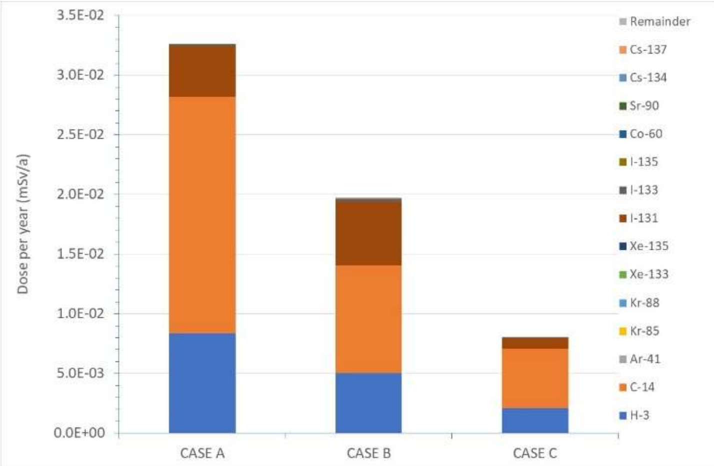

FIG. 37. Comparison of the results for each case showing the breakdown by nuclide (milk ingestion – Republic of Korea)

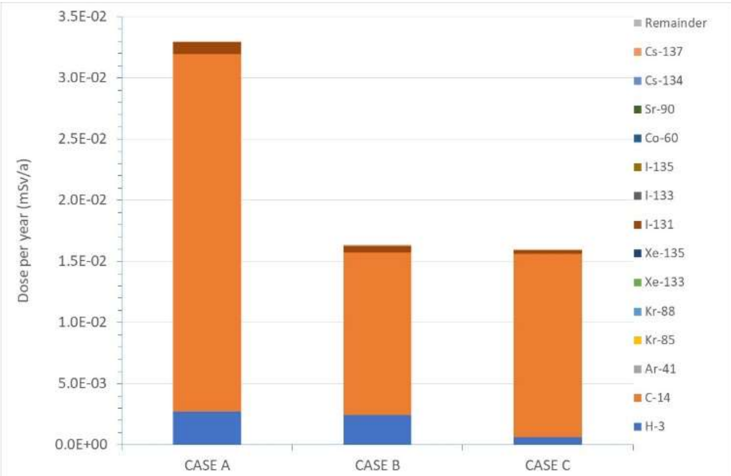

FIG. 38. Comparison of the results for each case showing the breakdown by nuclide (meat ingestion – Republic of Korea)

Figures 37, 38, and 39 show the comparison of the doses from milk, meat, and vegetable ingestion respectively broken down by nuclide for the participant from the Republic of Korea. Table 34 below shows the ratio of food consumption rates and the ingestion doses for cases A and C. For milk consumption, the main nuclide contributors are H-3, C-14, and I-131 for both cases with the same distribution pattern and the overall dose in proportion to the ratio of the milk consumption rate. For meat consumption, as with milk, the main nuclide contributors are H-3, C-14, and I-131 but with a larger relative contribution from C-14 for case A than was the case for milk and an even larger relative contributions from C-14 for case C than was the case for milk such that case C dose is predominantly C-14. The C-14 contribution change from case

A to C is approximately in line with the change in the meat consumption rate. The contributions from H-3 and I-131 in case C are smaller than would be expected from consideration of the consumption rate alone. For vegetable ingestion, the main nuclide contributors in both cases are H-3, C-14, and I-131. Case C has about the same contribution from H-3 but a much larger C-14 contribution (~4.5 times), and a smaller contribution from I-131 most likely reflecting the introduction of kimchi as an additional vegetable in case C.

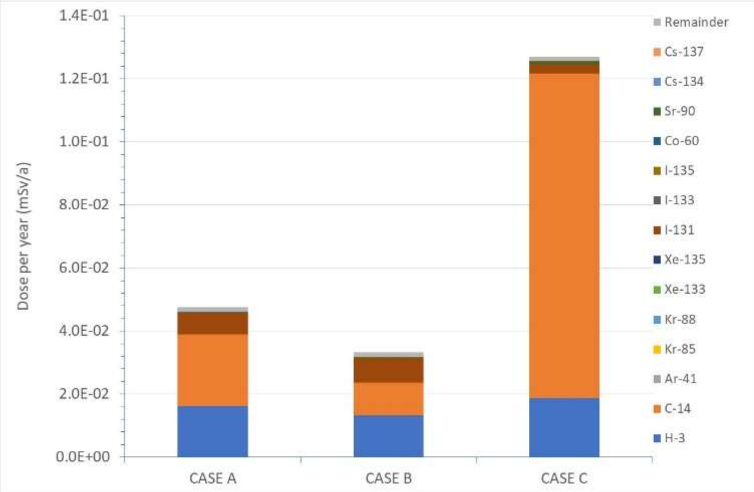

FIG. 39. Comparison of the results for each case showing the breakdown by nuclide (vegetable ingestion – Republic of Korea)

TABLE 34. COMPARISON OF FOOD CONUMPTION RATES AND INGESTION DOSES. REPUBLIC OF KOREA, CASE A AND C

Food	Consumption rate (kg or l/a)		Ratio of consumption rate, case A:C	Ratio of ingestion dose, case A:C
	Case A	Case C		
Milk	250.00	63.00	0.25	0.25
Beef		20.70		
Pork		12.40		
Poultry		22.00		
Total meat	100.00	55.10	0.55	0.48
Green vegetable	115.00			
Root vegetable	187.00			
Vegetables (leafy and root)		126.70	0.42	
Grains		188.50		
Kimchi		97.90		
Fruit	108.00	66.30	0.61	
Total fruit & veg	410.00	479.40	1.17	2.67

Figures 40, 41, and 42 show the comparison of the doses from milk, meat, and vegetable ingestion respectively broken down by nuclide for the participant from the Russian Federation. Table 35 below shows the ratio of food consumption rates and the ingestion doses for cases A and C. For consumption of all three food groups, the main nuclide contributors are I-131 and I-133 for the both cases with the ratio of the doses in proportion to the ratio of the consumption rates.

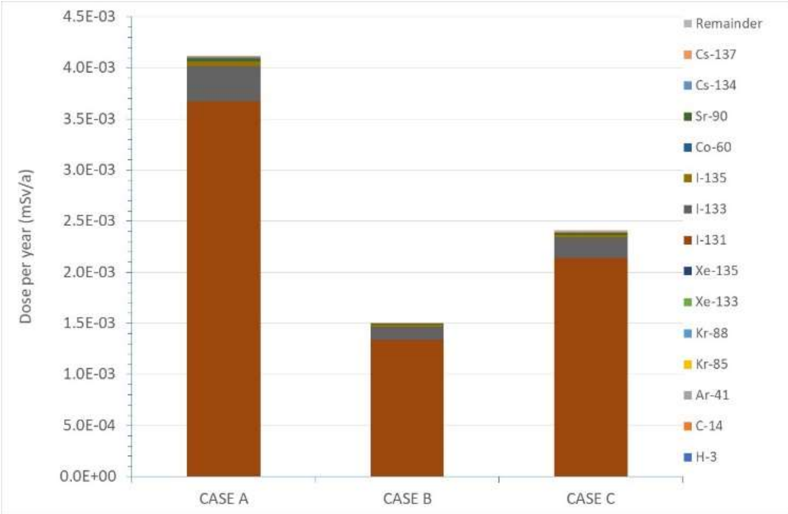

FIG. 40. Comparison of the results for each case showing the breakdown by nuclide (milk ingestion – Russian federation)

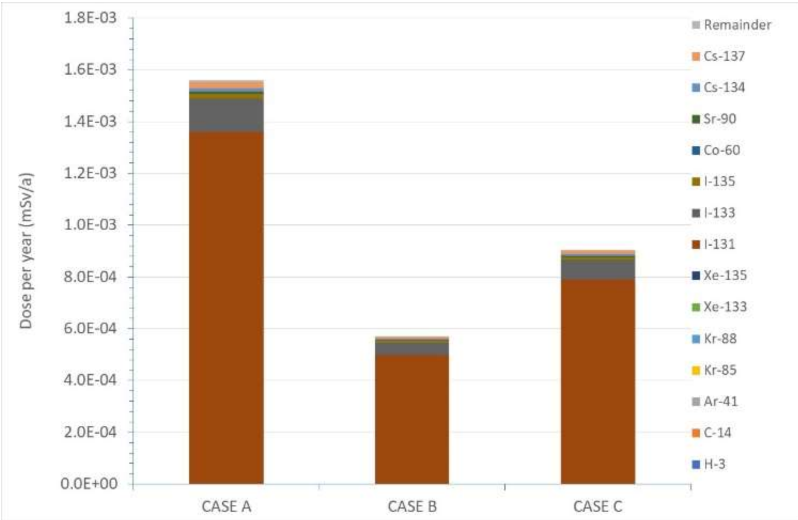

FIG. 41. Comparison of the results for each case showing the breakdown by nuclide (meat ingestion – Russian Federation)

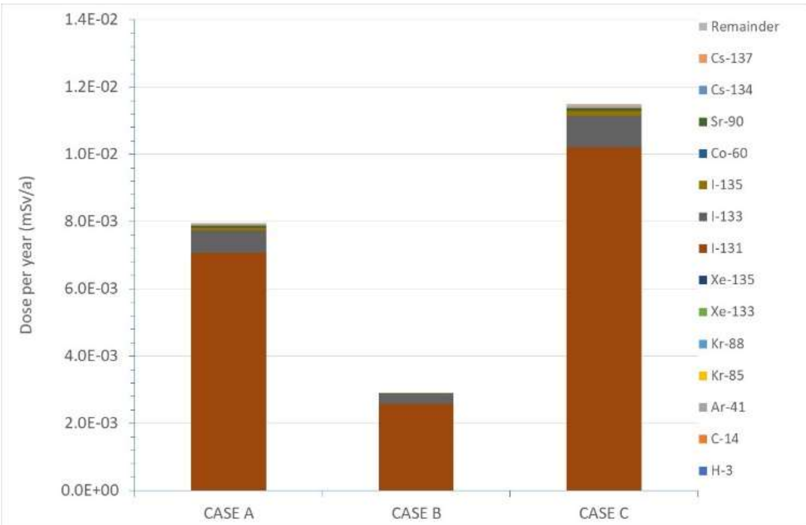

FIG. 42. Comparison of the results for each case showing the breakdown by nuclide (vegetable ingestion – Russian Federation)

TABLE 35. COMPARISON OF FOOD CONUMPTION RATES AND INGESTION DOSES. RUSSIAN FEDERATION, CASE A AND C

Food	Consumption rate (kg or l/a)		Ratio of consumption rate, case A:C	Ratio of ingestion dose, case A:C
	Case A	Case C		
Milk	250.00	146.00	0.58	0.58
Total meat	100.00	58.00	0.58	0.58
Cereals		192.00		
Green vegetable	115.00	184.00	1.60	
Root vegetable	187.00	188.00	1.01	
Fruit	108.00	30.00	0.28	
Total fruit & veg	410.00	594.00	1.45	1.44

Figures 43, 44, and 45 show the comparison of the doses from milk, meat, and vegetable ingestion respectively broken down by nuclide for the participant from Ukraine. Table 36 below shows the ratio of food consumption rates and the ingestion doses for cases A and C and Table 37 shows the ratios of uptake factors for milk and meat for the main nuclides used in case A and case C.

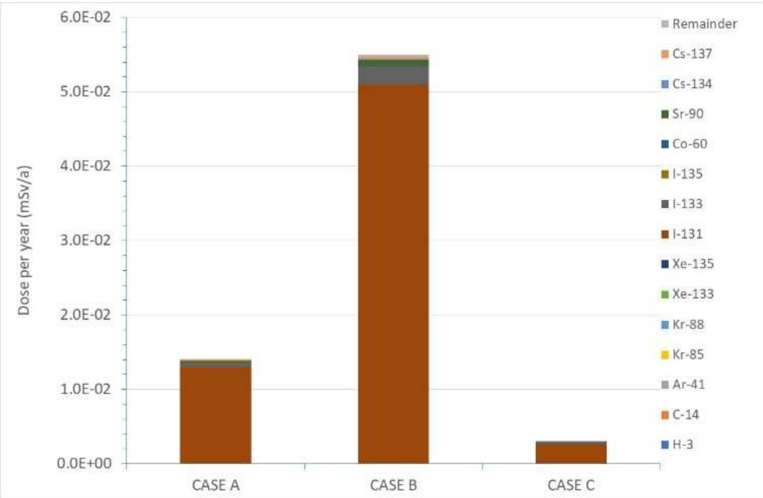

FIG. 43. Comparison of the results for each case showing the breakdown by nuclide (milk ingestion – Ukraine)

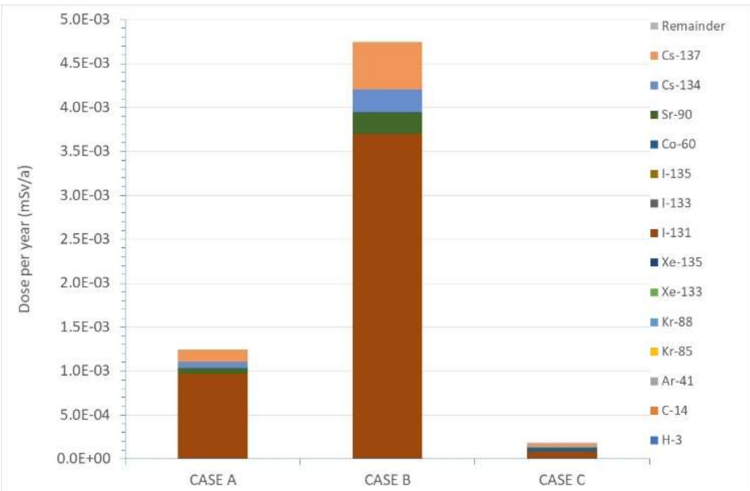

FIG. 44. Comparison of the results for each case showing the breakdown by nuclide (meat ingestion – Ukraine)

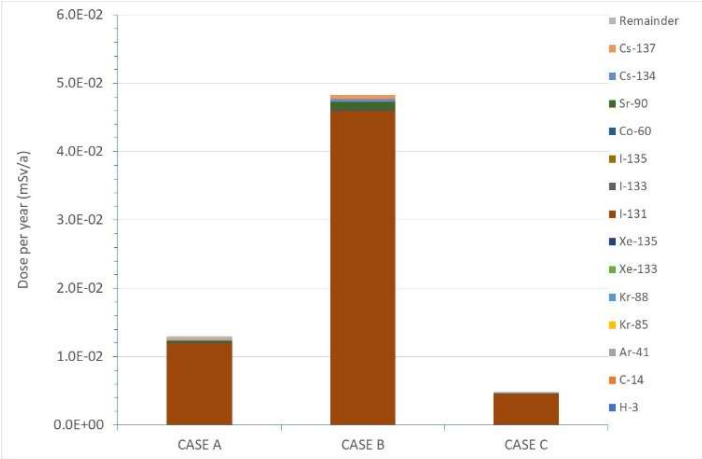

FIG. 45. Comparison of the results for each case showing the breakdown by nuclide (vegetable ingestion – Ukraine)

TABLE 36. COMPARISON OF FOOD CONSUMPTION RATES AND INGESTION DOSES. UKRAINE, CASE A AND C

Food	Consumption rate (kg or l/a)		Ratio of consumption rate, case A:C	Ratio of ingestion dose, case A:C
	Case A	Case C		
Milk	250.00	90.00	0.36	0.21
Meat	100.00	55.00	0.55	0.15
Green vegetable	115.00	18.00	0.16	
Root vegetable	187.00	70.00	0.37	
Fruit	108.00	66.00	0.61	
Total fruit & veg	410.00	154.00	0.38	0.37

TABLE 37. UPTAKE FACTORS FROM FEED TO MILK AND MEAT (FRACTION OF ANIMAL DAILY INTAKE). UKRAINE

	Case A	Case C	Ratio, case A:C	Combination of ratio in uptake rate and consumption ratio
Iodine-milk	5.4E-3	3.0E-3	0.56	0.20
Iodine-meat	6.7E-3	1.0E-3	0.15	0.08
Caesium-meat	2.2E-2	1.0E-2	0.45	0.25
Strontium-meat	1.3E-3	3.0E-4	0.23	0.17
Cobalt-meat	4.3E-4	3.0E-2	69.8	38.39

For milk consumption, the main nuclide contributor is I-131 with a small contribution from I-133 for both cases. The dose from milk consumption for case C is about 21% of that for case A which corresponds to the difference in milk consumption rates and in the uptake factors used for iodine in milk.

For meat consumption, the main nuclide contributor is I-131 with smaller contributions from Sr-90, Cs-134, and Cs-137 for case A; case C is similar but the relative contributions from Cs-134 and Cs-137 are larger and there is also a significant contribution from Co-60. The dose from meat consumption for case C is about 15% of that for case A and can be explained by the differences in consumption rates and in uptake factors; the ratio between case A and case C are larger for caesium and strontium than that for iodine and the factor for cobalt is much larger (see Table 37).

For vegetable consumption, the dose is virtually all from I-131 for both cases and the difference in dose between case A and case C corresponds to the difference in consumption rates for vegetables.

4.3 COMPARISON OF MARINE DISCHARGES

The participants from Belarus and France did not provide results for the marine cases and the participant from Ukraine provided results only for marine case A.

4.3.1 Marine case A.

Figure 46 shows the dose from each nuclide for each participant and the total dose on a logarithmic scale and Figure 47 shows the radionuclide breakdown for the total dose for each participant on a linear scale. Figure 48 shows the breakdown for the total dose by pathway (fish consumption and shellfish consumption) for each participant on a linear scale. Figures 49 and 50 show the radionuclide breakdown for these two pathways respectively.

FIG. 46. Summary of results showing dose for each nuclide and the total dose. Marine case A

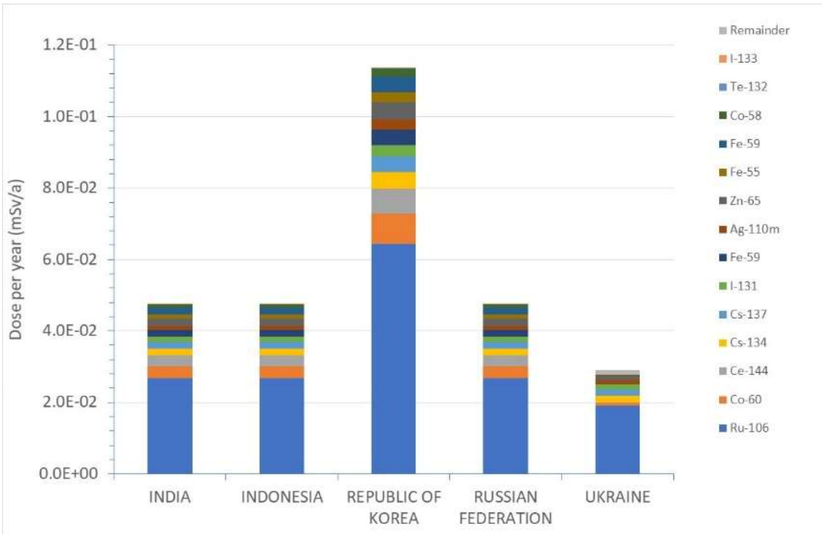

FIG. 47. Summary of results showing contribution of each nuclide. Marine case A

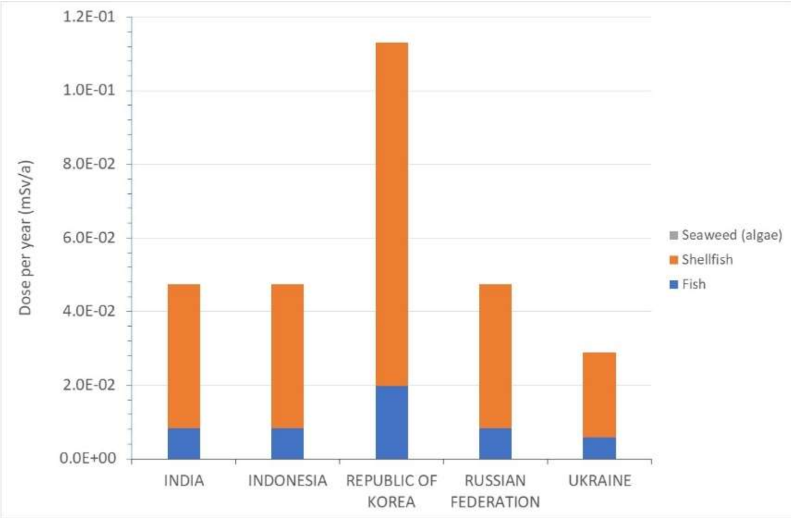

FIG. 48. Summary of results showing contribution of each pathway. Marine case A

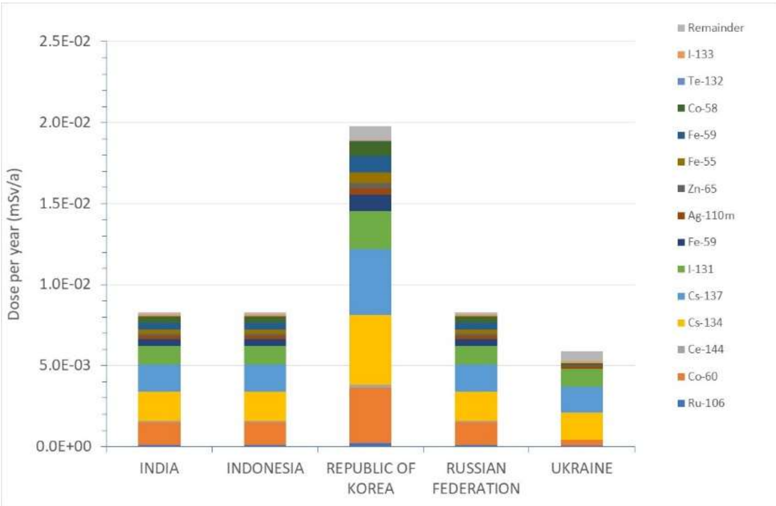

FIG. 49. Summary of results showing contribution of each nuclide for ingestion of fish only. Marine case A

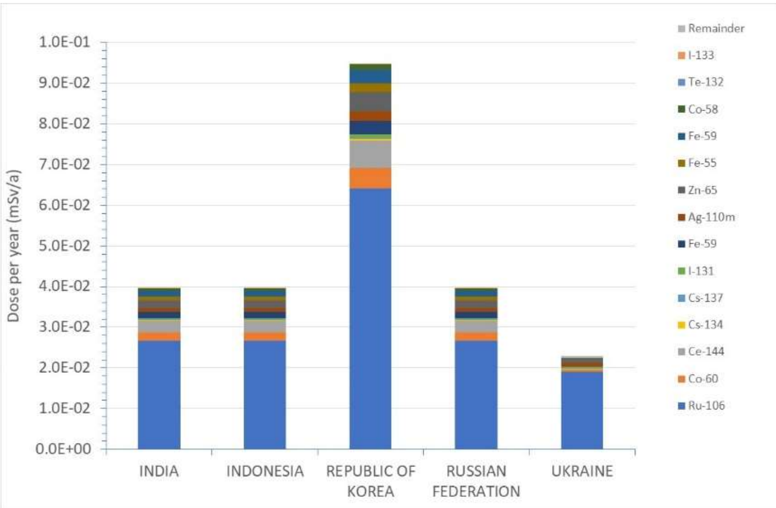

FIG. 50. Summary of results showing contribution of each nuclide for ingestion of shellfish only. Marine case A

The participants from India, Indonesia, and Russian Federation all obtained very similar results both in the total dose (0.0474 µSv/a) and in the contributions for the individual nuclides with Ru-106 the largest contributor. These are the results that would be expected by multiplying the provided marine activity concentrations, the bioaccumulation factors in fish and shellfish, the consumption factors, and the ingestion dose coefficients for each nuclide.

The result for the participant from Republic of Korea is about double (0.113 µSv/a) but shows a similar pattern to the results from the other participants in the relative contributions of the individual nuclides for the total dose and for contributions from the fish and shellfish ingestion pathways. The participant from Republic of Korea used the INDAC code using pre-defined fixed input parameters (see Annex V) which presumably calculates different marine activity concentrations, but all other parameters are the same as the provided values.

The results from the participant from Ukraine are about 60% of those from India, Indonesia, and Russian Federation (0.0290 µSv/a). The doses from most nuclides are similar but that from main contributor Ru-106 is about 70%, Co-60 the next largest contributor at about 25% and those from Mn, Fe, Y, Zr, Nb, and Ce nuclides are a few per cent or less when compared with the results from the participants using the provided parameter values.

Ru-106 is major contributor to the dose from shellfish consumption but makes very little contribution to the dose from fish consumption where the main contributors are Co-60, Cs-134, Cs-137, and I-131. The bioaccumulation factor for ruthenium is 2000 Bq/kg per Bq/l for shellfish compared with 2 Bq/kg per Bq/l for fish.

The ingestion of shellfish contributes about 80% of the total dose despite a higher rate of fish consumption compared with shellfish (50 kg/a for fish and 15 kg/a for shellfish). This is a result of higher bioaccumulation factors for most nuclides – sometimes much higher as for Ru-106 noted above – for shellfish compared with fish (see Table 18).

4.3.2 Marine case B

Only the participants from India, Indonesia, Republic of Korea, and Russian Federation provided results for case B.

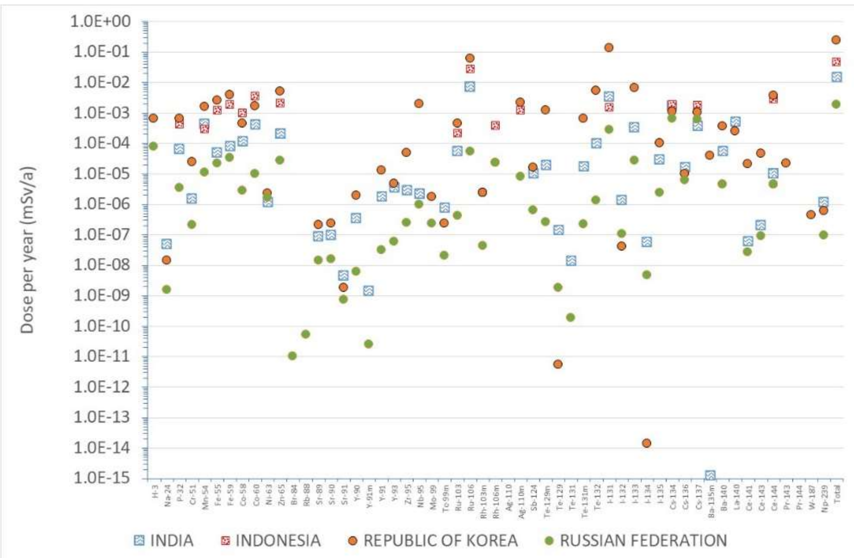

FIG. 51. Summary of results showing dose for each nuclide and the total dose. Marine case B

As for case A above, Figure 51 shows the dose from each nuclide for each participant and the total dose on a logarithmic scale and Figure 52 shows the radionuclide breakdown for the total dose for each participant on a linear scale. Figure 53 shows the breakdown for the total dose by pathway (fish consumption, shellfish consumption, and seaweed consumption for the Republic of Korea) for each participant on a linear scale. Figures 54-56 show the radionuclide breakdown for each of these three pathways. The participant from the Russian Federation did not provide a pathway breakdown only the total dose.

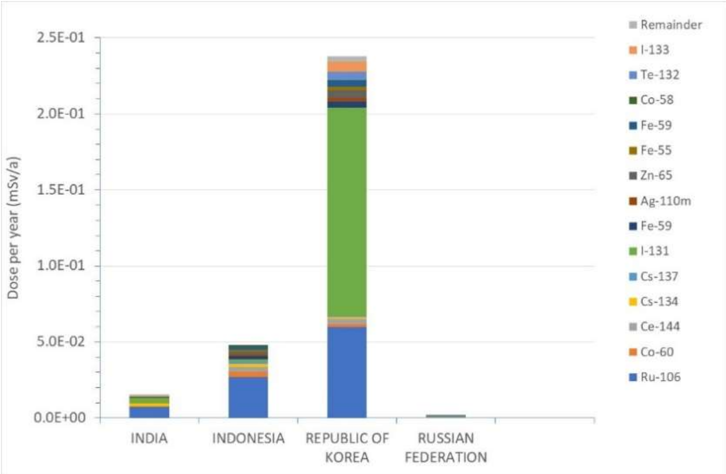

FIG. 52. Summary of results showing contribution of each nuclide. Marine case B

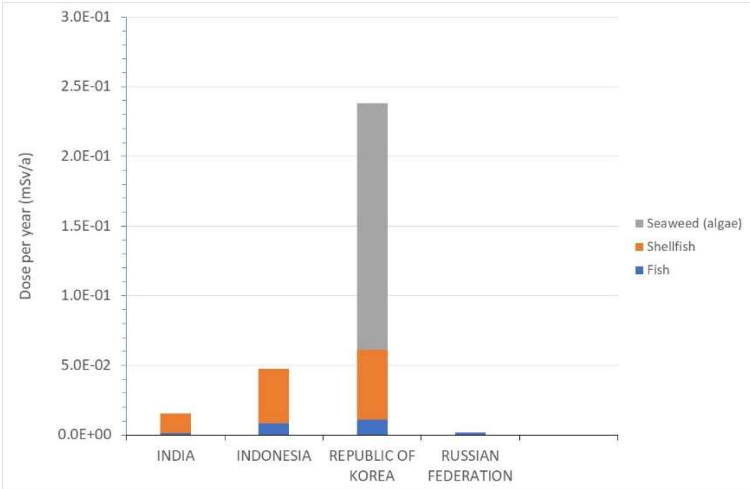

FIG. 53. Summary of results showing contribution of each pathway. Marine case B

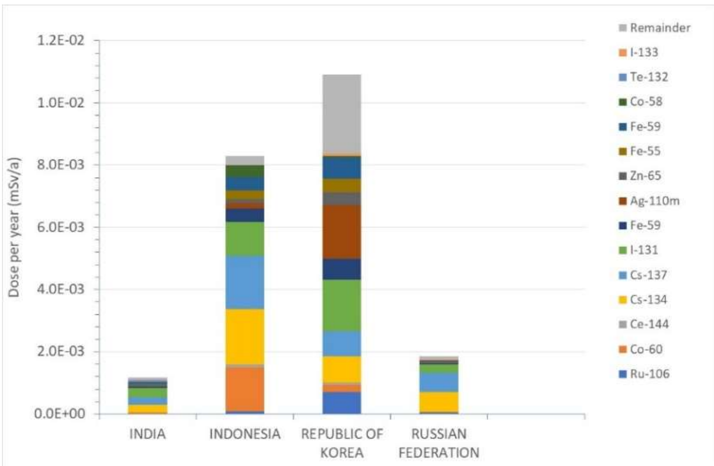

FIG. 54. Summary of results showing contribution of each nuclide for ingestion of fish only. Marine case B

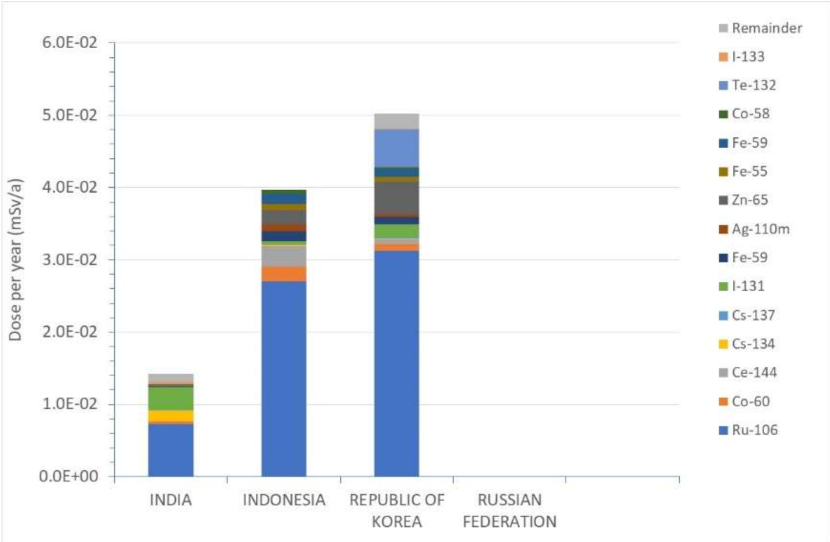

FIG. 55. Summary of results showing contribution of each nuclide for ingestion of shellfish only. Marine case B

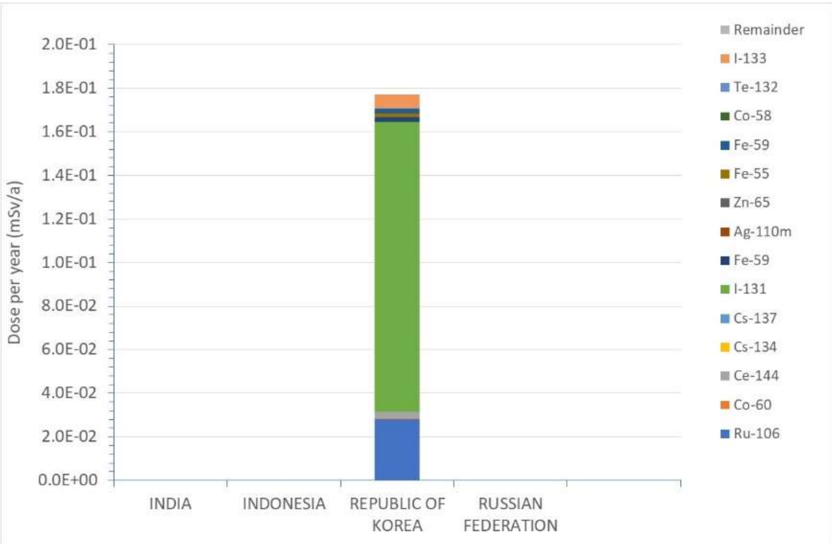

FIG. 56. Summary of results showing contribution of each nuclide for ingestion of seaweed only. Marine case B

As expected, the results show a larger variability between the participants as each used site-specific bioaccumulation factors and food consumption rates.

The results from the participant from Indonesia are very similar to those from case A. The results from the participant from India are about a third of those from case A with the main reduction coming from the fish ingestion component. The results from the participant from the Republic of Korea are about a half of those from case A for fish and shellfish consumption but adding seaweed consumption more than doubles the total dose when compared with that from case A for this participant. The results from the participant from the Russian Federation are significantly lower (about 4%) than those from case A.

The dose from Ru-106 still dominates the dose from shellfish ingestion and I-131 is the dominant contributor for seaweed ingestion in the case of the Republic of Korea with Ru-106 also making a significant contribution.

The pattern of nuclide contributions for fish consumption is very different among the participants although Cs-134, Cs-137, and I-131 are significant contributors for each of the three participants who provided pathway breakdowns. The results from each participant are discussed in more detail in turn below.

India. The difference between the results from case A and case B is the result of using country-specific bioaccumulation factors and food consumption rates. The provided values for fish and shellfish consumption rates used for case A were 50 and 15 kg/a respectively. For case B, a value 13.65 kg/a was used for both so a reduction in fish consumption of about a factor of 4 and a similar value for shellfish consumption compared with case A would be expected from changes in the consumption rates alone which is what the results show; this also explains why the shellfish consumption pathway is the dominant contributor for case B.

Indonesia. Annex IV notes that country-specific values for bioaccumulation factors for marine discharges were not available for this study and the only change between case A and B was the use of country-specific consumption rates. The values used aren’t provided but must have been very similar to the standard values used for case A as the results are very similar.

Republic of Korea. The same methodology and source term as for case A was used but with country-specific bioaccumulation factors (Table V–6) and consumption rates (Table V–7); the consumption rates are higher than the provided values for case A – 79.3 kg/a compared with 50 kg/a and 17.6 kg/a compared with 15 kg/a for fish and shellfish respectively. The ingestion pathway of seaweed was also added, as this is a typical food in Korea; this increased the dose significantly. The dose from fish and shellfish consumption was about half that from case A but the total including seaweed consumption was about double.

Russian Federation. In case B, only the dose from fish consumption was calculated. Country-specific bioaccumulation factors were used and a fish consumption rate of 12 kg/a compared with the provided value for case A of 50 kg/a. This leads to the lower doses seen compared with those from case A.

4.4 COMPARISON OF RIVERINE DISCHARGES

The participant from Republic of Korea did not provide results for the riverine cases.

4.4.1 Riverine case A.

Figure 57 shows the dose from each nuclide for each participant and the total dose on a logarithmic scale and Figure 58 shows the radionuclide breakdown for the total dose for each participant on a linear scale.

The participants from India, Indonesia, Russian Federation, and Ukraine all obtained very similar results both in the total dose (about 0.1 μSv/a) and in the contributions for the individual nuclides (Zn-65, Sr-90, I-131, Cs-134, and Cs-137 the main contributors). The participant from Belarus obtained a lower total dose (about 0.04 μSv/a) but with similar relative contributions from the significant nuclides. The participant from France obtained a lower total dose (about 0.016 μSv/a) and with a proportionally much lower contribution from I-131 and Zn-65. The participants from Belarus and France also included a contribution from tritium using a bioaccumulation factor of 1 (Table 21 does not give a value for the bioaccumulation factor and consequently the other participants did not include this nuclide); however, tritium was not a significant contributor to the total dose for either the participant from Belarus or from France – 1.5% and 3.7% respectively.

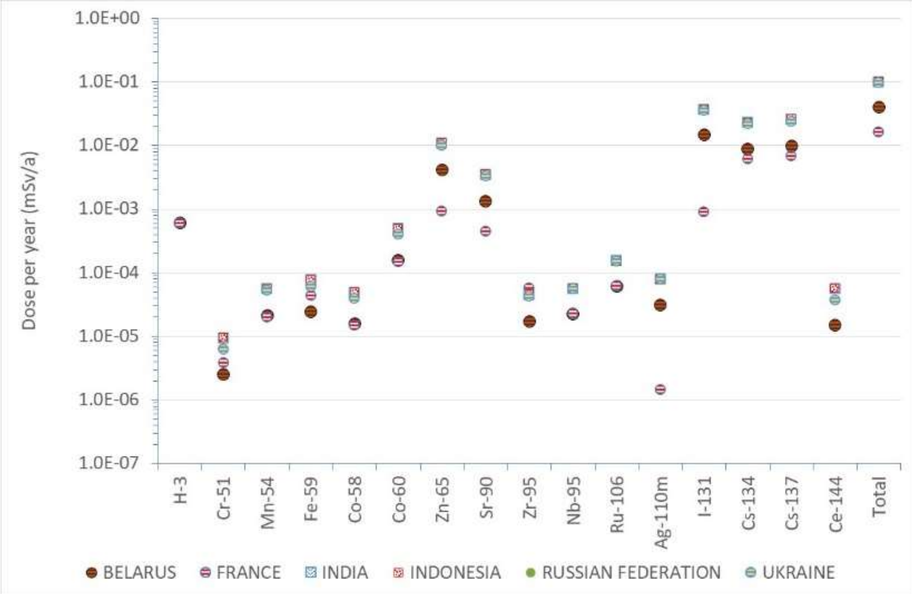

FIG. 57. Summary of results showing dose for each nuclide and total dose. Riverine case A

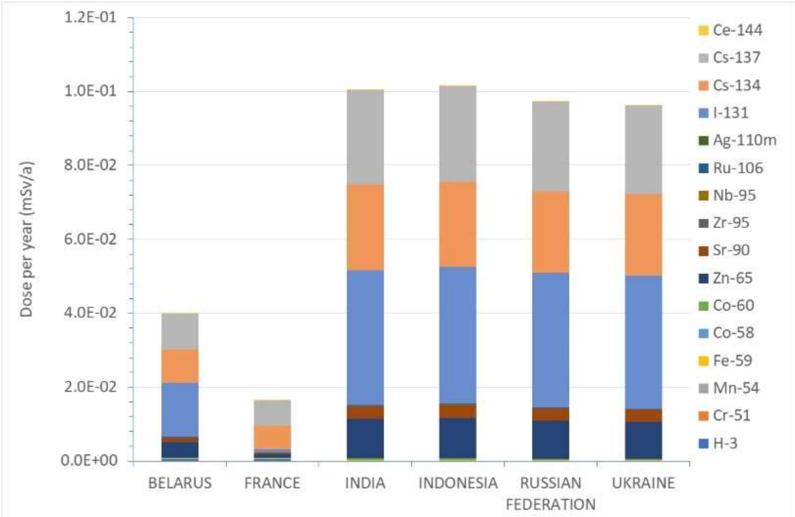

FIG. 58. Summary of results showing contribution of each nuclide. Riverine case A

The results obtained by the participants from India, Indonesia, Russian Federation, and Ukraine are what would be expected from using the fixed parameter values provided in Section 3.3.3 – multiplying together the activity concentration in the river, the bioaccumulation factor, the fish consumption rate, and ingestion dose coefficient for each nuclide. The results from the participants from Belarus and France were obtained using river models rather than the fixed parameter values directly leading to different results as these models will calculate activity concentrations that differ from the provided values.

The participant from Belarus used PC-CREAM to try and match the river water and fish activity concentrations provided in Table 22; the values provided Table I-6 for each are about 40% of those supplied in Table 21 for all nuclides.

The participant from France used the ABRICOT model of CERES platform but due to restrictions on the input data was able to change only the fish consumption rate to the fixed parameter value for case A.

4.4.2 Riverine case B

Figure 59 shows the dose from each nuclide for each participant and the total dose on a logarithmic scale and Figure 60 shows the radionuclide breakdown for the total dose for each participant on a linear scale.

The results from all the participants showed lower total doses than the corresponding values for case A; this reflected lower fish consumption rates than the 30 kg/a used in case A and for all participants (except the one from France) different – and generally lower for most nuclides – country-specific bioaccumulation factors than those used in case A. The participant from France had also used country-specific bioaccumulation factors in case A and so here the only difference was the fish consumption rate. The results for each participant are discussed in turn below.

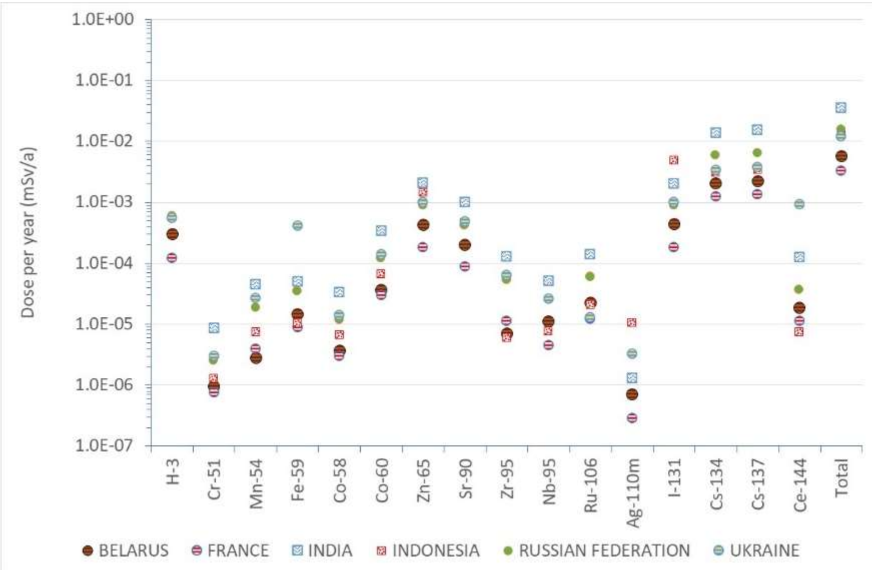

FIG. 59. Summary of results showing dose for each nuclide and total dose. Riverine case B

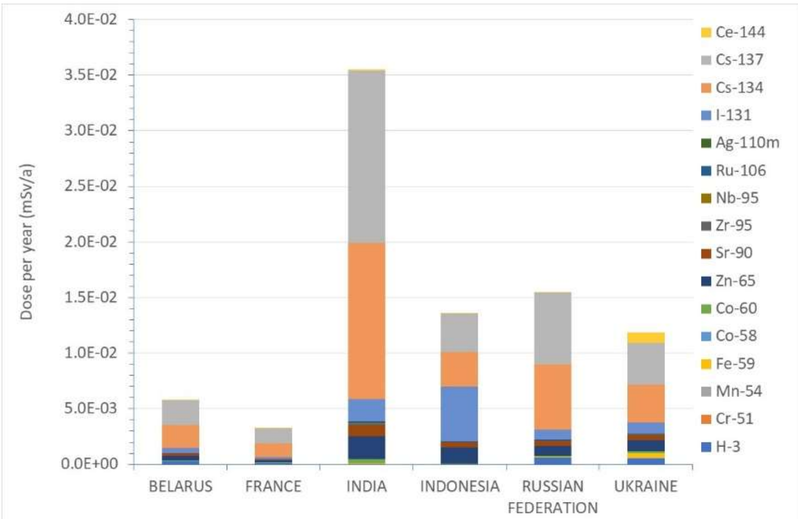

FIG. 60. Summary of results showing contribution of each nuclide. Riverine case B

Belarus. The same river water activity concentrations as case A were used but the PC-CREAM default transfer coefficients for fish were used and a country-specific fish consumption rate (14.83 kg/a as opposed to 30 kg/a year for case A). This leads to the total dose being about a factor of 7 lower than that for case A with Cs-134 and Cs-137 about a factor of 4 lower and I-131 about a factor of 30 lower.

France. As discussed above the ABRICOT model of CERES platform was used but this time with a country-specific fish consumption rate (6 kg/a as opposed to 30 kg/a year for case A). The results are consequently a factor of 5 lower than those for case A.

India. The total dose is nearly a factor of 3 lower with Cs-134 and Cs-137 a factor of 1.65 lower and I-131 about a factor of nearly 18 lower. The country-specific fish consumption rate is very similar to that used for case A (27.3 kg/a compared with 30 kg/a year for case A). The differences in the doses between case A and case B are due to the differences in the bioaccumulation factors used. There is a large difference for iodine in particular (40 l/kg based on Indian data Table III–2 and 650 l/kg in the case of standardized data set in Table 21); this difference combined with the small difference in consumption rate explains the reduction in dose from I-131 compared with that from I-131 in case A mentioned above.

Indonesia. The total dose and the contributions for all nuclides are a about a factor of 7 lower than those from case A. This is a result of only the fish consumption rate being changed (4.1 kg/a as opposed to 30 kg/a year for case A).

Russian Federation. For case B, the same radionuclide activity concentrations were applied as in case A. Country-specific bioaccumulation factors listed in Table VI–4 and a country-specific fish consumption rate (12 kg/a as opposed to 30 kg/a year for case A) were used.

Ukraine. For case B, the same radionuclide activity concentrations were applied as in case A. Country-specific transfer coefficients 'water–fish' listed in Table VII–5 and a country-specific fish consumption rate (14 kg/a as opposed to 30 kg/a year for case A) were used. Bioaccumulation factors of Cr and Nb are the same as for riverine case A. Factors for H, Mn, Fe, Zr and Ce are higher than in case A; the rest of factors are lower than in case A. This results in an overall dose about a factor of 8 lower than for case A.

4.5 RANKING OF RADIONUCLIDES

Tables 38–44 show the rankings of radionuclides using the alternative scheme introduced in section 3.4.2 for the total doses for each case for each participant.

TABLE 38. RANKINGS FOR ATMOSPHERIC DISCHARGE FOR EACH PARTICIPANT, ATMOSPHERIC CASE A

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
H-3	C_{50}	E_{25}	E_{25}	E_{25}	D_{33}	F_{10}	E_{25}
C-14	C_{50}	<0.5%	B_{75}	<0.5%	B_{75}	<0.5%	<0.5%
Ar-41	<0.5%	G_5	H_2	F_{10}	H_2	G_5	G_5
Cr-51	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Mn-54	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Fe-59	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Co-57	<0.5%	<0.5%	<0.5%	<0.5%	F_{10}	<0.5%	<0.5%
Co-58	<0.5%	H_2	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Co-60	<0.5%	G_5	<0.5%	G_5	H_2	H_2	H_2
Kr-85	H_2	G_5	G_5	F_{10}	H_2	G_5	G_5
Kr-85m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%

TABLE 38. RANKINGS FOR ATMOSPHERIC DISCHARGE FOR EACH PARTICIPANT, ATMOSPHERIC CASE A (cont.)

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
Kr-87	<0.5%	<0.5%	<0.5%	H_2	<0.5%	<0.5%	<0.5%
Kr-88	<0.5%	H_2	H_2	F_{10}	H_2	H_2	G_5
Sr-89	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sr-90	<0.5%	H_2	<0.5%	H_2	<0.5%	H_2	H_2
Zr-95	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Nb-95	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ru-103	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ru-106	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sb-125	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-131m	<0.5%	H_2	<0.5%	H_2	<0.5%	<0.5%	H_2
Xe-133	<0.5%	G_5	H_2	F_{10}	H_2	H_2	G_5
Xe-133m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-135	<0.5%	H_2	H_2	G_5	<0.5%	H_2	H_2
Xe-135m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-138	<0.5%	<0.5%	<0.5%	H_2	<0.5%	<0.5%	<0.5%
I-131	G_5	B_{75}	E_{25}	C_{50}	F_{10}	B_{75}	B_{75}
I-132	H_2	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-133	H_2	F_{10}	H_2	H_2	<0.5%	F_{10}	H_2
I-134	H_2	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-135	H_2	H_2	<0.5%	H_2	<0.5%	H_2	<0.5%
Cs-134	<0.5%	H_2	<0.5%	H_2	<0.5%	<0.5%	H_2
Cs-136	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Cs-137	<0.5%	G_5	<0.5%	H_2	H_2	H_2	H_2
Ba-140	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ce-141	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%

TABLE 39. RANKINGS FOR ATMOSPHERIC DISCHARGE FOR EACH PARTICIPANT, ATMOSPHERIC CASE B

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
H-3	C_{50}	E_{25}	E_{25}	E_{25}	D_{33}	F_{10}	E_{25}
C-14	C_{50}	<0.5%	B_{75}	<0.5%	C_{50}	<0.5%	<0.5%
Ar-41	<0.5%	G_5	H_2	F_{10}	H_2	G_5	F_{10}
Cr-51	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Mn-54	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Fe-59	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Co-57	<0.5%	<0.5%	<0.5%	<0.5%	F_{10}	<0.5%	<0.5%
Co-58	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Co-60	<0.5%	G_5	<0.5%	G_5	H_2	H_2	H_2
Kr-85	H_2	G_5	G_5	F_{10}	H_2	G_5	G_5
Kr-85m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Kr-87	<0.5%	<0.5%	<0.5%	H_2	<0.5%	<0.5%	<0.5%
Kr-88	<0.5%	G_5	H_2	F_{10}	H_2	H_2	G_5
Sr-89	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sr-90	<0.5%	G_5	<0.5%	H_2	H_2	H_2	H_2
Zr-95	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%

TABLE 39. RANKINGS FOR ATMOSPHERIC DISCHARGE FOR EACH PARTICIPANT, ATMOSPHERIC CASE B (cont.)

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
Nb-95	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ru-103	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ru-106	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sb-125	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-131m	<0.5%	H_2	<0.5%	H_2	<0.5%	<0.5%	H_2
Xe-133	<0.5%	G_5	H_2	F_{10}	H_2	H_2	G_5
Xe-133m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-135	<0.5%	H_2	H_2	G_5	<0.5%	H_2	H_2
Xe-135m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-138	<0.5%	<0.5%	<0.5%	H_2	<0.5%	<0.5%	<0.5%
I-131	G_5	B_{75}	E_{25}	C_{50}	E_{25}	B_{75}	B_{75}
I-132	H_2	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-133	H_2	F_{10}	H_2	H_2	<0.5%	F_{10}	H_2
I-134	H_2	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-135	H_2	H_2	<0.5%	H_2	<0.5%	H_2	<0.5%
Cs-134	<0.5%	H_2	<0.5%	H_2	<0.5%	<0.5%	H_2
Cs-136	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Cs-137	<0.5%	G_5	<0.5%	H_2	H_2	H_2	H_2
Ba-140	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ce-141	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%

TABLE 40. RANKINGS FOR ATMOSPHERIC DISCHARGE FOR EACH PARTICIPANT, ATMOSPHERIC CASE C

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
H-3	C_{50}	D_{33}	E_{25}	E_{25}	E_{25}	F_{10}	D_{33}
C-14	C_{50}	E_{25}	B_{75}	<0.5%	B_{75}	<0.5%	<0.5%
Ar-41	H_2	G_5	G_5	E_{25}	H_2	G_5	F_{10}
Cr-51	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Mn-54	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Fe-59	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Co-57	<0.5%	<0.5%	<0.5%	<0.5%	G_5	<0.5%	<0.5%
Co-58	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Co-60	H_2	G_5	<0.5%	G_5	<0.5%	H_2	G_5
Kr-85	H_2	H_2	G_5	F_{10}	H_2	G_5	F_{10}
Kr-85m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Kr-87	<0.5%	<0.5%	<0.5%	H_2	<0.5%	<0.5%	<0.5%
Kr-88	H_2	H_2	G_5	F_{10}	H_2	H_2	G_5
Sr-89	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sr-90	H_2	<0.5%	<0.5%	H_2	H_2	H_2	H_2
Zr-95	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Nb-95	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ru-103	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ru-106	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sb-125	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-131m	<0.5%	<0.5%	H_2	H_2	<0.5%	<0.5%	H_2

TABLE 40. RANKINGS FOR ATMOSPHERIC DISCHARGE FOR EACH PARTICIPANT, ATMOSPHERIC CASE C (cont.)

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
Xe-133	<0.5%	G_5	G_5	F_{10}	H_2	H_2	F_{10}
Xe-133m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-135	<0.5%	H_2	H_2	G_5	<0.5%	H_2	G_5
Xe-135m	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Xe-138	<0.5%	<0.5%	<0.5%	H2	<0.5%	<0.5%	<0.5%
I-131	G_5	D_{33}	E_{25}	C_{50}	G_5	B_{75}	D_{33}
I-132	H_2	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-133	H_2	G_5	H_2	H_2	<0.5%	F_{10}	H_2
I-134	H_2	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-135	H_2	H_2	<0.5%	H_2	<0.5%	H_2	H_2
Cs-134	<0.5%	<0.5%	<0.5%	H_2	<0.5%	<0.5%	H_2
Cs-136	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Cs-137	<0.5%	<0.5%	<0.5%	H_2	<0.5%	H_2	H_2
Ba-140	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ce-141	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%

TABLE 41. RANKINGS FOR MARINE DISCHARGE FOR EACH PARTICIPANT, MARINE CASE A

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
H-3	-	-	<0.5%	<0.5%	H_2	<0.5%	<0.5%
Na-24	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
P-32	-	-	H_2	H_2	H_2	H_2	H_2
Cr-51	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Mn-54	-	-	H_2	H_2	H_2	H_2	<0.5%
Fe-55	-	-	G_5	G_5	G_5	G_5	<0.5%
Fe-59	-	-	G_5	G_5	G_5	G_5	<0.5%
Co-58	-	-	G_5	G_5	G_5	G_5	H_2
Co-60	-	-	F_{10}	F_{10}	F_{10}	F_{10}	G_5
Ni-63	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Zn-65	-	-	G_5	G_5	G_5	G_5	G_5
Br-84	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Rb-88	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sr-89	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sr-90	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Sr-91	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Y-90	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Y-91m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Y-91	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Y-93	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Zr-95	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Nb-95	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Mo-99	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Tc-99m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ru-103	-	-	<0.5%	<0.5%	<0.5%	<0.5%	H_2
Ru-106	-	-	B_{75}	B_{75}	B_{75}	B_{75}	B_{75}
Rh-103m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%

TABLE 41. RANKINGS FOR MARINE DISCHARGE FOR EACH PARTICIPANT, MARINE CASE A (cont.)

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
Rh-106m	-	-	H_2	H_2	<0.5%	H_2	H_2
Ag-110	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ag-110m	-	-	G_5	G_5	G_5	G_5	G_5
Sb-124	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Te-129m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Te-129	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Te-131	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Te-131m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Te-132	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-131	-	-	G_5	G_5	G_5	G_5	F_{10}
I-132	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-133	-	-	<0.5%	<0.5%	<0.5%	<0.5%	H_2
I-134	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
I-135	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Cs-134	-	-	G_5	G_5	G_5	G_5	F_{10}
Cs-136	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Cs-137	-	-	G_5	G_5	G_5	G_5	F_{10}
Ba-135m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ba-140	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
La-140	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ce-141	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ce-143	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Ce-144	-	-	F_{10}	F_{10}	F_{10}	F_{10}	<0.5%
Pr-143	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Pr-144	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
W-187	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%
Np-239	-	-	<0.5%	<0.5%	<0.5%	<0.5%	<0.5%

TABLE 42. RANKINGS FOR MARINE DISCHARGE FOR EACH PARTICIPANT, MARINE CASE B

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
H-3	-	-	<0.5%	<0.5%	<0.5%	G_5	-
Na-24	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
P-32	-	-	<0.5%	H_2	<0.5%	<0.5%	-
Cr-51	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Mn-54	-	-	G_5	H_2	H_2	H_2	-
Fe-55	-	-	<0.5%	G_5	H_2	H_2	-
Fe-59	-	-	H_2	G_5	H_2	H_2	-
Co-58	-	-	H_2	G_5	<0.5%	<0.5%	-
Co-60	-	-	G_5	F_{10}	H_2	H_2	-
Ni-63	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Zn-65	-	-	H_2	G_5	G_5	H_2	-
Br-84	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Rb-88	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Sr-89	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Sr-90	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-

TABLE 42. RANKINGS FOR MARINE DISCHARGE FOR EACH PARTICIPANT, MARINE CASE B (cont.)

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
Sr-91	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Y-90	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Y-91m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Y-91	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Y-93	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Zr-95	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Nb-95	-	-	<0.5%	<0.5%	H_2	<0.5%	-
Mo-99	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Tc-99m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Ru-103	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Ru-106	-	-	C_{50}	B_{75}	D_{33}	G_5	-
Rh-103m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Rh-106m	-	-	<0.5%	H_2	<0.5%	H_2	-
Ag-110	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Ag-110m	-	-	<0.5%	G_5	H_2	<0.5%	-
Sb-124	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Te-129m	-	-	<0.5%	<0.5%	H_2	<0.5%	-
Te-129	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Te-131	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Te-131m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Te-132	-	-	H_2	<0.5%	G_5	<0.5%	-
I-131	-	-	E_{25}	G_5	B_{75}	E_{25}	-
I-132	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
I-133	-	-	G_5	<0.5%	G_5	H_2	-
I-134	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
I-135	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Cs-134	-	-	E_{25}	G_5	<0.5%	C_{50}	-
Cs-136	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Cs-137	-	-	G_5	G_5	<0.5%	D_{33}	-
Ba-135m	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Ba-140	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
La-140	-	-	G_5	<0.5%	<0.5%	<0.5%	-
Ce-141	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Ce-143	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Ce-144	-	-	<0.5%	F_{10}	H_2	<0.5%	-
Pr-143	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Pr-144	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
W-187	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-
Np-239	-	-	<0.5%	<0.5%	<0.5%	<0.5%	-

TABLE 43. RANKINGS FOR RIVERINE DISCHARGE FOR EACH PARTICIPANT, RIVERINE CASE A

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
H-3	H_2	G_5	<0.5%	<0.5%	-	<0.5%	<0.5%
Cr-51	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Mn-54	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Fe-59	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Co-58	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Co-60	<0.5%	H_2	<0.5%	<0.5%	-	<0.5%	<0.5%
Zn-65	E_{25}	F_{10}	E_{25}	E_{25}	-	E_{25}	E_{25}
Sr-90	G_5	G_5	G_5	G_5	-	G_5	G_5
Zr-95	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Nb-95	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Ru-106	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Ag-110m	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
I-131	C_{50}	F_{10}	C_{50}	C_{50}	-	C_{50}	C_{50}
Cs-134	E_{25}	C_{50}	E_{25}	E_{25}	-	E_{25}	E_{25}
Cs-137	E_{25}	C_{50}	D_{33}	D_{33}	-	E_{25}	E_{25}
Ce-144	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%

TABLE 44. RANKINGS FOR RIVERINE DISCHARGE FOR EACH PARTICIPANT, RIVERINE CASE B

Radionuclide	Belarus	France	India	Indonesia	Republic of Korea	Russian Federation	Ukraine
H-3	F_{10}	G_5	<0.5%	<0.5%	-	G_5	G_5
Cr-51	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Mn-54	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Fe-59	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	G_5
Co-58	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Co-60	H_2	H_2	H_2	<0.5%	-	H_2	H_2
Zn-65	F_{10}	F_{10}	F_{10}	E_{25}	-	F_{10}	F_{10}
Sr-90	G_5	G_5	G_5	G_5	-	G_5	G_5
Zr-95	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	H_2
Nb-95	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Ru-106	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
Ag-110m	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	<0.5%
I-131	F_{10}	F_{10}	F_{10}	C_{50}	-	F_{10}	F_{10}
Cs-134	C_{50}	C_{50}	C_{50}	E_{25}	-	C_{50}	D_{33}
Cs-137	C_{50}	C_{50}	C_{50}	D_{33}	-	C_{50}	D_{33}
Ce-144	<0.5%	<0.5%	<0.5%	<0.5%	-	<0.5%	F_{10}

Following that scheme, Tables 45–47 provide tabulated results from this exercise to demonstrate the utility of the method in identifying the key radionuclide and exposure pathways for each scenario.

TABLE 45. RANKINGS FOR ATMOSPHERIC DISCHARGE

Rank	Inhalation	Plume immersion		Ground deposition	Ingestion		Total dose		
		Cases A, C	Case B		Cases A, B	Case C	Case A	Case B	Case C
A_{100}	H-3	-	-	-	I-131	I-131	-	-	-
B_{75}	-	-	-	-	-	-	I-131	I-131	-
C_{50}	-	-	-	Co-60	-	-	-	-	-
D_{33}	-	-	Ar-41	-	-	-	-	-	H-3, I-131
E_{25}	-	Ar-41, Kr-85, Kr-88, Xe-133	Kr-85, Kr-88, Xe-133	I-131, Cs-137	-	-	H-3	H-3	-
F_{10}	-	Xe-135	Xe-135	I-133, I-135	-	-	-	Ar-41	Ar-41, Kr-85, Xe-133
G_5	-	Xe-131m	Kr-87, Xe-131m	Co-58, Sr-90, I-132, Cs-134	I-133	Sr-90	Ar-41, Kr-85, Kr-88, Xe-133	Kr-85, Kr-88, Xe-133	Co-60, Kr-85, Xe-135
H_2	I-131, I-133	Kr-85m, Kr-87	Kr-85m, Xe-135m, Xe-138	Mn-54, I-134	Sr-90, Cs-134, Cs-137	Co-60, I-133, Cs-134, Cs-137	Co-60, Sr-90, I-133, Xe-131m, Xe-135, Cs-134, Cs-137	Co-60, Sr-90, I-133, Xe-131m, Xe-135, Cs-134, Cs-137	Sr-90, I-133, I-135, Xe-131m, Cs-134, Cs-137

TABLE 46. RANKINGS FOR MARINE DISCHARGE

Rank	Fish	Shellfish	Total dose (ingestion)
A_{100}	-	Ru-106	-
B_{75}	-	-	Ru-106
C_{50}	-	-	-
D_{33}	Cs-134, Cs-137	-	-
E_{25}	I-131	-	-
F_{10}	P-32, Co-60	-	I-131, Cs-134, Cs-137
G_5	Ag-110m	Co-60, Zn-65, Ag-110m	Co-60, Zn-65, Ag-110m
H_2	Co-58, Zn-65, Ru-106, Rh-106m, I-133	Co-58, Ru-103, Rh-106m, I-131, Cs-134, Cs-137	P-32, Co-58, Ru-103, Rh-106m, I-133

TABLE 47. RANKINGS FOR RIVERINE DISCHARGE

Rank	Case A	Case B
A_{100}	-	-
B_{75}	-	-
C_{50}	I-131	-
D_{33}	-	Cs-134, Cs-137
E_{25}	Zn-65, Cs-134, Cs-137	-
F_{10}	-	Zn-65, I-131, Ce-144
G_5	Sr-90	H-3, Fe-59, Sr-90
H_2	-	Co-60, Zr-95

5 CONCLUSIONS

One of the objectives of this project was to compare existing methodologies used by Member States and available for assessing radiological environmental impacts of nuclear energy systems (water cooled NPPs) under normal operation. As seen in chapter 4, variation of certain parameters (e.g. atmospheric conditions, food habits, etc.) will have an effect on the total doses imparted by radionuclides in a given fixed source term.

The meteorological conditions used in the calculations are clearly important as they will affect the dose from all pathways. Likewise for marine or riverine discharges, modelling the transport and dispersion of the released radionuclides will play a major role in determining the water and sediment activities and hence activity concentrations in fish, shellfish, or other aquatic food, and hence the ingestion dose received by people consuming the food.

It is important to take into account specific local factors such as consumption of special foods; this is shown in the results from the Republic of Korea where consumption of kimchi and seaweed make significant contributions to the dose from atmospheric and marine discharges respectively. Seaweed concentrates iodine from the seawater and so can be a particularly important contributor to the total dose if consumed.

For ingestion pathways, consumption rates vary considerably among the participants reflecting different habits in different countries and again illustrating the importance of using local site-specific data.

In general, different food types will have different bioaccumulation factors for each of the nuclides and this will affect the contributions of particular nuclides to the total ingestion dose. For example, the bioaccumulation factor for ruthenium is 2000 Bq/kg per Bq/l for shellfish but only 2 Bq/kg per Bq/l for fish; this results in Ru-106 being a major contributor to the dose from shellfish consumption but making very little contribution to the dose from fish consumption where the main contributors are Co-60, Cs-134, Cs-137, and I-131

H-3 and C-14 can be significant contributors to the total dose but the way these nuclides were treated varied considerably among the participants contributing to the spread in results. This probably reflects lack in scientific knowledge about modelling the behaviour of these nuclides in the foodchain and could be an area for further research.

In summary, some of the differences between the results of the different participants are due to real differences in the systems being modelled – different food consumptions rates or different food types – and some is due to different modelling approaches and choice of parameter values.

In addition, the calculations are sensitive both to the model used and to the specific data set and assumptions used by each modeller. The difference in calculated total dose in different cases (Case A, where all input data were fixed and only the model used was varied) were within a factor of 10. Moreover, when contributions of specific radionuclides were considered, additional variations may occur that tend to be averaged out in the total dose calculations. These variances are particularly sensitive to input data and the model used.

However, in all cases, the calculated total doses are more than a factor of 1000 less, and in most cases over 10,000 times less, than typical national regulatory limits and international requirements set for maximum public exposures. Hence, given the very large difference between all estimates and required dose limits, all models and approaches applied in the study are suitable for estimations of releases, during normal NPP operations, similar to those used as inputs for this exercise.

Building upon the estimates presented in chapter 4, chapter 5 discusses development of a generic approach to dose estimation and radionuclide ranking.

Ranking of the nuclides showed the following in general (considering all the results from all participants and all cases):

- For atmospheric releases
    - Major nuclide contributors (>33%): H-3, C-14, and I-131
    - Minor nuclide contributors (>2%): Ar-41, Co-60, Kr-85, Kr-88, Sr-90, Xe-133, Xe-135, I-133, Cs-134, and Cs-137
- For marine releases
    - Major nuclide contributors (>33%): Ru-106
    - Minor nuclide contributors (>2%): Fe-55, Fe-59, Co-58, Co-60, Zn-65, Ag-110m, I-131, Cs-134, Cs-137, Ce-144
- For riverine releases
    - Major nuclide contributors (>33%): I-131, Cs-134, and Cs-137
    - Minor nuclide contributors (>2%): Zn-65, Sr-90

Despite variances, the rank ordering of importance of radioisotopes in the different cases was sufficiently comparable (when taken as a percent of total dose) that the above cursory rank ordering scheme can be suggested. Such an approach should be sufficient for use in hypothetical situations, or for a conservative cursory evaluation. Following this, when moving to the next stage of assessment, use of more site-specific parameter values will result in a more realistic estimation of the doses.

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ANNEX I. BELARUS

I–1. DESCRIPTION OF MODELS AND METHODOLOGIES APPLIED

The basic modeling package used by Belarus to estimate radiological doses was PC-CREAM 08 (Consequences of Releases to the Environment: Assessment Methodology [I–9]), further PC-CREAM. This tool was developed by the Health Protection Agency for the assessment of the radiological impact of routine discharges of radioactive material into the environment. The recommendations of the ICRP Publication 103 [I–5], have been taken into account in developing the assessment methodology. Dose coefficients based on revised radiation and tissue weighting factors were taken from ICRP Publication 60 [I–3].

PC-CREAM consists of two modules called ‘Models’ and ‘Assessor’. ‘Models’ includes a series of mathematical representations that evaluates the characteristics of radionuclides transfer through the environment and provide estimates of activity concentrations in various environmental media following the routine release. The output of these models is then used as an input to the dose assessment component, Assessor.

PLUME is the atmospheric dispersion model used within PC-CREAM. It is a Gaussian plume model which takes into account the meteorological conditions during the release, the roughness of the land surface and the physical characteristics of the radionuclides being released. The model calculates activity concentrations in air, deposition rates and external gamma dose rates from radionuclides in the cloud (cloud gamma) at various distances downwind of the release point. The output from the model can be used as input to ASSESSOR which combines these results with site specific meteorological data and actual release rates to calculate actual activity concentrations in air, deposition rates and cloud gamma dose rates downwind of the release point. The deposition rates from PLUME are used to scale the results from other models within the code, namely RESUS, GRANIS and FARMLAND (described below), to estimate doses from various exposure routes arising from the discharge of radionuclides to the atmosphere.

RESUS can be used to estimate activity concentrations in air arising from the re-suspension of previously deposited radionuclides. It uses a formula derived by Garland et al. [I–1] which is independent of the radionuclide considered with the exception that differences in radioactive decay are taken into account. The activity concentrations, which are calculated for a user-defined deposition rate, are input to ASSESSOR which scales them by the actual deposition rate at various locations downwind of the discharge point and combines them with habit data to calculate doses from inhalation of re-suspended material.

GRANIS calculates exposure to gamma radiation from radionuclides deposited on the ground. GRANIS models the transfer of radionuclides through the soil and takes into account the shielding properties of the soil when estimating doses one metre above the soil surface. The calculated doses are based on a user-defined deposition rate. GRANIS is the only model in PC-CREAM that includes some organ doses as well as an effective dose. Effective doses are input to ASSESSOR which scales them by the actual deposition rate at various locations downwind of the discharge point and combines them with habit data to estimate actual exposures.

FARMLAND is a suite of models that can be used to predict the transfer of radionuclides into terrestrial foods following deposition onto the ground. The food categories considered are those that are most important in the European human diet, namely, green vegetables, root vegetables, fruit, grain, cow milk, cow milk products, cow meat, cow liver, sheep meat, and sheep liver. Activity concentrations in each food are calculated for a user-defined deposition rate. These activity concentrations are input to ASSESSOR which scales them by the actual deposition rate at various locations downwind of the discharge point and combines them with habit data to calculate ingestion doses.

PC-CREAM includes two models for calculating the dispersion of radionuclides released to rivers. The *Screening model* is a simple dilution model which assumes instantaneous equilibrium between the water and river sediments and should be used as a screening tool. It can be used in three modes depending on the amount of input data available (namely, Simple Screening Model, Extended Screening Model with complete mixing and Extended Screening Model with incomplete mixing). For more detailed assessments the *Dynamic model* can be used, which is a time-dependent compartment model and requires a greater amount of input data to run. For the INPRO study, the extended Screening model was used. From that, only the estimated concentrations in fish were passed on for dose estimation via ingestion using ASSESSOR.

ASSESSOR is the dose assessment part of PC-CREAM, to calculate effective doses. There are five parts of ASSESSOR to calculate individual and collective doses from discharges to the atmosphere and sea and individual doses from discharges into rivers. Each part of ASSESSOR displays all the model runs that are available for use, including the default set. The results of these models are combined with actual discharge rates, site-specific data, habit data and dose coefficients, to calculate effective doses for the most important exposure pathways. For exposure via inhalation or ingestion, the dose per unit intake values cannot be changed. If the user wishes to use different values for these parameters, then the doses calculated by ASSESSOR must be scaled in a spreadsheet by multiplying by the ratio of the user value to the default value.

I–2. STRUCTURE OF CONSIDERATION OF PUBLIC EXPOSURES FROM NORMAL OPERATION

Only atmospheric and riverine dispersion scenarios were considered relevant to Belarus. For the atmospheric dispersion scenario, annual adult radiological doses via the following exposure pathways were considered: Inhalation of plume; External gamma and beta from air; External gamma and beta from ground; Inhalation of re-suspended material; and Ingestion of foodstuff (cow meat, cow liver, cow milk, sheep meat, sheep liver, green vegetables, root vegetables, fruit and grain). For the riverine dispersion, doses derived from external gamma and beta due to adult exposure from riverbank sediments; and from the ingestion of fish and drinking water, were estimated.

There was discussion between participants on the best way to compare the various approaches being used to estimate dose. To standard responses as far as possible, there was general agreement on what factors should be fixed for all participants. However, some of those agreed factors were not able to be followed by Belarus as a consequence of there being unalterable default settings in PC-CREAM. This Section discusses those modifications for the atmospheric dispersion.

In atmospheric release case A, it was not possible to use the dilution factors (x/Q values) provided from the Brazilian data as input to the PC-CREAM model. Therefore, a new input file of meteorological data for PLUME, based on the Pasquill meteorological scheme (Turner classes A to F), was created using meteorological data provided by Brazil. This comprised a frequency distribution of wind speed and wind direction by stability class (Table I–1).

There are slight differences in milk, cow meat and goat meat transfer coefficients for Cs, Sr and I between TRS 472 [I–2] values (usage agreed by the participants) and the PC-CREAM default values. Values of transfer coefficients used in PC-CREAM are provided in Table I–2. No attempt was made to adjust the outputs of the model to account for these differences.

There are also some differences in the inhalation dose coefficient values (Sv/Bq) in Table 16 (as agreed by the participants) and those in PC-CREAM (Table I–3) as a result of using different inhalation types.

TABLE I–1. FREQUENCIES OF METEOROLOGICAL CONDITIONS USED IN CASE A

Sectors[a]	Pasquill/Hosker/Smith weather conditions category							
	A	B	C	D	E	F	C Rain	D Rain
1	2.26E-02	8.15E-03	3.59E-03	1.51E-02	6.69E-03	1.98E-03	0.00E-00	0.00E-00
2	1.83E-02	9.80E-03	4.94E-03	1.98E-02	8.50E-03	2.32E-03	0.00E-00	0.00E-00
3	8.51E-03	4.29E-03	2.87E-03	1.28E-02	4.42E-03	9.29E-04	0.00E-00	0.00E-00
4	4.43E-03	2.19E-03	1.39E-03	6.55E-03	2.39E-03	3.21E-04	0.00E-00	0.00E-00
5	4.14E-03	2.28E-03	9.29E-04	5.11E-03	2.49E-03	5.65E-04	0.00E-00	0.00E-00
6	6.77E-03	4.23E-03	1.90E-03	7.74E-03	6.00E-03	2.39E-03	0.00E-00	0.00E-00
7	1.06E-02	7.61E-03	4.18E-03	1.72E-02	1.95E-02	6.22E-03	0.00E-00	0.00E-00
8	1.36E-02	1.13E-02	6.90E-03	3.78E-02	4.89E-02	1.52E-02	0.00E-00	0.00E-00
9	1.66E-02	1.44E-02	8.74E-03	6.16E-02	8.15E-02	3.09E-02	0.00E-00	0.00E-00
10	1.08E-02	9.41E-03	5.41E-03	4.65E-02	3.99E-02	3.30E-02	0.00E-00	0.00E-00
11	3.28E-03	2.30E-03	1.88E-03	1.22E-02	1.32E-02	2.28E-02	0.00E-00	0.00E-00
12	2.40E-03	1.22E-03	8.61E-04	5.03E-03	6.84E-03	8.29E-03	0.00E-00	0.00E-00
13	2.75E-03	1.17E-03	5.72E-04	3.85E-03	5.40E-03	2.31E-03	0.00E-00	0.00E-00
14	3.58E-03	1.24E-03	5.68E-04	3.47E-03	4.25E-03	7.86E-04	0.00E-00	0.00E-00
15	5.91E-03	1.47E-03	7.46E-04	3.74E-03	3.73E-03	5.99E-04	0.00E-00	0.00E-00
16	9.58E-03	2.67E-03	1.30E-03	5.30E-03	3.92E-03	5.72E-04	0.00E-00	0.00E-00
17	1.32E-02	4.92E-03	2.14E-03	7.69E-03	4.00E-03	5.64E-04	0.00E-00	0.00E-00
18	1.70E-02	6.04E-03	2.35E-03	1.02E-02	5.53E-03	1.05E-03	0.00E-00	0.00E-00

a - Sector 1 – 0° to 20°, sector 2 – 20° to 40°, sector 3 – 40° to 60°, etc.

TABLE I–2. MILK AND MEAT TRANSFER COEFFICIENTS

Radio-nuclide	Milk, d/L		Meat (beef), d/kg		Meat (goat), d/kg	
	TRS-472	PC-CREAM	TRS-472	PC-CREAM	TRS-472	PC-CREAM
Sr-89	1.30E-03	2.00E-03	1.30E-03	3.00E-04	2.90E-03	3.00E-03
Sr-90	1.30E-03	2.00E-03	1.30E-03	3.00E-04	2.90E-03	3.00E-03
I-131	5.40E-03	5.00E-03	6.70E-03	2.00E-03	n/a	5.00E-02
I-132(e)	5.40E-03	5.00E-03	6.70E-03	2.00E-03	n/a	5.00E-02
I-133 (e)	5.40E-03	5.00E-03	6.70E-03	2.00E-03	n/a	5.00E-02
I-134 (e)	5.40E-03	5.00E-03	6.70E-03	2.00E-03	n/a	5.00E-02
I-135 (e)	5.40E-03	5.00E-03	6.70E-03	2.00E-03	n/a	5.00E-02
Cs-134	4.60E-03	5.00E-03	2.20E-02	3.00E-02	3.20E-01	5.00E-01
Cs-136	4.60E-03	5.00E-03	2.20E-02	3.00E-02	3.20E-01	5.00E-01
Cs-137	4.60E-03	5.00E-03	2.20E+02	3.00E-02	3.20E-01	5.00E-01

In atmospheric release case B, country-specific meteorological conditions were used (Pasquill meteorological scheme, Turner A to F stability classes) based on measurements taken at the Ostrovets site in Grodno, Belarus (54°45′42.8″N 26°7′11.5″E). This site is approved for the construction of Belorussian NPP with two VVR-1200 reactor units. The effective release height was 100 m. According to long-term observations for the Ostrovets site, mean values of wind speed and frequency of wind direction (Table I–4) were used for the calculations.

TABLE I–3. INHALATION TYPES AND DOSE COEFFICIENTS DIFFERENCE

	Inhalation dose coefficient (Sv/Bq)		ICRP publication 72 inhalation type	
Radionuclide	From Table 16	PC-CREAM	From Table 16	PC-CREAM
Fe-59	4.00E-09	3.70E-09	S	M
Co-57	1.00E-09	5.50E-10	S	M
Co-58	2.10E-09	1.60E-09	S	M
Co-60	3.10E-08	1.00E-08	S	M
Sr-89	7.90E-09	6.10E-09	S	M
Sr-90	1.60E-07	3.60E-08	S	M
Zr-95	5.90E-09	4.80E-09	S	M
Nb-95	1.80E-09	1.50E-09	S	M
Ru-103	3.00E-09	2.70E-09	S	M
Ru-106	6.60E-08	2.80E-08	S	M
Sb-125	1.20E-08	4.80E-09	S	M
Ce-141	3.80E-09	3.20E-09	S	M

TABLE I–4, AVERAGE WIND SPEED AND FREQUENCY OF WIND DIRECTION

Month	Wind speed, m/s	Frequency of wind direction, %							
		N	NE	E	SE	S	SW	W	NW
January	3.6	5	10	8	10	18	25	16	8
February	3.4	7	13	10	12	14	20	16	8
March	3.3	6	12	13	12	16	19	15	7
April	3.1	10	15	13	11	13	14	14	10
May	2.8	13	18	13	9	11	12	13	11
June	2.7	13	14	8	6	11	15	18	15
July	2.6	11	12	7	5	9	19	22	15
August	2.4	9	12	7	7	12	20	21	12
September	2.8	7	9	9	8	15	24	19	9
October	3.3	6	6	8	11	17	27	17	8
November	3.5	5	7	9	13	22	25	14	5
December	3.6	5	8	7	10	19	27	16	8
Average per year	3.1	8	11	9	9	15	21	17	10

In atmospheric release case C, country-specific parameters were used for breathing rate, transfer coefficients and food consumption. The breathing rate applied was 8400 m^3/a (adult). For local transfer coefficients, the default values used in PC-CREAM were applied. Local adult food consumption rates are given in Table I–5.

TABLE I–5. FOOD AND WATER CONSUMPTION BY ADULTS IN BELARUS [6]

Product	Intake, kg/a (l/a)
Cow milk	62.99
Cow meat	33.82
Sheep meat	0.35
Green vegetables	15.28
Root vegetables	82.03
Fruit	29.82

In riverine release case A, the ASSESSOR model in PC-CREAM is not able to directly accept water concentrations at the point of sampling as input, as agreed by the participants. Hence, by adjusting the river characteristics as well as the radionuclide discharge rates and concentrations accordingly, the River model in PC-CREAM was used to estimate concentrations in stream bed sediments, water and fish at a defined point downstream (Table I–6), that were approximately equivalent to the input values provided to the other participants. The transfer coefficients used to estimate concentrations in fish (Table I–6) were adjusted according to participants agreement.

TABLE I–6. ACTIVITY CONCENTRATIONS IN RIVER WATER, SEDIMENTS AND FISH FROM A CONTINUOUS DISCHARGE AT 1 KM DOWNSTREAM

Radionuclide	Concentration type			
	Unfiltered water, Bq/m^3	Filtered water, Bq/m^3	Bed sediment, Bq/kg	Fish, Bq/kg
Ag-110m	3.44E-03	3.41E-03	6.82E-04	3.75E-04
Ce-144	1.20E-02	8.01E-03	8.01E-02	9.61E-05
Co-58	2.24E-03	1.79E-03	8.97E-03	7.17E-04
Co-60	4.88E-03	3.91E-03	1.95E-02	1.56E-03
Cr-51	1.68E-02	1.12E-02	1.12E-01	2.24E-03
Cs-134	5.44E-03	5.19E-03	5.19E-03	1.56E-02
Cs-137	8.81E-03	8.39E-03	8.39E-03	2.52E-02
Fe-59	4.08E-03	3.27E-03	1.63E-02	4.57E-04
H-3	1.12E+03	1.12E+03	3.36E-02	1.12E+00
I-131	3.43E-02	3.43E-02	3.43E-04	2.23E-02
Mn-54	2.32E-03	2.21E-03	2.21E-03	9.95E-04
Nb-95	4.32E-03	4.30E-03	4.30E-04	1.29E-03
Ru-106	2.96E-02	2.89E-02	1.45E-02	2.89E-04
Sr-90	8.81E-03	8.39E-03	8.39E-03	1.59E-03
Zn-65	7.85E-03	7.66E-03	3.83E-03	3.60E-02
Zr-95	6.64E-03	6.33E-03	6.33E-03	6.01E-04

In riverine release case B, the same river water activity concentrations were used as in case A but country-specific data for transfer coefficients were used to estimate concentrations in the sediment and fish flesh. The transfer coefficients used were defaults according to PC-CREAM methodology. To estimate dose via ingestion of fish flesh, a Belarus consumption rate of 14.83 kg/a (WW) was used (Ministry of Statistics and Analysis of the Republic of Belarus Data Book [I–6]).

I–3. RESULTS OF ASSESSMENT

Total dose and contribution to the total dose from different radionuclides in the atmospheric release case A are provided in Tables I-7, I-8, and Figures I-1 to I-5. Rankings based on contribution to the total dose and contribution to the dose from a given pathway for the atmospheric release case A are presented in Tables I-9 and I-10.

TABLE I–7. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	1.35E-03	0.00E+00	3.01E-03	9.36E-04	4.38E-03	8.33E-03	0.00E+00	9.68E-03
C-14 CO2	7.84E-04	3.67E-09	1.81E-03	2.16E-03	5.92E-03	9.89E-03	0.00E+00	1.07E-02
Ar-41	0.00E+00	9.94E-05	0.00E+00	0.00E+00	4.11E-09	4.11E-09	0.00E+00	9.94E-05
Cr-51	1.83E-10	9.16E-12	3.06E-10	1.08E-08	1.92E-09	1.30E-08	1.30E-08	2.62E-08
Mn-54	4.37E-09	1.48E-10	9.95E-10	5.34E-09	6.24E-08	6.87E-08	2.01E-06	2.08E-06
Fe-59	5.32E-09	1.04E-10	3.83E-10	1.35E-09	3.10E-08	3.28E-08	2.25E-07	2.63E-07
Co-57	2.30E-10	3.07E-12	5.77E-11	4.99E-11	1.74E-09	1.84E-09	2.25E-07	2.27E-07
Co-58	3.93E-08	1.44E-09	9.54E-09	3.91E-09	2.63E-07	2.76E-07	4.98E-06	5.29E-06
Co-60	5.62E-08	8.60E-10	1.86E-08	2.39E-08	9.18E-07	9.61E-07	4.85E-05	4.95E-05
Kr-85	0.00E+00	1.67E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.67E-04
Kr-85m	0.00E+00	2.79E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E-06

TABLE I–7. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE A (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Kr-87	1.21E-19	6.89E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.89E-06
Kr-88	6.25E-06	7.39E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.02E-05
Sr-89	4.98E-08	1.15E-11	9.26E-08	7.21E-09	3.51E-07	4.50E-07	1.94E-07	6.94E-07
Sr-90	1.16E-07	1.22E-12	5.09E-06	4.36E-07	4.48E-05	5.03E-05	1.25E-07	5.05E-05
Zr-95	2.45E-09	2.28E-11	8.08E-12	1.33E-12	7.55E-09	7.56E-09	1.44E-07	1.55E-07
Nb-95	3.21E-09	9.89E-11	2.07E-12	1.18E-13	1.41E-08	1.41E-08	1.71E-07	1.89E-07
Ru-103	2.08E-09	2.41E-11	2.50E-11	4.34E-10	7.30E-09	7.76E-09	4.94E-08	5.93E-08
Ru-106	1.12E-09	6.33E-13	1.66E-11	1.24E-09	4.58E-09	5.84E-09	1.09E-08	1.78E-08
Sb-125	1.50E-10	7.78E-13	1.01E-11	1.45E-10	7.97E-10	9.52E-10	2.94E-08	3.05E-08
Xe-131m	0.00E+00	1.67E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.67E-05
Xe-133	0.00E+00	9.14E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.14E-05
Xe-133m	0.00E+00	1.01E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-06
Xe-135	4.62E-14	3.27E-05	1.44E-11	2.97E-11	1.57E-11	5.98E-11	3.67E-14	3.27E-05
Xe-135m	0.00E+00	1.02E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-06
Xe-138	6.65E-07	5.74E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.40E-06
I-131	1.40E-05	4.29E-08	3.72E-04	4.88E-05	3.63E-04	7.84E-04	3.00E-05	8.28E-04
I-132(e)	5.93E-07	8.70E-07	3.78E-09	1.27E-19	1.91E-07	1.95E-07	1.28E-04	1.30E-04
I-133 (e)	9.44E-06	2.34E-07	1.34E-05	1.42E-07	2.48E-05	3.83E-05	1.21E-04	1.69E-04
I-134 (e)	3.19E-07	1.12E-06	6.98E-11	1.07E-36	3.11E-08	3.12E-08	1.74E-04	1.76E-04
I-135 (e)	2.98E-06	1.11E-06	3.40E-07	1.81E-11	2.57E-06	2.91E-06	1.54E-04	1.61E-04
Cs-134	1.62E-08	2.31E-10	2.21E-06	4.39E-06	2.84E-06	9.44E-06	6.68E-06	1.61E-05
Cs-136	2.02E-09	2.20E-10	5.18E-08	3.90E-08	7.14E-08	1.62E-07	1.46E-07	3.10E-07
Cs-137	2.11E-08	1.66E-10	5.58E-06	1.14E-05	5.65E-06	2.26E-05	2.29E-05	4.55E-05
Ba-140	1.09E-09	2.86E-12	2.47E-10	2.57E-11	6.94E-09	7.21E-09	2.21E-08	3.04E-08
Ce-141	2.12E-09	3.04E-12	3.70E-11	1.20E-12	5.07E-09	5.11E-09	7.27E-09	1.45E-08
Total dose	2.17E-03	5.02E-04	5.22E-03	3.16E-03	1.07E-02	1.91E-02	6.93E-04	2.25E-02

TABLE I–8. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	6.23E+01	0.00E+00	5.77E+01	2.96E+01	4.08E+01	4.35E+01	0.00E+00	4.30E+01
C-14 CO2	3.62E+01	7.31E-04	3.47E+01	6.83E+01	5.51E+01	5.17E+01	0.00E+00	4.75E+01
Ar-41	0.00E+00	1.98E+01	0.00E+00	0.00E+00	3.82E-05	2.15E-05	0.00E+00	4.42E-01
Cr-51	8.44E-06	1.82E-06	5.86E-06	3.42E-04	1.79E-05	6.81E-05	1.88E-03	1.17E-04
Mn-54	2.02E-04	2.95E-05	1.91E-05	1.69E-04	5.80E-04	3.59E-04	2.90E-01	9.26E-03
Fe-59	2.45E-04	2.08E-05	7.34E-06	4.27E-05	2.89E-04	1.71E-04	3.25E-02	1.17E-03
Co-57	1.06E-05	6.11E-07	1.11E-06	1.58E-06	1.61E-05	9.63E-06	3.25E-02	1.01E-03
Co-58	1.81E-03	2.87E-04	1.83E-04	1.24E-04	2.45E-03	1.44E-03	7.18E-01	2.35E-02
Co-60	2.59E-03	1.71E-04	3.56E-04	7.56E-04	8.54E-03	5.02E-03	7.00E+00	2.20E-01
Kr-85	0.00E+00	3.33E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.44E-01
Kr-85m	0.00E+00	5.55E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-02
Kr-87	5.58E-15	1.37E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.06E-02
Kr-88	2.88E-01	1.47E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.57E-01
Sr-89	2.30E-03	2.30E-06	1.77E-03	2.28E-04	3.26E-03	2.35E-03	2.81E-02	3.09E-03
Sr-90	5.35E-03	2.44E-07	9.75E-02	1.38E-02	4.17E-01	2.63E-01	1.81E-02	2.25E-01
Zr-95	1.13E-04	4.54E-06	1.55E-07	4.20E-08	7.02E-05	3.95E-05	2.09E-02	6.87E-04
Nb-95	1.48E-04	1.97E-05	3.97E-08	3.73E-09	1.31E-04	7.36E-05	2.47E-02	8.39E-04

TABLE I–8. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Ru-103	9.60E-05	4.81E-06	4.79E-07	1.37E-05	6.79E-05	4.06E-05	7.13E-03	2.64E-04
Ru-106	5.16E-05	1.26E-07	3.18E-07	3.92E-05	4.26E-05	3.05E-05	1.57E-03	7.92E-05
Sb-125	6.92E-06	1.55E-07	1.94E-07	4.60E-06	7.41E-06	4.98E-06	4.24E-03	1.35E-04
Xe-131m	0.00E+00	3.32E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.41E-02
Xe-133	0.00E+00	1.82E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.07E-01
Xe-133m	0.00E+00	2.01E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.50E-03
Xe-135	2.13E-09	6.51E+00	2.76E-07	9.39E-07	1.46E-07	3.13E-07	5.29E-09	1.45E-01
Xe-135m	0.00E+00	2.03E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.54E-03
Xe-138	3.07E-02	1.14E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.85E-02
I-131	6.46E-01	8.54E-03	7.13E+00	1.54E+00	3.38E+00	4.10E+00	4.34E+00	3.68E+00
I-132(e)	2.73E-02	1.73E-01	7.24E-05	4.02E-15	1.78E-03	1.02E-03	1.85E+01	5.77E-01
I-133 (e)	4.35E-01	4.66E-02	2.57E-01	4.49E-03	2.30E-01	2.00E-01	1.74E+01	7.50E-01
I-134 (e)	1.47E-02	2.23E-01	1.34E-06	3.38E-32	2.90E-04	1.63E-04	2.51E+01	7.80E-01
I-135 (e)	1.37E-01	2.21E-01	6.51E-03	5.73E-07	2.39E-02	1.52E-02	2.22E+01	7.14E-01
Cs-134	7.47E-04	4.59E-05	4.23E-02	1.39E-01	2.64E-02	4.93E-02	9.65E-01	7.18E-02
Cs-136	9.31E-05	4.38E-05	9.93E-04	1.23E-03	6.64E-04	8.48E-04	2.11E-02	1.38E-03
Cs-137	9.73E-04	3.30E-05	1.07E-01	3.61E-01	5.26E-02	1.18E-01	3.30E+00	2.02E-01
Ba-140	5.04E-05	5.69E-07	4.73E-06	8.14E-07	6.46E-05	3.77E-05	3.19E-03	1.35E-04
Ce-141	9.78E-05	6.06E-07	7.09E-07	3.80E-08	4.72E-05	2.67E-05	1.05E-03	6.45E-05
Total dose	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02

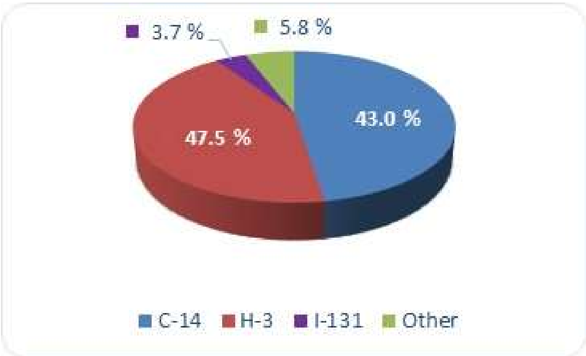

FIG. I–1. Total dose contribution per radionuclide, %. Atmospheric case A

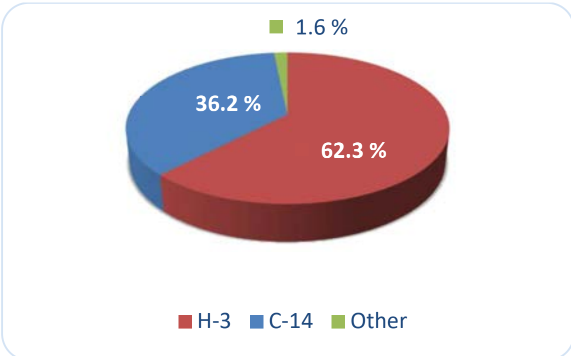

FIG. I–2. Inhalation dose contribution per radionuclide, %. Atmospheric case A

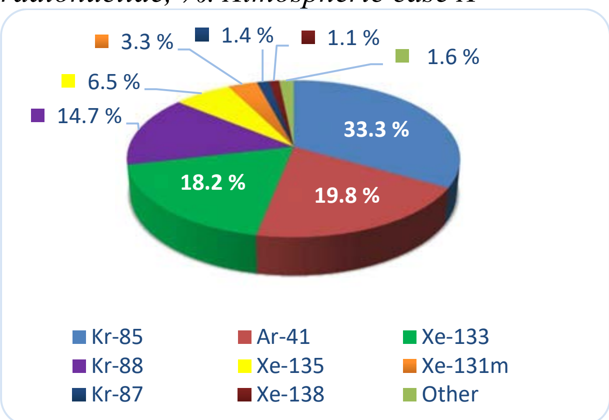

FIG. I–3. Immersion dose contribution per radionuclide, %, Atmospheric case A

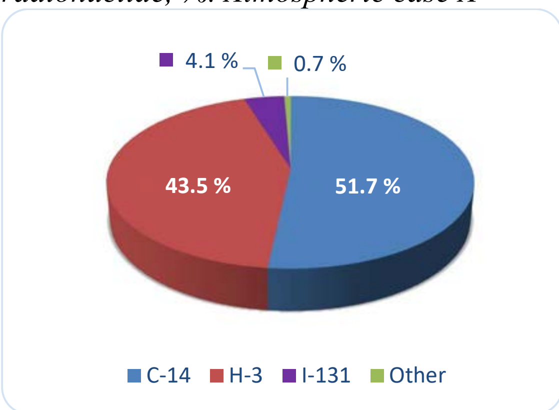

FIG. I–4. Ingestion dose contribution per radionuclide, %, Atmospheric case A

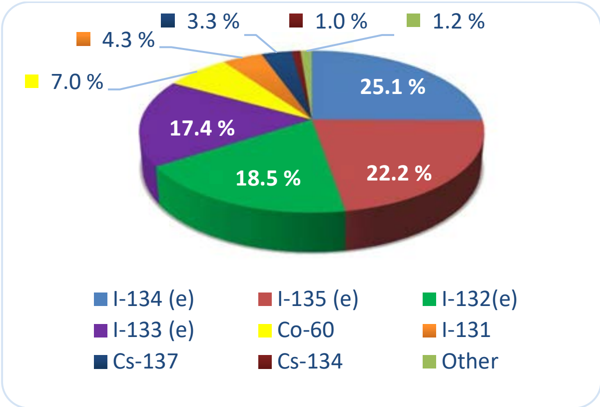

FIG. I–5. External dose contribution per radionuclide, %, Atmospheric case A

TABLE I–9. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE (UP TO CUT-OFF LEVEL OF 0.5%). ATMOSPHERIC CASE A

Radionuclide	Pathway	Dose, µSv/a	Contribution to total dose, all pathways, %	Rank	Rank category
C-14 CO_2	ingestion	4.75E+01	47.46	1	C_{50}
H-3	inhalation	4.30E+01	43.03	2	C_{50}
I-131	ingestion	3.68E+00	3.68	3	G_5
I-134 (e)	external	7.80E-01	0.78	4	G_5
I-133 (e)	external	7.50E-01	0.75	5	G_5
Kr-85	immersion	7.44E-01	0.74	6	G_5
I-135 (e)	external	7.14E-01	0.71	7	G_5
I-132(e)	external	5.77E-01	0.58	8	G_5

TABLE I–10. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE A

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
1	H-3	62.25	Kr-85	33.30	C-14 CO_2	51.71	I-134 (e)	25.12
2	C-14 co_2	36.15	Ar-41	19.80	H-3	43.53	I-135 (e)	22.17
3	I-131	0.65	Xe-133	18.20	I-131	4.10	I-132(e)	18.50
4	I-133 (e)	0.44	Kr-88	14.72	Sr-90	0.26	I-133 (e)	17.41
5	Kr-88	0.29	Xe-135	6.51	I-133 (e)	0.20	Co-60	7.00
6	I-135 (e)	0.14	Xe-131m	3.32	Cs-137	0.12	I-131	4.34
7	Xe-138	0.03	Kr-87	1.37	Cs-134	0.05	Cs-137	3.30
8	I-132(e)	0.03	Xe-138	1.14	I-135 (e)	0.02	Cs-134	0.96
9	I-134 (e)	0.01	Kr-85m	0.55	Co-60	0.01	Co-58	0.72
10	Sr-90	0.01	I-134 (e)	0.22	Sr-89	0.002	Mn-54	0.29
11	Co-60	0.003	I-135 (e)	0.221	Co-58	0.001	Co-57	0.03
12	Sr-89	0.002	Xe-135m	0.203	I-132(e)	0.0010	Fe-59	0.032
13	Co-58	0.0018	Xe-133m	0.201	Cs-136	0.0008	Sr-89	0.028
14	Cs-137	0.0010	I-132(e)	0.173	Mn-54	0.0004	Nb-95	0.025
15	Cs-134	0.0007	I-133 (e)	0.047	Fe-59	0.0002	Cs-136	0.021
16	Fe-59	0.0002	I-131	0.009	I-134 (e)	0.0002	Zr-95	0.021
17	Mn-54	0.00020	C-14 co_2	0.001	Nb-95	0.0001	Sr-90	0.018
18	Nb-95	0.00015	Co-58	0.0003	Cr-51	0.00007	Ru-103	0.007
19	Zr-95	0.00011	Co-60	0.0002	Ru-103	0.00004	Sb-125	0.004
20	Ce-141	0.00010	Cs-134	0.00005	Zr-95	0.00004	Ba-140	0.003

TABLE I–10. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE A (cont.)

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
21	Ru-103	0.00010	Cs-136	0.00004	Ba-140	0.00004	Cr-51	0.002
22	Cs-136	0.00009	Cs-137	0.00003	Ru-106	0.00003	Ru-106	0.0016
23	Ru-106	0.00005	Mn-54	0.000029	Ce-141	0.00003	Ce-141	0.0010
24	Ba-140	0.000050	Fe-59	0.000021	Ar-41	0.00002	Xe-135	0.0000
25	Co-57	0.000011	Nb-95	0.000020	Co-57	0.00001	H-3	0.0000
26	Cr-51	0.000008	Ru-103	0.000005	Sb-125	0.00000	C-14 CO_2	0.0000
27	Sb-125	0.000007	Zr-95	0.000005	Xe-135	0.00000	Ar-41	0.0000
28	Xe-135	0.000000	Sr-89	0.000002	Kr-85	0.00000	Kr-85	0.0000
29	Kr-87	0.000000	Cr-51	0.000002	Kr-85m	0.00000	Kr-85m	0.0000
30	Ar-41	0.000000	Co-57	0.000001	Kr-87	0.00000	Kr-87	0.0000
31	Kr-85	0.000000	Ce-141	0.000001	Kr-88	0.00000	Kr-88	0.0000
32	Kr-85m	0.000000	Ba-140	0.000001	Xe-131m	0.00000	Xe-131m	0.0000
33	Xe-131m	0.000000	Sr-90	0.000000	Xe-133	0.00000	Xe-133	0.0000
34	Xe-133	0.000000	Sb-125	0.000000	Xe-133m	0.00000	Xe-133m	0.0000
35	Xe-133m	0.000000	Ru-106	0.000000	Xe-135m	0.00000	Xe-135m	0.0000
36	Xe-135m	0.000000	H-3	0.000000	Xe-138	0.00000	Xe-138	0.0000

Total dose and contribution to the total dose from different radionuclides in the atmospheric release case B are provided in Tables I-11, I-12, and Figures I-6 to I-10. Rankings based on contribution to the total dose and contribution to the dose from a given pathway for the atmospheric release case B are presented in Tables I-13 and I-14.

TABLE I–11. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	1.47E-03	0.00E+00	3.28E-03	1.02E-03	4.78E-03	9.08E-03	0.00E+00	1.06E-02
C-14 CO2	8.55E-04	4.00E-09	1.97E-03	2.36E-03	6.45E-03	1.08E-02	0.00E+00	1.16E-02
Ar-41	0.00E+00	1.25E-04	0.00E+00	0.00E+00	5.59E-09	5.59E-09	0.00E+00	1.25E-04
Cr-51	2.00E-10	9.64E-12	4.17E-10	1.47E-08	2.62E-09	1.77E-08	1.77E-08	3.57E-08
Mn-54	4.78E-09	1.53E-10	1.35E-09	7.27E-09	8.50E-08	9.36E-08	2.74E-06	2.84E-06
Fe-59	5.80E-09	1.07E-10	5.21E-10	1.84E-09	4.23E-08	4.47E-08	3.07E-07	3.57E-07
Co-57	2.52E-10	3.26E-12	7.86E-11	6.80E-11	2.37E-09	2.51E-09	3.07E-07	3.09E-07
Co-58	4.30E-08	1.50E-09	1.30E-08	5.33E-09	3.58E-07	3.77E-07	6.77E-06	7.20E-06
Co-60	6.14E-08	8.83E-10	2.53E-08	3.25E-08	1.25E-06	1.31E-06	6.61E-05	6.75E-05
Kr-85	0.00E+00	1.81E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.81E-04
Kr-85m	0.00E+00	3.17E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.17E-06
Kr-87	6.37E-20	9.16E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.16E-06
Kr-88	5.38E-06	7.90E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.44E-05
Sr-89	0.00E+00	1.79E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.79E-05
Sr-90	0.00E+00	9.89E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.89E-05
Zr-95	3.44E-12	3.19E-14	3.82E-13	9.76E-13	2.84E-09	2.84E-09	8.39E-11	2.93E-09
Nb-95	3.51E-09	1.03E-10	2.82E-12	1.61E-13	1.91E-08	1.91E-08	2.33E-07	2.56E-07
Ru-103	2.28E-09	2.52E-11	3.40E-11	5.91E-10	9.93E-09	1.06E-08	6.73E-08	8.01E-08
Ru-106	1.64E-10	1.48E-12	1.37E-11	1.68E-10	7.47E-10	9.28E-10	4.20E-08	4.31E-08
Sb-125	1.27E-07	1.29E-12	6.93E-06	5.94E-07	6.10E-05	6.85E-05	1.70E-07	6.88E-05
Xe-131m	0.00E+00	2.53E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.53E-09
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	2.07E-14	3.58E-05	7.91E-12	1.62E-11	8.58E-12	3.27E-11	2.01E-14	3.58E-05

TABLE I–11. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Xe-135	0.00E+00	2.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.24E-06
Xe-135m	8.86E-07	9.14E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-05
Xe-138	2.68E-09	2.37E-11	1.08E-11	1.24E-12	8.64E-09	8.65E-09	1.97E-07	2.08E-07
I-131	1.53E-05	4.52E-08	5.07E-04	6.66E-05	4.95E-04	1.07E-03	4.10E-05	1.13E-03
I-132(e)	7.53E-07	1.05E-06	6.00E-09	2.01E-19	3.04E-07	3.10E-07	2.04E-04	2.06E-04
I-133 (e)	1.05E-05	2.49E-07	1.86E-05	1.97E-07	3.43E-05	5.31E-05	1.67E-04	2.31E-04
I-134 (e)	4.93E-07	1.65E-06	1.36E-10	2.07E-36	6.06E-08	6.07E-08	3.38E-04	3.40E-04
I-135 (e)	3.44E-06	1.15E-06	4.89E-07	2.61E-11	3.71E-06	4.20E-06	2.21E-04	2.29E-04
Cs-134	1.77E-08	2.40E-10	3.01E-06	5.98E-06	3.87E-06	1.29E-05	9.11E-06	2.20E-05
Cs-136	2.21E-09	2.29E-10	7.06E-08	5.31E-08	9.72E-08	2.21E-07	2.00E-07	4.23E-07
Cs-137	2.31E-08	1.72E-10	7.59E-06	1.55E-05	7.70E-06	3.08E-05	3.11E-05	6.19E-05
Ba-140	1.19E-09	2.70E-12	3.37E-10	3.51E-11	9.44E-09	9.82E-09	3.00E-08	4.10E-08
Ce-141	2.32E-09	3.23E-12	5.04E-11	1.63E-12	6.91E-09	6.96E-09	9.88E-09	1.92E-08
Total dose	2.36E-03	5.65E-04	5.79E-03	3.47E-03	1.18E-02	2.11E-02	1.09E-03	2.51E-02

TABLE I–12. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	6.22E+01	0.00E+00	5.66E+01	2.94E+01	4.04E+01	4.30E+01	0.00E+00	4.20E+01
C-14 CO_2	3.62E+01	7.08E-04	3.40E+01	6.80E+01	5.45E+01	5.11E+01	0.00E+00	4.63E+01
Ar-41	0.00E+00	2.21E+01	0.00E+00	0.00E+00	4.72E-05	2.65E-05	0.00E+00	4.97E-01
Cr-51	8.47E-06	1.71E-06	7.20E-06	4.24E-04	2.22E-05	8.41E-05	1.63E-03	1.42E-04
Mn-54	2.02E-04	2.71E-05	2.33E-05	2.10E-04	7.18E-04	4.44E-04	2.52E-01	1.13E-02
Fe-59	2.46E-04	1.90E-05	8.99E-06	5.30E-05	3.57E-04	2.12E-04	2.82E-02	1.42E-03
Co-57	1.07E-05	5.77E-07	1.36E-06	1.96E-06	2.00E-05	1.19E-05	2.82E-02	1.23E-03
Co-58	1.82E-03	2.66E-04	2.24E-04	1.54E-04	3.03E-03	1.79E-03	6.23E-01	2.86E-02
Co-60	2.60E-03	1.56E-04	4.37E-04	9.37E-04	1.06E-02	6.19E-03	6.08E+00	2.69E-01
Kr-85	0.00E+00	3.20E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.20E-01
Kr-85m	0.00E+00	5.61E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E-02
Kr-87	2.70E-15	1.62E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.65E-02
Kr-88	2.28E-01	1.40E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.36E-01
Sr-89	0.00E+00	3.17E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.13E-02
Sr-90	0.00E+00	1.75E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.94E-01
Zr-95	0.00E+00	0.00E+00	3.80E-09	1.62E-08	1.38E-05	7.73E-06	1.39E-07	6.50E-06
Nb-95	1.49E-04	1.82E-05	4.87E-08	4.64E-09	1.62E-04	9.07E-05	2.15E-02	1.02E-03
Ru-103	9.66E-05	4.47E-06	5.87E-07	1.70E-05	8.39E-05	5.00E-05	6.19E-03	3.19E-04
Ru-106	6.94E-06	2.62E-07	2.36E-07	4.84E-06	6.31E-06	4.40E-06	3.86E-03	1.72E-04
Sb-125	5.38E-03	2.29E-07	1.20E-01	1.71E-02	5.15E-01	3.25E-01	1.56E-02	2.74E-01
Xe-131m	0.00E+00	4.47E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-05
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	8.76E-10	6.34E+00	1.37E-07	4.67E-07	7.25E-08	1.55E-07	1.85E-09	1.43E-01
Xe-135	0.00E+00	3.96E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.91E-03
Xe-135m	3.75E-02	1.62E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.99E-02
Xe-138	1.14E-04	4.19E-06	1.86E-07	3.57E-08	7.30E-05	4.10E-05	1.81E-02	8.29E-04
I-131	6.48E-01	7.99E-03	8.75E+00	1.92E+00	4.18E+00	5.06E+00	3.77E+00	4.48E+00
I-132(e)	3.19E-02	1.86E-01	1.04E-04	5.79E-15	2.57E-03	1.47E-03	1.87E+01	8.19E-01
I-133 (e)	4.45E-01	4.40E-02	3.21E-01	5.68E-03	2.90E-01	2.52E-01	1.53E+01	9.18E-01

TABLE I–12. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
I-134 (e)	2.09E-02	2.91E-01	2.35E-06	5.97E-32	5.12E-04	2.88E-04	3.11E+01	1.35E+00
I-135 (e)	1.46E-01	2.03E-01	8.44E-03	7.52E-07	3.13E-02	1.99E-02	2.03E+01	9.13E-01
Cs-134	7.49E-04	4.24E-05	5.20E-02	1.72E-01	3.27E-02	6.09E-02	8.38E-01	8.75E-02
Cs-136	9.36E-05	4.06E-05	1.22E-03	1.53E-03	8.21E-04	1.05E-03	1.84E-02	1.68E-03
Cs-137	9.78E-04	3.05E-05	1.31E-01	4.47E-01	6.50E-02	1.46E-01	2.86E+00	2.46E-01
Ba-140	5.04E-05	4.78E-07	5.82E-06	1.01E-06	7.98E-05	4.65E-05	2.76E-03	1.63E-04
Ce-141	9.82E-05	5.71E-07	8.70E-07	4.70E-08	5.84E-05	3.30E-05	9.09E-04	7.63E-05
Total dose	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02

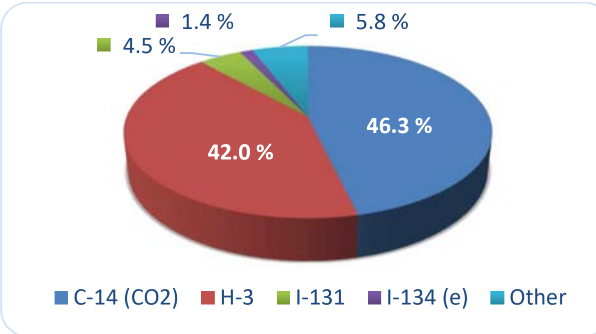

FIG. I–6. Total dose contribution per radionuclide, %. Atmospheric case B

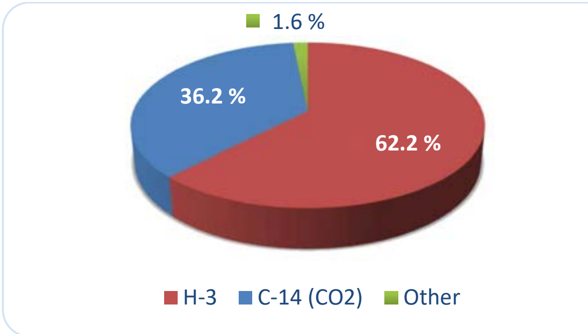

FIG. I–7. Inhalation dose contribution per radionuclide, %. Atmospheric case B

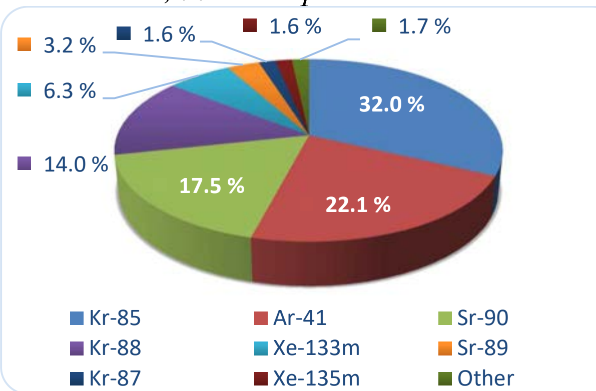

FIG. I–8. Immersion dose contribution per radionuclide, %. Atmospheric case B

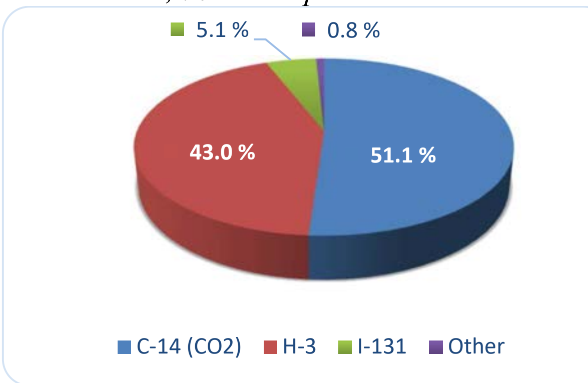

FIG. I–9. Ingestion dose contribution per radionuclide, %. Atmospheric case B

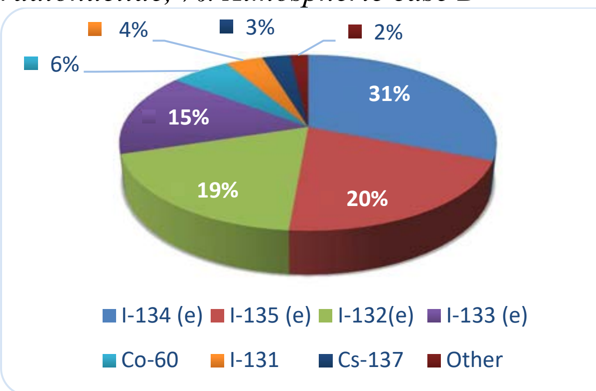

FIG. I–10. External dose contribution per radionuclide, %. Atmospheric case B

TABLE I–13. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE (UP TO CUT-OFF LEVEL OF 0.5%). ATMOSPHERIC CASE B

Radionuclide	Pathway	Dose, μSv/a	Contribution to total dose, all pathways, %	Rank	Rank category
C-14 CO_2	ingestion	1,16E-02	46.33	1	C_{50}
H-3	inhalation	1,06E-02	42.01	2	C_{50}
I-131	ingestion	1,13E-03	4.48	3	G_5
I-134 (e)	external	3,40E-04	1.35	4	G_5
I-133 (e)	external	2,31E-04	0.92	5	G_5
I-135 (e)	external	2,29E-04	0.91	6	G_5
I-132(e)	external	2,06E-04	0.82	7	G_5
Kr-85	immersion	1,81E-04	0.72	8	G_5
Ar-41	immersion	1,25E-04	0.50	9	G_5

TABLE I–14. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE B

Rank	Inhalation pathway		Immersion pathway		Ingestion pathway		External exposure	
	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
1	H-3	62.23	Kr-85	32.01	C-14 CO_2	51.09	I-134 (e)	31.08
2	C-14 CO_2	36.20	Ar-41	22.08	H-3	43.03	I-135 (e)	20.29
3	I-131	0.65	Sr-90	17.49	I-131	5.06	I-132(e)	18.72
4	I-133 (e)	0.44	Kr-88	13.98	Sb-125	0.32	I-133 (e)	15.33
5	Kr-88	0.23	Xe-133m	6.34	I-133 (e)	0.25	Co-60	6.08
6	I-135 (e)	0.15	Sr-89	3.17	Cs-137	0.15	I-131	3.77
7	Xe-135m	0.04	Kr-87	1.62	Cs-134	0.06	Cs-137	2.86
8	I-132(e)	0.03	Xe-135m	1.62	I-135 (e)	0.02	Cs-134	0.84
9	I-134 (e)	0.02	Kr-85m	0.56	Co-60	0.01	Co-58	0.62
10	Sb-125	0.01	Xe-135	0.40	Co-58	0.002	Mn-54	0.25
11	Co-60	0.003	I-134 (e)	0.29	I-132(e)	0.001	Co-57	0.03
12	Co-58	0.002	I-135 (e)	0.20	Cs-136	0.001	Fe-59	0.03
13	Cs-137	0.001	I-132(e)	0.19	Mn-54	0.0004	Nb-95	0.02
14	Cs-134	0.0007	I-133 (e)	0.04	I-134 (e)	0.0003	Cs-136	0.02
15	Fe-59	0.00025	I-131	0.01	Fe-59	0.0002	Xe-138	0.02
16	Mn-54	0.00020	C-14 CO_2	0.001	Nb-95	0.0001	Sb-125	0.02
17	Nb-95	0.00015	Xe-131m	0.0004	Cr-51	0.00008	Ru-103	0.01
18	Xe-138	0.00011	Co-58	0.0003	Ru-103	0.00005	Ru-106	0.004
19	Ce-141	0.00010	Co-60	0.0002	Ba-140	0.000047	Ba-140	0.003
20	Ru-103	0.00010	Cs-134	0.00004	Xe-138	0.000041	Cr-51	0.002
21	Cs-136	0.00009	Cs-136	0.000041	Ce-141	0.000033	Ce-141	0.001
22	Ba-140	0.00005	Cs-137	0.000030	Ar-41	0.000026	Zr-95	0.00001
23	Co-57	0.00001	Mn-54	0.000027	Zr-95	0.000013	Xe-133m	0.00000
24	Cr-51	0.000008	Fe-59	0.000019	Co-57	0.000012	H-3	0.00000
25	Ru-106	0.000007	Nb-95	0.000018	Ru-106	0.00000	C-14 CO_2	0.00000
26	Zr-95	0.00000	Ru-103	0.00000	Xe-133m	0.00000	Ar-41	0.00000
27	Xe-133m	0.00000	Xe-138	0.00000	Kr-85	0.00000	Kr-85	0.00000
28	Kr-87	0.00000	Cr-51	0.00000	Kr-85m	0.00000	Kr-85m	0.00000
29	Ar-41	0.00000	Co-57	0.00000	Kr-87	0.00000	Kr-87	0.00000
30	Kr-85	0.00000	Ce-141	0.00000	Kr-88	0.00000	Kr-88	0.00000
31	Kr-85m	0.00000	Ba-140	0.00000	Sr-89	0.00000	Sr-89	0.00000
32	Sr-89	0.00000	Ru-106	0.00000	Sr-90	0.00000	Sr-90	0.00000
33	Sr-90	0.00000	Sb-125	0.00000	Xe-131m	0.00000	Xe-131m	0.00000

TABLE I–14. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE B (cont.)

Rank	Inhalation pathway		Immersion pathway		Ingestion pathway		External exposure	
	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
34	Xe-131m	0.00000	Zr-95	0.00000	Xe-133	0.00000	Xe-133	0.00000
35	Xe-133	0.00000	H-3	0.00000	Xe-135	0.00000	Xe-135	0.00000
36	Xe-135	0.00000	Xe-133	0.00000	Xe-135m	0.00000	Xe-135m	0.00000

Total dose and contribution to the total dose from different radionuclides in the atmospheric release case C are provided in Tables I-15, I-16, and Figures I-11 to I-15. Rankings based on contribution to the total dose and contribution to the dose from a given pathway for the atmospheric release case C are presented in Tables I-17 and I-18.

TABLE I–15. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	1.35E-03	0.00E+00	7.58E-04	3.16E-04	1.36E-03	2.43E-03	0.00E+00	3.78E-03
C-14 CO_2	7.84E-04	3.67E-09	4.55E-04	7.32E-04	1.83E-03	3.02E-03	0.00E+00	3.80E-03
Ar-41	0.00E+00	9.94E-05	0.00E+00	0.00E+00	2.87E-09	2.87E-09	0.00E+00	9.94E-05
Cr-51	1.83E-10	9.16E-12	1.48E-11	1.67E-10	1.35E-09	1.53E-09	1.30E-08	1.47E-08
Mn-54	4.37E-09	1.48E-10	9.83E-10	1.21E-09	2.42E-08	2.64E-08	2.01E-06	2.04E-06
Fe-59	5.32E-09	1.04E-10	1.15E-10	2.74E-11	2.15E-08	2.16E-08	2.25E-07	2.52E-07
Co-57	2.30E-10	3.07E-12	1.12E-11	3.31E-12	9.25E-10	9.40E-10	2.25E-07	2.26E-07
Co-58	3.93E-08	1.44E-09	1.83E-09	2.58E-10	1.66E-07	1.68E-07	4.98E-06	5.18E-06
Co-60	5.62E-08	8.60E-10	3.58E-09	1.58E-09	2.22E-07	2.27E-07	4.85E-05	4.88E-05
Kr-85	0.00E+00	1.67E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.67E-04
Kr-85m	0.00E+00	2.79E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E-06
Kr-87	1.21E-19	6.89E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.89E-06
Kr-88	6.25E-06	7.39E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.02E-05
Sr-89	0.00E+00	1.67E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.67E-05
Sr-90	0.00E+00	9.24E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.24E-05
Zr-95	0.00E+00	0.00E+00	3.44E-14	1.27E-14	7.82E-10	7.82E-10	1.11E-12	7.83E-10
Nb-95	3.21E-09	9.89E-11	4.25E-13	3.85E-14	9.68E-09	9.68E-09	1.71E-07	1.84E-07
Ru-103	2.08E-09	2.41E-11	5.63E-13	3.71E-11	5.06E-09	5.10E-09	4.94E-08	5.66E-08
Ru-106	1.50E-10	1.41E-12	5.64E-12	2.93E-11	3.87E-10	4.21E-10	3.08E-08	3.14E-08
Sb-125	1.16E-07	1.22E-12	9.76E-07	1.12E-07	2.25E-06	3.34E-06	1.25E-07	3.58E-06
Xe-131m	0.00E+00	5.54E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.54E-09
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	4.62E-14	3.27E-05	2.90E-12	8.00E-12	4.00E-12	1.49E-11	3.67E-14	3.27E-05
Xe-135	0.00E+00	1.02E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-06
Xe-135m	6.65E-07	5.74E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.40E-06
Xe-138	2.45E-09	2.28E-11	2.80E-13	2.16E-14	4.36E-09	4.36E-09	1.44E-07	1.51E-07
I-131	1.40E-05	4.29E-08	7.66E-05	1.35E-05	2.12E-04	3.02E-04	3.00E-05	3.46E-04
I-132(e)	5.93E-07	8.70E-07	7.62E-10	3.43E-20	1.34E-07	1.35E-07	1.28E-04	1.30E-04
I-133 (e)	9.44E-06	2.34E-07	2.71E-06	3.85E-08	1.72E-05	1.99E-05	1.21E-04	1.50E-04
I-134 (e)	3.19E-07	1.12E-06	1.40E-11	2.89E-37	2.19E-08	2.19E-08	1.74E-04	1.75E-04
I-135 (e)	2.98E-06	1.11E-06	6.85E-08	4.90E-12	1.81E-06	1.88E-06	1.54E-04	1.60E-04
Cs-134	1.62E-08	2.31E-10	4.58E-07	1.22E-06	1.24E-06	2.91E-06	6.68E-06	9.61E-06
Cs-136	2.02E-09	2.20E-10	1.07E-08	1.08E-08	3.89E-08	6.04E-08	1.46E-07	2.09E-07
Cs-137	2.11E-08	1.66E-10	1.13E-06	3.10E-06	1.72E-06	5.95E-06	2.29E-05	2.88E-05
Ba-140	1.09E-09	2.86E-12	1.65E-10	2.57E-11	4.85E-09	5.04E-09	2.21E-08	2.82E-08
Ce-141	2.12E-09	3.04E-12	3.89E-11	1.69E-12	3.55E-09	3.59E-09	7.27E-09	1.30E-08
Total dose	2.17E-03	5.02E-04	1.29E-03	1.07E-03	3.43E-03	5.79E-03	6.93E-04	9.15E-03

TABLE I–16. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	6.23E+01	0.00E+00	5.85E+01	2.96E+01	3.97E+01	4.21E+01	0.00E+00	4.13E+01
C-14 CO_2	3.62E+01	7.31E-04	3.51E+01	6.87E+01	5.34E+01	5.21E+01	0.00E+00	4.15E+01
Ar-41	0.00E+00	1.98E+01	0.00E+00	0.00E+00	8.36E-05	4.95E-05	0.00E+00	1.09E+00
Cr-51	8.44E-06	1.82E-06	1.14E-06	1.57E-05	3.95E-05	2.65E-05	1.88E-03	1.61E-04
Mn-54	2.02E-04	2.95E-05	7.59E-05	1.14E-04	7.06E-04	4.56E-04	2.90E-01	2.23E-02
Fe-59	2.45E-04	2.08E-05	8.89E-06	2.57E-06	6.26E-04	3.73E-04	3.25E-02	2.76E-03
Co-57	1.06E-05	6.11E-07	8.65E-07	3.11E-07	2.70E-05	1.62E-05	3.25E-02	2.47E-03
Co-58	1.81E-03	2.87E-04	1.41E-04	2.42E-05	4.85E-03	2.91E-03	7.18E-01	5.66E-02
Co-60	2.59E-03	1.71E-04	2.76E-04	1.48E-04	6.46E-03	3.92E-03	7.00E+00	5.33E-01
Kr-85	0.00E+00	3.33E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.83E+00
Kr-85m	0.00E+00	5.55E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.04E-02
Kr-87	5.58E-15	1.37E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.52E-02
Kr-88	2.88E-01	1.47E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.76E-01
Sr-89	0.00E+00	3.32E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.82E-01
Sr-90	0.00E+00	1.84E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E+00
Zr-95	0.00E+00	0.00E+00	2.66E-09	1.19E-09	2.28E-05	1.35E-05	1.60E-07	8.56E-06
Nb-95	1.48E-04	1.97E-05	3.28E-08	3.61E-09	2.82E-04	1.67E-04	2.47E-02	2.01E-03
Ru-103	9.60E-05	4.81E-06	4.35E-08	3.48E-06	1.48E-04	8.80E-05	7.13E-03	6.19E-04
Ru-106	6.92E-06	2.81E-07	4.36E-07	2.75E-06	1.13E-05	7.28E-06	4.45E-03	3.43E-04
Sb-125	5.35E-03	2.44E-07	7.54E-02	1.05E-02	6.56E-02	5.76E-02	1.81E-02	3.91E-02
Xe-131m	0.00E+00	1.10E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.06E-05
Xe-133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	2.13E-09	6.51E+00	2.24E-07	7.50E-07	1.17E-07	2.57E-07	5.29E-09	3.58E-01
Xe-135	0.00E+00	2.03E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E-02
Xe-135m	3.07E-02	1.14E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.99E-02
Xe-138	1.13E-04	4.54E-06	2.16E-08	2.03E-09	1.27E-04	7.53E-05	2.09E-02	1.65E-03
I-131	6.46E-01	8.54E-03	5.92E+00	1.27E+00	6.19E+00	5.22E+00	4.34E+00	3.79E+00
I-132(e)	2.73E-02	1.73E-01	5.88E-05	3.22E-15	3.92E-03	2.33E-03	1.85E+01	1.42E+00
I-133 (e)	4.35E-01	4.66E-02	2.09E-01	3.61E-03	5.02E-01	3.45E-01	1.74E+01	1.64E+00
I-134 (e)	1.47E-02	2.23E-01	1.08E-06	2.71E-32	6.38E-04	3.78E-04	2.51E+01	1.92E+00
I-135 (e)	1.37E-01	2.21E-01	5.29E-03	4.60E-07	5.27E-02	3.24E-02	2.22E+01	1.74E+00
Cs-134	7.47E-04	4.59E-05	3.54E-02	1.14E-01	3.61E-02	5.03E-02	9.65E-01	1.05E-01
Cs-136	9.32E-05	4.38E-05	8.26E-04	1.01E-03	1.14E-03	1.04E-03	2.11E-02	2.28E-03
Cs-137	9.73E-04	3.30E-05	8.73E-02	2.91E-01	5.01E-02	1.03E-01	3.30E+00	3.15E-01
Ba-140	5.04E-05	5.69E-07	1.27E-05	2.41E-06	1.41E-04	8.71E-05	3.19E-03	3.08E-04
Ce-141	9.78E-05	6.06E-07	3.00E-06	1.59E-07	1.04E-04	6.21E-05	1.05E-03	1.42E-04
Total dose	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02	1.E+02

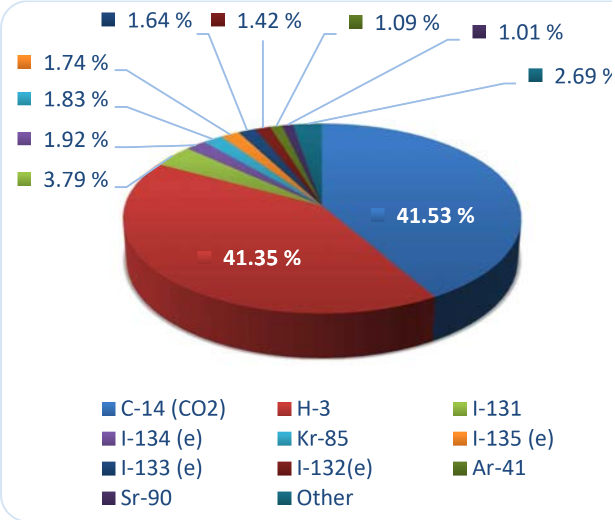

FIG. I–11. Total dose contribution per radionuclide, %. Atmospheric case C

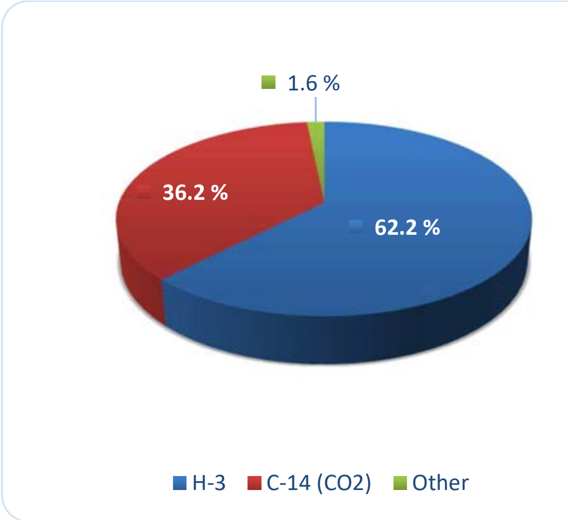

FIG. I–12. Inhalation dose contribution per radionuclide, %. Atmospheric case C

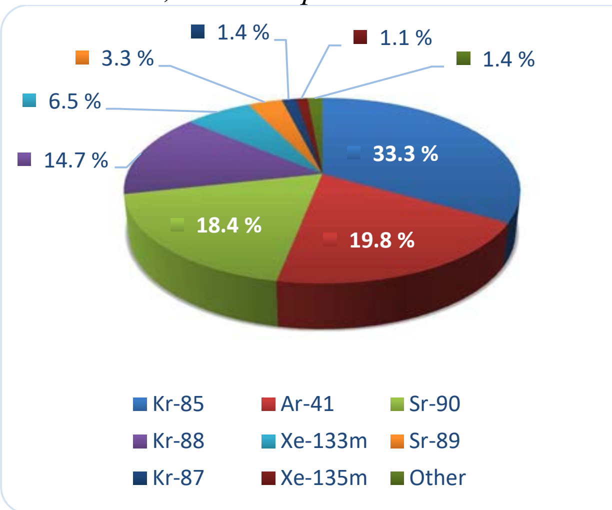

FIG. I–13. Immersion dose contribution per radionuclide, %. Atmospheric case C

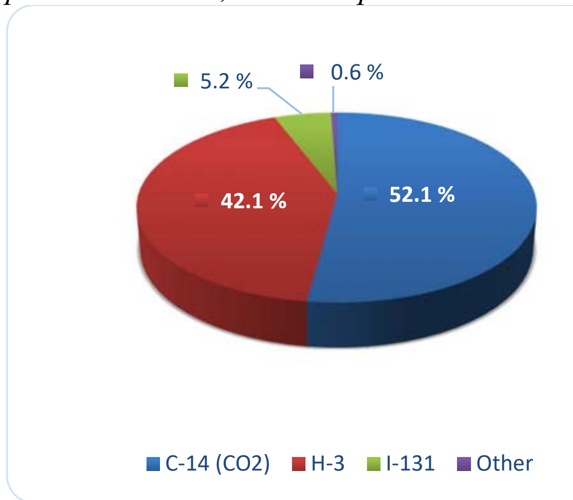

FIG. I–14. Ingestion dose contribution per radionuclide, %. Atmospheric case C

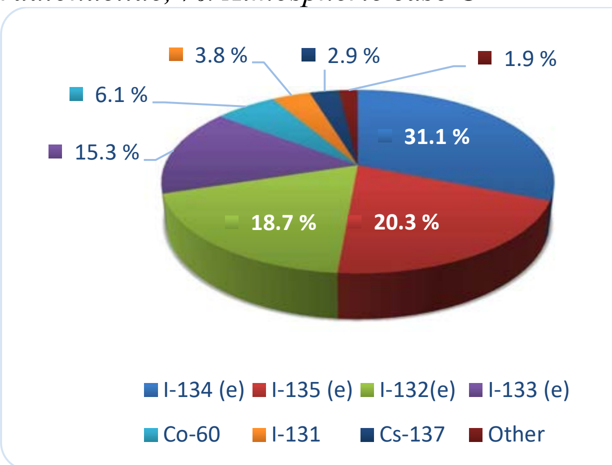

FIG. I–15. External dose contribution per radionuclide, %. Atmospheric case C

TABLE I–17. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE (UP TO CUT-OFF LEVEL OF 0.5%). ATMOSPHERIC CASE C

Radionuclide	Pathway	Dose, µSv/a	Contribution to total dose, all pathways, %	Rank	Rank category
C-14 CO_2	ingestion	4.15E+01	41.53	1	C_{50}
H-3	inhalation	4.13E+01	41.35	2	C_{50}
I-131	ingestion	3.79E+00	3.79	3	G_5
I-134 (e)	external	1.92E+00	1.92	4	G_5
Kr-85	immersion	1.83E+00	1.83	5	G_5
I-135 (e)	external	1.74E+00	1.74	6	G_5
I-133 (e)	external	1.64E+00	1.64	7	G_5
I-132(e)	external	1.42E+00	1.42	8	G_5
Ar-41	immersion	1.09E+00	1.09	9	G_5
Sr-90	immersion	1.01E+00	1.01	10	G_5
Kr-88	immersion	8.76E-01	0.88	11	G_5
Co-60	external	5.33E-01	0.53	12	G_5

TABLE I–18. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contrib.,%	Nuclide	Contrib.,%	Nuclide	Contrib.,%	Nuclide	Contrib.,%
1	H-3	62.25	Kr-85	33.30	C-14 CO_2	52.12	I-134 (e)	31.08
2	C-14 CO_2	36.15	Ar-41	19.80	H-3	42.05	I-135 (e)	20.29
3	I-131	0.65	Sr-90	18.40	I-131	5.22	I-132(e)	18.72
4	I-133 (e)	0.44	Kr-88	14.72	I-133 (e)	0.34	I-133 (e)	15.33
5	Kr-88	0.29	Xe-133m	6.51	Cs-137	0.10	Co-60	6.08
6	I-135 (e)	0.14	Sr-89	3.32	Sb-125	0.06	I-131	3.77
7	Xe-135m	0.03	Kr-87	1.37	Cs-134	0.05	Cs-137	2.86
8	I-132(e)	0.027	Xe-135m	1.14	I-135 (e)	0.03	Cs-134	0.84
9	I-134 (e)	0.015	Kr-85m	0.55	Co-60	0.00	Co-58	0.62
10	Sb-125	0.005	I-134 (e)	0.22	Co-58	0.00	Mn-54	0.25
11	Co-60	0.003	I-135 (e)	0.22	I-132(e)	0.00	Co-57	0.03
12	Co-58	0.002	Xe-135	0.20	Cs-136	0.00	Fe-59	0.03
13	Cs-137	0.001	I-132(e)	0.17	Mn-54	0.00	Nb-95	0.02
14	Cs-134	0.0007	I-133 (e)	0.05	I-134 (e)	0.00	Cs-136	0.02
15	Fe-59	0.0002	I-131	0.01	Fe-59	0.00	Xe-138	0.02
16	Mn-54	0.0002	Xe-131m	0.001	Nb-95	0.00	Sb-125	0.02
17	Nb-95	0.0001	C-14 CO_2	0.0007	Ru-103	0.00	Ru-103	0.01
18	Xe-138	0.00011	Co-58	0.0003	Ba-140	0.00	Ru-106	0.00
19	Ce-141	0.00010	Co-60	0.0002	Xe-138	0.00	Ba-140	0.00
20	Ru-103	0.00010	Cs-134	0.00005	Ce-141	0.00	Cr-51	0.00
21	Cs-136	0.00009	Cs-136	0.00004	Ar-41	0.00	Ce-141	0.00
22	Ba-140	0.00005	Cs-137	0.00003	Cr-51	0.00	Zr-95	0.00
23	Co-57	0.00001	Mn-54	0.00003	Co-57	0.00	Xe-133m	0.00
24	Cr-51	0.000008	Fe-59	0.00002	Zr-95	0.00	H-3	0.00
25	Ru-106	0.000007	Nb-95	0.000020	Ru-106	0.00	C-14 CO_2	0.00
26	Xe-133m	0.000000	Ru-103	0.000005	Xe-133m	0.00	Ar-41	0.00
27	Kr-87	0.000000	Xe-138	0.000005	Kr-85	0.00	Kr-85	0.00
28	Ar-41	0.000000	Cr-51	0.000002	Kr-85m	0.00	Kr-85m	0.00
29	Kr-85	0.000000	Co-57	0.000001	Kr-87	0.00	Kr-87	0.00
30	Kr-85m	0.000000	Ce-141	0.000001	Kr-88	0.00	Kr-88	0.00

TABLE I–18. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C (cont.)

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contrib.,%	Nuclide	Contrib.,%	Nuclide	Contrib.,%	Nuclide	Contrib.,%
31	Sr-89	0.000000	Ba-140	0.000001	Sr-89	0.00	Sr-89	0.00
32	Sr-90	0.000000	Ru-106	0.000000	Sr-90	0.00	Sr-90	0.00
33	Zr-95	0.000000	Sb-125	0.000000	Xe-131m	0.00	Xe-131m	0.00
34	Xe-131m	0.000000	H-3	0.000000	Xe-133	0.00	Xe-133	0.00
35	Xe-133	0.000000	Zr-95	0.000000	Xe-135	0.00	Xe-135	0.00
36	Xe-135	0.000000	Xe-133	0.000000	Xe-135m	0.00	Xe-135m	0.00

Contribution to the total dose from different pathways in the atmospheric release cases A, B and C is provided in Table I-19.

TABLE I–19. DOSE CONTRIBUTIONS PER PATHWAY. ATMOSPHERIC CASES A, B, C

Pathway of exposure	Atmospheric case A		Atmospheric case B		Atmospheric case C	
	Dose, μSv/a	% of total	Dose, μSv/a	% of total	Dose, μSv/a	% of total
Inhalation	2.17E-03	9.6	2.36E-03	9.4	2.17E-03	23.7
Immersion	5.02E-04	2.2	5.65E-04	2.3	5.02E-04	5.5
Ingestion	1.91E-02	85.0	2.11E-02	84.0	5.79E-03	63.2
External exposure	6.93E-04	3.1	1.09E-03	4.3	6.93E-04	7.6
Total dose	2.25E-02	100	2.51E-02	100.0	9.15E-03	100.0

The results for the three atmospheric cases showed that the calculated dose values did not substantially differ between cases: case A – 2.25E-02 μSv/a; case B – 2.51E-02 μSv/a; case C - 9.15E-03 μSv/a. The range overall is less than a factor of 3.

TABLE I–20. DOSE FROM INGESTION OF FISH. RIVERINE CASES A AND B

Riverine Case A			Riverine Case B		
Nuclide	Dose, μSv/a	Contribution, %	Nuclide	Dose, μSv/a	Contribution, %
H-3	6.05E-04	1.52	H-3	2.99E-04	5.15
Cr-51	2.55E-06	0.01	Cr-51	9.47E-07	0.02
Mn-54	2.12E-05	0.05	Mn-54	2.79E-06	0.05
Fe-59	2.47E-05	0.06	Fe-59	1.45E-05	0.25
Co-58	1.59E-05	0.04	Co-58	3.69E-06	0.06
Co-60	1.59E-04	0.40	Co-60	3.69E-05	0.64
Zn-65	4.21E-03	10.55	Zn-65	4.32E-04	7.45
Sr-90	1.34E-03	3.36	Sr-90	2.00E-04	3.45
Zr-95	1.71E-05	0.04	Zr-95	7.02E-06	0.12
Nb-95	2.24E-05	0.06	Nb-95	1.11E-05	0.19
Ru-106	6.07E-05	0.15	Ru-106	2.28E-05	0.39
Ag-110m	3.15E-05	0.08	Ag-110m	7.08E-07	0.01
I-131	1.47E-02	36.83	I-131	4.42E-04	7.62
Cs-134	8.87E-03	22.22	Cs-134	2.05E-03	35.33
Cs-137	9.82E-03	24.60	Cs-137	2.26E-03	38.95
Ce-144	1.50E-05	0.04	Ce-144	1.85E-05	0.32
Total	3.99E-02	100.00	Total	5.80E-03	100.00

For all cases, the radionuclides that made major contributions to total adult dose were C-14 and H-3 (from 41.5 % to 47.5 % and from 41.3 % to 43 % accordingly). In case A, the next highest was I-131 but it provided a much smaller contribution to the total adult dose – from 3.7 % to 4.5 %. Other radionuclides contribute less than 1% each. In case B, I-134 contributes 1.4 % to the total dose, other radionuclides – less than 1%. In case C, a range of radionuclides made an appreciable (more than 1 %) contribution to the total dose: I-134 - 1.92 %; Kr-85 – 1.83 %; I-135 – 1.74 %; I-133 – 1.64 %; I-132 – 1.42 %; Ar-41 – 1.49 %; and Sr-90 – 1.01 %.

The major pathway in all cases was ingestion (63.2-85 % contributed to the total dose), then inhalation - 23.7-9.6 %, followed by external exposure – 7.6-3.1 % and immersion – 5.5-2.2 %.

There were no substantive changes between cases A and B which meant that altering the meteorological conditions did not influence the overall radiological dose or the ranking of radionuclides and exposure pathways. The difference between cases A (B) and C was greater and that could be explained by the difference of transfer coefficients and consumption rates.

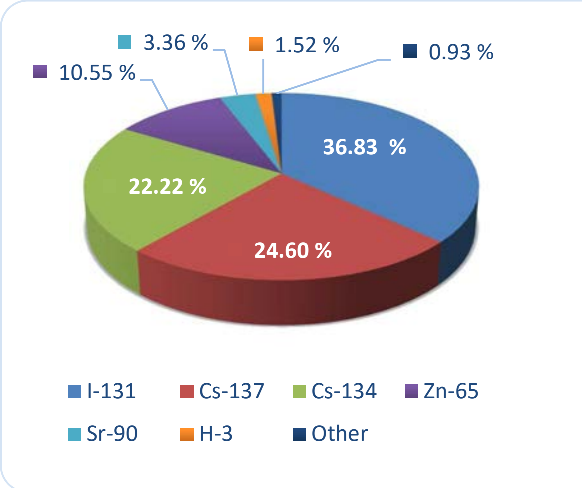

FIG. I–16. Total dose contribution per radionuclide, %, Riverine case A

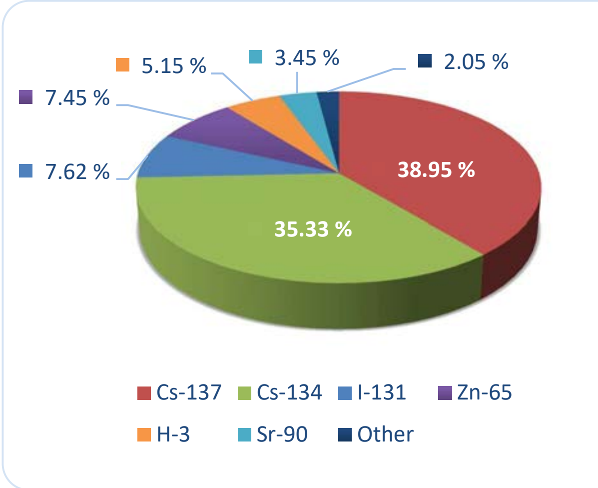

FIG. I–17. Total dose contribution per radionuclide, %, Riverine case B

TABLE I–21. RANKING OF RADIONUCLIDES BASED ON CONTRIBUTION TO TOTAL DOSE. RIVERINE CASES A AND B

Riverine Case A			Riverine Case B		
Nuclide	Contribution, %	Rank	Nuclide	Contribution, %	Rank
I-131	36.83	1	Cs-137	38.95	1
Cs-137	24.60	2	Cs-134	35.33	2
Cs-134	22.22	3	I-131	7.62	3
Zn-65	10.55	4	Zn-65	7.45	4
Sr-90	3.36	5	H-3	5.15	5
H-3	1.52	6	Sr-90	3.45	6
Co-60	0.40	7	Co-60	0.64	7
Ru-106	0.15	8	Ru-106	0.393	8
Ag-110m	0.08	9	Ce-144	0.319	9
Fe-59	0.06	10	Fe-59	0.25	10
Nb-95	0.056	11	Nb-95	0.19	11
Mn-54	0.053	12	Zr-95	0.12	12
Zr-95	0.043	13	Co-58	0.06	13
Co-58	0.040	14	Mn-54	0.05	14
Ce-144	0.038	15	Cr-51	0.02	15
Cr-51	0.006	16	Ag-110m	0.012	16

Total dose and contribution to the total dose from different radionuclides in the riverine release cases A and B are provided in Table I-20 and Figures I-16, I-17. Ranking of radionuclides based on contribution to the total dose for the riverine release cases A and B are presented in Table I-21.

Total adult dose estimates were 3.99E-02 μSv/a, for case A, and 5.80E-02 μSv/a for case B. Most (98-99 %) of the annual adult total dose were generated by the following radionuclides, listed in order of contribution:

- In riverine case A – I-131, Cs-137, Cs-134, Zn-65, Sr-90 and H-3;
- In riverine case B – Cs-137, Cs-134, I-131, Zn-65, H-3 and Sr-90.

The difference between cases A and B can be explained by the difference in the values of transfer coefficients and consumption rates.

REFERENCES TO ANNEX I

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[I–9] SMITH, J.G., SIMMONDS, J.R., The Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment Used in PC CREAM 08. Research Report HPA-RPD-058, Health Protection Agency, Chilton, Didcot, UK (2009).

ANNEX II. FRANCE

II–1. DESCRIPTION OF MODELS AND METHODOLOGIES APPLIED

Models described in this section come from the CERES platform [II–1]. The atmospheric dispersion model GASCON was developed by the CEA for the assessment of environmental impact from routine releases. It assumes Gaussian dispersion of pollutants and the model parameters are calibrated for flat terrain without buildings or topographic obstacles. Model uses yearly statistical meteorological data of wind speed and direction for each atmospheric stability class.

The riverine dispersion model ABRICOT was developed by the CEA for the release authorization studies. This model can be used for the assessment of environmental impact from the release of radionuclides into rivers. This simplistic model assumes instantaneous dilution of the pollutant in the river (based on the ratio between the river flow rate and the liquid effluent flow rate).

$$C_{river} = \frac{Q_i}{d_{release} + D_{river}}$$

Q_i – pollutant (i) released; $d_{release}$ – pollutant flow rate; D_{river} – river flow rate. This model was developed primarily for the assessment of human dose and the partitioning of pollutants onto sediments was not considered. This is an upper bound method assuming that water is used directly for irrigation and intake, and considering that external exposure is provided due to soil contamination.

Transfer of radionuclides in the food chain is evaluated by a compartmental tool, EA impact model, where boxes are connected via transfer functions. Instantaneous equilibrium is assumed. This tool involves special model for estimation of impacts from tritium, which uses the following approach:

- Plume exposure leads to internal exposure in humans by inhalation and skin transfer;
- The direct exposure to plume and the surface deposition are considered insignificant and not evaluated;
- No soil accumulation assumed;
- Foliar translocation exists only for the HTO form and root transfer exists only for the tritium gas after transformation by micro-organisms in the soil. After assimilation by plants, part (40%) of the HTO is converted into OBT.

II–2. STRUCTURE OF CONSIDERATION OF PUBLIC EXPOSURES FROM NORMAL OPERATION

In all considered scenarios the dose evaluations have been performed for adult population only. In atmospheric scenarios A, B and C the four radionuclides dispersion pathways were considered including the inhalation, plume immersion, ingestion and external/ground irradiation. Dose coefficients for external exposure from ground deposited activity have been added to the scenario parameters file. In riverine scenarios A and B only consumption of fish was considered as a pathway for radiation impact on humans.

In atmospheric release case A, data on concentrations of radionuclides for atmospheric releases were provided by Korea. Original meteorological data were provided by Brazil, corresponding to a 100 m release height. These meteorological data were converted to be used in DOURY formalism.

Other parameters agreed among project participant include the dose coefficients, transfer factors, consumption rates, etc. The transfer factors were defined for dry weight. The vegetable consumption was converted from wet weight to dry weight using average dry matter content from Ref. [II–4].

TABLE II–1. CADARACHE METEOROLOGICAL DATA. QUANTITIES OF EVENTS. DOURY DIFFUSION CLASS DF

Sector centerline, grad.	Doury diffusion class: DF (per mil)					
	Wind speed, m/s					
	0.5	1	2	4.5	8	13
0	0.0	0.0	0.0	0.1	0.1	0.1
20	0.9	2.2	3.0	2.0	0.1	0.0
40	3.7	12.1	23.3	22.7	0.7	0.0
60	6.3	18.3	38.3	41.5	1.5	0.0
80	5.6	11.4	17.5	14.2	0.2	0.0
100	4.5	6.5	6.0	4.7	0.1	0.0
120	3.2	4.3	4.6	6.7	0.7	0.1
140	3.4	4.6	6.7	24.2	12.4	1.3
160	2.9	3.7	3.7	8.6	2.6	0.0
180	2.7	3.2	2.4	3.5	0.5	0.0
200	2.5	2.9	2.1	1.9	0.1	0.0
220	2.4	3.1	2.6	1.5	0.1	0.0
240	2.5	4.0	4.8	4.7	0.4	0.0
260	2.7	5.1	10.4	33.4	6.0	0.2
280	2.4	5.3	10.9	40.1	20.7	0.4
300	2.1	4.3	8.0	17.6	23.0	1.0
320	1.4	3.0	3.7	7.5	19.2	3.1
340	0.5	1.1	0.9	2.2	5.6	2.2
Total, %	5.0	9.5	14.9	23.7	9.4	0.8

Atmospheric release case B uses the same approach as case A except for meteorological data. Dose coefficients, transfer factors, habit data including consumption rates in case B coincide with those in case A. Like in case A the vegetable consumption was converted from wet weight to dry weight using average dry matter content from Ref. [II–4]. Data on concentrations of radionuclides for atmospheric releases were provided by the Republic of Korea.

Meteorological data for atmospheric release case B calculations were provided by CEA Cadarache and presented in Tables II–1, II–2. These data include the relative quantities of events (in %) of a given wind speed and direction which are divided into three Doury diffusion classes

Atmospheric release case C uses the same approach as case A except for breathing rate and consumption data, and transfer coefficients. Meteorological data provided by Brazil and used by all participants of this study were converted into Doury formalism. Data on concentrations of radionuclides for atmospheric releases were provided by the Republic of Korea. Food is assumed to be provided from the locations where concentrations of radionuclides had been evaluated. Concentration of radionuclides in the species consumed is evaluated at equilibrium conditions. Potential effects on the total dose from the food preparation were omitted.

TABLE II–2. CADARACHE METEOROLOGICAL DATA. QUANTITIES OF EVENTS. DOURY DIFFUSION CLASSES DN DRY AND DN RAIN

Sector centerline, grad.	Doury diffusion class: DN dry (per mil)							Doury diffusion class: DN rain (per mil)						
	Wind speed, m/s							Wind speed, m/s						
	0.5	1	2	4.5	8	13	10	0.5	1	2	4.5	8	13	10
0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.1	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.4	1.3	3.6	5.5	0.5	0.0	0.0	0.0	0.1	0.2	0.5	0.1	0.0	0.0
60	0.9	3.4	8.2	7.7	0.5	0.0	0.0	0.1	0.1	0.5	0.7	0.3	0.0	0.0
80	0.9	2.6	3.3	1.7	0.1	0.0	0.0	0.1	0.1	0.2	0.5	0.1	0.0	0.0
100	0.8	1.6	1.4	0.5	0.1	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.0
120	0.6	1.3	1.1	1.3	0.4	0.0	0.0	0.1	0.1	0.2	0.3	0.1	0.0	0.0
140	0.7	1.1	1.6	20.6	35.8	5.1	0.0	0.0	0.1	0.1	1.1	1.2	0.0	0.0
160	0.5	0.9	1.1	10.6	8.8	0.2	0.0	0.1	0.1	0.1	0.4	0.5	0.0	0.0
180	0.6	0.9	0.9	3.9	0.8	0.0	0.0	0.1	0.1	0.0	0.2	0.2	0.0	0.0
200	0.6	0.9	1.1	2.8	0.6	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
220	0.5	1.0	1.2	1.7	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
240	0.4	1.0	1.6	3.9	0.7	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0
260	0.6	1.6	3.3	22.6	9.8	0.2	0.0	0.0	0.1	0.1	0.5	0.1	0.0	0.0
280	0.5	1.8	5.4	43.0	30.1	0.6	0.0	0.1	0.1	0.2	0.8	0.2	0.0	0.0
300	0.4	1.6	3.8	11.9	17.1	1.8	0.0	0.0	0.1	0.2	0.3	0.1	0.0	0.0
320	0.1	0.6	1.5	3.1	15.3	4.1	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0
340	0.0	0.1	0.2	0.5	4.7	3.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Total, %	0.9	2.2	4.0	14.2	12.6	1.5	0.0	0.1	0.1	0.2	0.6	0.3	0.0	0.0

In the evaluation of dose from the ingestion in atmospheric scenario C the milk, eggs and different meats and vegetables were considered. One more pathway 'skin' was added to separate and compare effects from H-3 HTO.

Half-lives of radioisotopes, deposit speed, solubility, size of aerosols and dose coefficients are provided in Table II–3. Coefficients for transfer of radionuclides from soil to plants are provided in Table II–4. Translocation factor defining the ratio of radionuclides in the eatable part of plant to the total leaf-intercepted airborne radionuclides are presented in Table II–5. Coefficients for transfer of radionuclides to the meat and the forage consumption rates for the considered animals are provided in Tables II–6 and II–7. Table II–8 presents the breathing rate and food consumption rate by humans for atmospheric case C and for riverine case B (see discussion below).

TABLE II–3. BASIC PARAMETERS OF RADIOISOTOPES AND RELEASE, AND DOSE COEFFICIENTS. ATMOSPHERIC CASE C

Isotopes	Half-life, s	Deposit speed, m/s	Dose coefficients		Solubility	Size, µm	Dose coefficients	
			Immersion, (Sv/s)/(Bq/m^3)	External, (Sv/s)/(Bq/m^2)			Inhalation, Sv/Bq	Ingestion, Sv/Bq
Ba-137m	1.53E+02	5.00E-03	2.88E-14	5.86E-16	M	1	0.00E+00	0.00E+00
Ba-140	1.10E+06	1.15E-02	8.58E-15	1.80E-16	M	1	5.10E-09	2.60E-09
C-14 CO_2	1.81E+11	1.00E-04	2.24E-19	1.61E-20			6.20E-12	5.80E-10
Ce-141	2.81E+06	1.15E-02	3.43E-15	7.38E-17	S	1	3.80E-09	7.10E-10
Co-57	2.34E+07	1.15E-02	5.61E-15	1.15E-16	S	1	1.00E-09	2.10E-10
Co-58	6.12E+06	1.15E-02	4.76E-14	9.50E-16	S	1	2.10E-09	7.40E-10
Co-60	1.66E+08	1.15E-02	1.26E-13	2.35E-15	S	1	3.10E-08	3.40E-09
Cr-51	2.39E+06	1.15E-02	1.51E-15	3.08E-17	S	1	3.70E-11	3.80E-11
Cs-134	6.50E+07	1.15E-02	7.57E-14	1.52E-15	F	1	6.60E-09	1.90E-08

TABLE II–3. BASIC PARAMETERS OF RADIOISOTOPES AND RELEASE, AND DOSE COEFFICIENTS. ATMOSPHERIC CASE C (cont.)

Isotopes	Half-life, s	Deposit speed, m/s	Dose coefficients		Solubility	Size, μm	Dose coefficients	
			Immersion, (Sv/s)/(Bq/m³)	External, (Sv/s)/(Bq/m²)			Inhalation, Sv/Bq	Ingestion, Sv/Bq
Cs-135	7.25E+13	5.00E-03	5.65E-19	3.33E-20	F	1	6.90E-10	2.00E-09
Cs-136	1.13E+06	1.15E-02	1.06E-13	2.09E-15	F	1	1.20E-09	3.00E-09
Cs-137	9.46E+08	1.15E-02	7.74E-18	2.85E-19	F	1	4.60E-09	1.30E-08
Cs-138	1.93E+03	5.00E-03	1.21E-13	2.19E-15	F	1	2.40E-11	9.20E-11
Fe-59	3.85E+06	1.15E-02	5.97E-14	1.12E-15	M	1	3.70E-09	1.80E-09
H-3 HTO	3.89E+08	3.00E-03	0.00E+00	0.00E+00			1.80E-11	1.80E-11
I-131(a)[a]	6.95E+05	1.15E-02	1.82E-14	3.76E-16	F	1	7.40E-09	2.20E-08
I-132(a)	8.28E+03	1.15E-02	1.12E-13	2.21E-15	F	1	9.40E-11	2.90E-10
I-133(a)	7.49E+04	1.15E-02	2.94E-14	5.97E-16	F	1	1.50E-09	4.30E-09
I-134(a)	3.16E+03	1.15E-02	1.30E-13	2.53E-15	F	1	4.50E-11	1.10E-10
I-135(a)	2.38E+04	1.15E-02	7.98E-14	1.47E-15	F	1	3.20E-10	9.30E-10
La-140	1.45E+05	5.00E-03	1.17E-13	2.16E-15	M	1	1.10E-09	2.00E-09
Mn-54	2.70E+07	1.15E-02	4.09E-14	8.12E-16	M	1	1.50E-09	7.10E-10
Nb-95	3.04E+06	1.15E-02	3.74E-14	7.48E-16	S	1	1.80E-09	5.80E-10
Nb-95m	3.12E+05	5.00E-03	2.93E-15	6.26E-17	S	1	8.80E-10	5.60E-10
H-3 OBT	3.89E+08	0.00E+00	0.00E+00	0.00E+00			4.10E-11	4.20E-11
R-b88	1.07E+03	5.00E-03	3.36E-14	5.95E-16	F	1	1.60E-11	9.00E-11
Rh-103m	3.37E+03	5.00E-03	8.80E-18	1.25E-18	S	1	2.70E-12	3.80E-12
Ru-103	3.39E+06	1.15E-02	2.25E-14	4.63E-16	S	1	3.00E-09	7.30E-10
Ru-106+	3.18E+07	1.15E-02	1.04E-14	2.12E-16	S	1	6.60E-08	7.00E-09
Sb-125	8.74E+07	1.15E-02	2.02E-14	4.25E-16	M	1	4.80E-09	1.10E-09
Sr-89	4.36E+06	1.15E-02	7.73E-17	2.27E-18	M	1	6.10E-09	2.60E-09
Sr-90	9.18E+08	1.15E-02	7.53E-18	2.84E-19	M	1	3.60E-08	2.80E-08
Te-125m	5.01E+06	5.00E-03	4.53E-16	3.61E-17	M	1	3.40E-09	8.70E-10
Y-90	2.30E+05	5.00E-03	1.90E-16	5.32E-18	S	1	1.50E-09	2.70E-09
Zr-95	5.53E+06	1.15E-02	3.50E-14	7.23E-16	M	1	4.80E-09	9.50E-10
Ar-41	6.58E+03		6.50E-14					
Kr-85	3.38E+08		1.19E-16					
Kr-85m	1.61E+04		7.48E-15					
Kr-87	4.58E+03		4.12E-14					
Kr-88	1.02E+04		1.02E-13					
Xe-131m	1.03E+06		3.89E-16					
Xe-133	4.53E+05		1.56E-15					
Xe-133m	1.89E+05		1.37E-15					
Xe-135	3.27E+04		1.19E-14					
Xe-135m	9.17E+02		2.04E-14					
Xe-138	8.50E+02		5.77E-14					

a – '(a)' index stands for aerosol.

TABLE II–4. TRANSFER FACTORS FOR DRY WEIGHT SOIL/PLANT, (Bq/kg of plant)/(Bq/kg of soil). ATMOSPHERIC CASE C

Isotopes	Salad	Carrot	Tomato	Apple	Hay grass	Herb	Corn
Ba-137m	2.40E-03	4.80E-03	1.80E-03	4.80E-03	2.37E-02	3.00E-03	9.30E-03
Ba-140	2.40E-03	4.80E-03	1.80E-03	4.80E-03	2.37E-02	3.00E-03	9.30E-03
C-14 CO_2	1.00E-01	1.00E-01	1.00E-01	0.00E+00	1.00E-01	1.25E-01	1.00E-01
Ce-141	2.40E-03	4.80E-03	1.80E-03	4.80E-03	2.37E-02	3.00E-03	9.30E-03

TABLE II–4. TRANSFER FACTORS FOR DRY WEIGHT SOIL/PLANT, (Bq/kg of plant)/(Bq/kg of soil). ATMOSPHERIC CASE C (cont.)

Isotopes	Salad	Carrot	Tomato	Apple	Hay grass	Herb	Corn
Co-57	2.24E-02	2.08E-02	1.00E-03	1.00E-03	4.27E-02	5.40E-03	5.89E-03
Co-58	2.24E-02	2.08E-02	1.00E-03	1.00E-03	4.27E-02	5.40E-03	5.89E-03
Co-60	2.24E-02	2.08E-02	1.00E-03	1.00E-03	4.27E-02	5.40E-03	5.89E-03
Cr-51	8.00E-05	1.60E-04	6.00E-05	1.60E-04	7.90E-04	1.00E-04	3.10E-04
Cs-134	3.68E-02	6.40E-03	1.32E-02	2.00E-02	2.00E-02	2.40E-02	2.00E-02
Cs-135	3.68E-02	6.40E-03	1.32E-02	2.00E-02	2.00E-02	2.40E-02	2.00E-02
Cs-136	3.68E-02	6.40E-03	1.32E-02	2.00E-02	2.00E-02	2.40E-02	2.00E-02
Cs-137	3.68E-02	6.40E-03	1.32E-02	2.00E-02	2.00E-02	2.40E-02	2.00E-02
Cs-138	3.68E-02	6.40E-03	1.32E-02	2.00E-02	2.00E-02	2.40E-02	2.00E-02
Fe-59	3.20E-04	6.40E-04	2.40E-04	6.40E-04	3.16E-03	4.00E-04	1.24E-03
H-3 HTO	5.00E-01	5.00E-01	5.00E-01	0.00E+00	5.00E-01	5.00E-01	0.00E+00
I-131(a)	2.00E-03	3.00E-03	1.00E-03	4.00E-03	6.00E-03	4.00E-04	6.00E-03
I-132(a)	2.00E-03	3.00E-03	1.00E-03	4.00E-03	6.00E-03	4.00E-04	6.00E-03
I-133(a)	2.00E-03	3.00E-03	1.00E-03	4.00E-03	6.00E-03	4.00E-04	6.00E-03
I-134(a)	2.00E-03	3.00E-03	1.00E-03	4.00E-03	6.00E-03	4.00E-04	6.00E-03
I-135(a)	2.00E-03	3.00E-03	1.00E-03	4.00E-03	6.00E-03	4.00E-04	6.00E-03
La-140	3.00E-03	1.60E-04	3.00E-03	3.00E-03	3.00E-03	3.00E-03	9.30E-06
Mn-54	6.88E-02	3.04E-01	4.02E-02	3.00E-02	5.37E-01	6.80E-02	3.00E-02
Nb-95	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02
Nb-95m	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02
H-3 OBT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-88	7.20E-02	1.44E-01	5.40E-02	1.44E-01	7.11E-01	9.00E-02	2.79E-01
Rh-103m	7.20E-02	1.44E-01	5.40E-02	1.44E-01	7.11E-01	9.00E-02	2.79E-01
Ru-103	3.20E-03	6.40E-03	2.40E-03	6.40E-03	3.16E-02	4.00E-03	1.24E-02
Ru-106+	3.20E-03	6.40E-03	2.40E-03	6.40E-03	3.16E-02	4.00E-03	1.24E-02
Sb-125	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02
Sr-89	2.40E-01	2.24E-01	7.00E-01	7.00E-01	1.34E+00	1.70E-01	3.00E-01
Sr-90	2.40E-01	2.24E-01	7.00E-01	7.00E-01	1.34E+00	1.70E-01	3.00E-01
Te-125m	5.60E-01	1.12E+00	4.20E-01	1.12E+00	5.53E+00	7.00E-01	2.17E+00
Y-90	8.00E-04	1.60E-03	6.00E-04	1.60E-03	7.90E-03	1.00E-03	3.10E-03
Zr-95	8.00E-05	1.60E-04	6.00E-05	1.60E-04	7.90E-04	1.00E-04	3.10E-04

TABLE II–5. TRANSLOCATION FACTORS (PORTION OF LEAF-INTERCEPTED RADIONUCLIDE IN FOOD). ATMOSPHERIC CASE C

Isotopes	Salad	Carrot	Tomato	Apple	Hay	Herb	Corn	Isotopes	Salad	Carrot	Tomato	Apple	Hay	Herb	Corn
Ba-137m	1	0.001	0.02	0.02	1	1	0.02	I-134(a)	1	0.1	0.1	0.1	1	1	0.1
Ba-140	1	0.001	0.02	0.02	1	1	0.02	I-135(a)	1	0.1	0.1	0.1	1	1	0.1
C-14 CO	1	1	1	1	1	1	1	La-140	1	0.1	0.1	0.1	1	1	0.1
Ce-141	1	0.01	0.02	0.025	1	1	0.02	Mn-54	1	0.1	0.1	0.1	1	1	0.1
Co-57	1	0.1	0.1	0.1	1	1	0.1	Nb-95	1	0.001	0.02	0.02	1	1	0.02
Co-58	1	0.1	0.1	0.1	1	1	0.1	Nb-95m	1	0.001	0.02	0.02	1	1	0.02
Co-60	1	0.1	0.1	0.1	1	1	0.1	H-3 OBT	0	0	0	0	0	0	0
Cr-51	1	0.1	0.1	0.1	1	1	0.1	R-b88	1	0.1	0.1	0.1	1	1	0.1
Cs-134	1	0.03	0.15	0.5	1	1	0.15	Rh-103m	1	0.1	0.1	0.1	1	1	0.1
Cs-135	1	0.03	0.15	0.5	1	1	0.15	Ru-103	1	0.05	0.05	0.05	1	1	0.05
Cs-136	1	0.03	0.15	0.5	1	1	0.15	Ru-106+	1	0.05	0.05	0.05	1	1	0.05
Cs-137	1	0.03	0.15	0.5	1	1	0.15	Sb-125	1	0.1	0.1	0.1	1	1	0.1
Cs-138	1	0.03	0.15	0.5	1	1	0.15	Sr-89	1	0.01	0.02	0.12	1	1	0.02

TABLE II–5. TRANSLOCATION FACTORS (PORTION OF LEAF-INTERCEPTED RADIONUCLIDE IN FOOD). ATMOSPHERIC CASE C (cont.)

Isotopes	Salad	Carrot	Tomato	Apple	Hay	Herb	Corn	Isotopes	Salad	Carrot	Tomato	Apple	Hay	Herb	Corn
Fe-59	1	0.1	0.1	0.1	1	1	0.1	Sr-90	1	0.01	0.02	0.12	1	1	0.02
H-3 HTO	1	1	1	1	1	1	1	Te-125m	1	0.1	0.1	0.1	1	1	0.1
I-131(a)	1	0.1	0.1	0.1	1	1	0.1	Y-90	1	0.1	0.1	0.1	1	1	0.1
I-132(a)	1	0.1	0.1	0.1	1	1	0.1	Zr-95	1	0.001	0.02	0.02	1	1	0.02
I-133(a)	1	0.1	0.1	0.1	1	1	0.1								

TABLE II–6. TRANSFER FACTOR TO MEAT FOR ATMOSPHERIC DISCHARGES, d/kg. FRESH WEIGHT, ATMOSPHERIC CASE C

Isotopes	Sheep	Egg	Chicken	Milk (goat)	Isotopes	Sheep	Egg	Chicken	Milk (goat)
Ba-137m	5.00E-03	9.00E-01	9.00E-03	4.60E-03	I-134(a)	4.00E-02	3.00E+00	1.00E-01	4.30E-01
Ba-140	5.00E-03	9.00E-01	9.00E-03	4.60E-03	I-135(a)	4.00E-02	3.00E+00	1.00E-01	4.30E-01
C-14 CO_2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	La-140	5.00E-02	9.00E-03	1.00E-01	4.00E-04
Ce-141	1.00E-02	4.00E-05	2.00E-03	6.00E-04	Mn-54	5.90E-03	6.00E-02	5.00E-02	6.00E-04
Co-57	6.20E-02	1.00E-01	2.00E+00	6.00E-03	Nb-95	3.00E-04	1.00E-03	3.00E-04	6.40E-06
Co-58	6.20E-02	1.00E-01	2.00E+00	6.00E-03	Nb-95m	3.00E-04	1.00E-03	3.00E-04	6.40E-06
Co-60	6.20E-02	1.00E-01	2.00E+00	6.00E-03	H-3 OBT	4.10E-01	5.80E+00	5.80E+00	3.20E-01
Cr-51	5.00E-02	1.00E+00	5.00E-02	4.00E-02	R-b88	6.90E-01	3.00E+00	2.00E+00	2.40E-01
Cs-134	4.90E-01	4.00E-01	1.00E+01	1.00E-01	Rh-103m	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-135	4.90E-01	4.00E-01	1.00E+01	1.00E-01	Ru-103	1.50E+00	5.00E-03	8.00E+00	6.60E-05
Cs-136	4.90E-01	4.00E-01	1.00E+01	1.00E-01	Ru-106+	1.50E+00	5.00E-03	8.00E+00	6.60E-05
Cs-137	4.90E-01	4.00E-01	1.00E+01	1.00E-01	Sb-125	1.00E-02	9.20E-04	9.20E-04	5.00E-04
Cs-138	4.90E-01	4.00E-01	1.00E+01	1.00E-01	Sr-89	3.30E-01	2.00E-01	8.00E-02	2.80E-02
Fe-59	7.30E-02	1.00E+00	1.00E+00	6.00E-04	Sr-90	3.30E-01	2.00E-01	8.00E-02	2.80E-02
H-3 HTO	4.10E-01	5.80E+00	5.80E+00	3.20E-01	Te-125m	5.00E-02	5.00E+00	6.00E-01	4.40E-03
I-131(a)	4.00E-02	3.00E+00	1.00E-01	4.30E-01	Y-90	1.00E-02	2.00E-03	1.00E-02	4.00E-04
I-132(a)	4.00E-02	3.00E+00	1.00E-01	4.30E-01	Zr-95	1.00E-04	2.00E-04	6.00E-05	5.50E-06
I-133(a)	4.00E-02	3.00E+00	1.00E-01	4.30E-01					

TABLE II–7. CONSUMPTION BY ANIMALS, FRESH WEIGHT, kg/a. ATMOSPHERIC CASE C

	Sheep	Chicken	Goat
Herb	0	0	420
Corn	0	6	0
Hay	360	0	360

TABLE II–8. BREATHING RATE AND CONSUMPTION OF FOOD BY HUMANS, FRESH WEIGHT. ATMOSPHERIC CASE C AND RIVERINE CASE B

Characteristics	Values
Consumption of leafy vegetables (salad), kg/a	15
Consumption of root vegetables (carrots), kg/a	25
Consumption of non-leafy vegetables (tomatoes) incl. fruits, kg/a	10
Consumption of apples, kg/a	40
Consumption of goat milk, kg/a	42
Consumption of sheep meat, kg/a	3
Consumption of eggs, kg/a	6
Consumption of chicken meat, kg/a	11
Consumption of fish, kg/a	6
Breathing rate, m^3/h	0.96

In riverine release case A, data on radionuclide concentrations were provided by Ukraine. In the calculations of riverine case A, the same set of input parameters including the dose coefficients, transfer factors and consumption rates was used by all participants. However, in this national study a bioaccumulation factor for H-3 was assumed equal to 1. Food (fish) is assumed to be provided from the locations where concentrations of radionuclides had been evaluated.

Riverine release case B uses the same approach as case A except for consumption data and transfer coefficients. Data on radionuclide concentrations for riverine releases were provided by Ukraine. In case B the same dose coefficients are used as in case A. The consumption rate of fish (site specific) was assumed 6 kg/a (see Table II–8). The transfer factors are provided in Table II–9. Like in riverine case A in the riverine case B a bioaccumulation factor for H-3 was assumed equal to 1 and fish is assumed to be provided from the locations where concentrations of radionuclides had been evaluated.

TABLE II–9. TRANSFER FACTOR TO FISH FOR RIVERINE DISCHARGES, l/kg. FRESH WEIGHT, RIVERINE CASE B

Isotopes	Transfer factors	Isotopes	Transfer factors	Isotopes	Transfer factors	Isotopes	Transfer factors
Ag-110m	5.00E+00	Cs-134	2.00E+03	I-131(a)	4.00E+01	Ru-106+	1.00E+01
Ce-144	3.00E+01	Cs-137	2.00E+03	Mn-54	4.00E+02	Sr-90	6.00E+01
Co-58	3.00E+02	Fe-59	2.00E+02	Nb-95	3.00E+02	Zn-65	1.00E+03
Co-60	3.00E+02	H-3 HTO	1.00E+00	H-3 OBT	1.00E+00	Zr-95	3.00E+02
Cr-51	2.00E+02						

II–3. RESULTS OF ASSESSMENT

Total dose, contribution to the total dose from different radionuclides and from different pathways in the atmospheric release case A are provided in Tables II-10 to II-12 and Figures II-1 to II-6. Rankings based on contribution to the total dose and contribution to the dose from a given pathway for the atmospheric release case A are presented in Tables II-13 and II-14.

TABLE II–10. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Ar-41	0.00E+00	2.89E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.89E-03
Ba-140	3.15E-08	0.00E+00	3.71E-09	2.18E-09	5.05E-08	5.64E-08	0.00E+00	8.79E-08
C-14 (CO_2)	2.92E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.92E-05
Ce-141	7.32E-08	0.00E+00	6.98E-11	4.19E-09	0.00E+00	4.26E-09	2.56E-07	3.33E-07
Co-57	1.21E-08	0.00E+00	1.12E-06	2.26E-09	2.40E-07	1.36E-06	0.00E+00	1.37E-06
Co-58	1.49E-06	1.27E-07	2.05E-04	4.14E-07	4.41E-05	2.50E-04	2.57E-04	5.09E-04
Co-60	5.04E-06	8.70E-08	2.54E-04	5.12E-07	5.32E-05	3.07E-04	4.00E-03	4.31E-03
Cr-51	5.31E-09	8.18E-10	3.88E-09	7.22E-07	1.61E-07	8.87E-07	6.64E-07	1.56E-06
Cs-134	4.69E-07	2.03E-08	4.78E-04	6.35E-05	5.14E-05	5.93E-04	4.47E-04	1.04E-03
Cs-136	5.83E-08	1.96E-08	2.48E-05	3.30E-06	2.60E-06	3.07E-05	7.28E-06	3.81E-05
Cs-137	6.15E-07	1.38E-08	6.45E-04	8.58E-05	6.56E-05	7.97E-04	3.06E-03	3.86E-03
Fe-59	1.66E-07	9.39E-09	1.05E-05	1.76E-06	6.45E-07	1.29E-05	1.13E-05	2.44E-05
H-3 HTO	1.04E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.04E-02
I-131(a)	4.02E-04	3.75E-06	2.22E-02	5.90E-03	2.90E-02	5.71E-02	8.95E-04	5.84E-02
I-132(a)	1.40E-05	6.35E-05	9.93E-06	3.30E-06	1.63E-05	2.95E-05	1.75E-04	2.82E-04
I-133(a)	2.31E-04	1.74E-05	3.25E-03	4.32E-04	2.20E-03	5.88E-03	4.55E-04	6.58E-03
I-134(a)	5.69E-06	6.32E-05	1.20E-06	3.98E-07	2.00E-06	3.59E-06	6.54E-05	1.38E-04
I-135(a)	8.00E-05	7.73E-05	1.50E-04	4.98E-05	2.53E-04	4.52E-04	5.63E-04	1.17E-03

TABLE II–10. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE A (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Kr-85	0.00E+00	3.02E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.02E-03
Kr-85m	0.00E+00	7.60E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.60E-05
Kr-87	0.00E+00	1.88E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E-04
Kr-88	0.00E+00	1.76E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E-03
Mn-54	1.26E-07	1.30E-08	1.78E-07	7.50E-08	7.13E-07	9.66E-07	1.17E-04	1.18E-04
Nb-95	1.12E-07	8.84E-09	4.85E-11	1.46E-11	2.57E-07	2.57E-07	8.91E-06	9.29E-06
Ru-103	7.52E-08	2.14E-09	1.58E-04	9.64E-08	1.79E-07	1.58E-04	2.52E-06	1.60E-04
Ru-106	7.62E-08	4.94E-11	9.06E-05	5.54E-08	1.11E-07	9.08E-05	7.98E-07	9.17E-05
Sb-125	1.09E-08	6.99E-11	1.09E-11	2.57E-09	3.54E-10	2.94E-09	2.18E-06	2.20E-06
Sr-89	1.86E-06	3.94E-10	6.13E-05	1.39E-06	9.03E-06	7.17E-05	4.49E-06	7.81E-05
Sr-90	1.49E-05	3.43E-11	3.20E-04	7.28E-06	4.87E-05	3.76E-04	4.10E-04	8.01E-04
Xe-131m	0.00E+00	5.10E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.10E-04
Xe-133	0.00E+00	2.70E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.70E-03
Xe-133m	0.00E+00	3.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.01E-05
Xe-135	0.00E+00	1.01E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-03
Xe-135m	0.00E+00	2.15E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.15E-05
Xe-138	0.00E+00	4.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.02E-05
Zr-95	8.69E-08	1.92E-09	3.50E-10	1.89E-06	0.00E+00	0.00E+00	7.57E-06	7.65E-06
Total dose	1.12E-02	1.25E-02	2.78E-02	6.55E-03	3.18E-02	6.61E-02	1.05E-02	1.00E-01

TABLE II–11. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Ar-41	0.00	23.20	0.00	0.00	0.00	0.00	0.00	2.88
Ba-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-14 CO_2	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Ce-141	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Co-57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Co-58	0.01	0.00	0.74	0.01	0.14	0.38	2.45	0.51
Co-60	0.05	0.00	0.91	0.01	0.17	0.46	38.10	4.30
Cr-51	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
Cs-134	0.00	0.00	1.72	0.97	0.16	0.90	4.26	1.04
Cs-136	0.00	0.00	0.09	0.05	0.01	0.05	0.07	0.04
Cs-137	0.01	0.00	2.32	1.31	0.21	1.20	29.21	3.85
Fe-59	0.00	0.00	0.04	0.03	0.00	0.02	0.11	0.02
H-3 HTO	92.96	0.00	0.00	0.00	0.00	0.00	0.00	10.37
I-131(a)	3.59	0.03	79.66	90.04	91.35	86.31	8.53	58.21
I-132(a)	0.13	0.51	0.04	0.05	0.05	0.04	1.66	0.28
I-133(a)	2.06	0.14	11.68	6.60	6.92	8.89	4.33	6.57
I-134(a)	0.05	0.51	0.00	0.01	0.01	0.01	0.62	0.14
I-135(a)	0.72	0.62	0.54	0.76	0.80	0.68	5.37	1.17
Kr-85	0.00	24.20	0.00	0.00	0.00	0.00	0.00	3.01
Kr-85m	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.08
Kr-87	0.00	1.51	0.00	0.00	0.00	0.00	0.00	0.19
Kr-88	0.00	14.12	0.00	0.00	0.00	0.00	0.00	1.76
Mn-54	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.12
Nb-95	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01

TABLE II–11. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Ru-103	0.00	0.00	0.57	0.00	0.00	0.24	0.02	0.16
Ru-106	0.00	0.00	0.33	0.00	0.00	0.14	0.01	0.09
Sb-125	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Sr-89	0.02	0.00	0.22	0.02	0.03	0.11	0.04	0.08
Sr-90	0.13	0.00	1.15	0.11	0.15	0.57	3.91	0.80
Xe-131m	0.00	4.09	0.00	0.00	0.00	0.00	0.00	0.51
Xe-133	0.00	21.64	0.00	0.00	0.00	0.00	0.00	2.69
Xe-133m	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.03
Xe-135	0.00	8.08	0.00	0.00	0.00	0.00	0.00	1.00
Xe-135m	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.02
Xe-138	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.04
Zr-95	0.00	0.00	0.00	0.03	0.00	0.00	0.07	0.01

TABLE II–12. CONTRIBUTION TO TOTAL DOSE FROM DIFFERENT PATHWAYS, ATMOSPHERIC CASE A

Pathway of exposure	Adult dose from all nuclides, µSv/a	Contribution, %
Inhalation	1.12E-02	11.2
Immersion	1.25E-02	12.4
Ingestion	6.61E-02	65.9
External exposure	1.05E-02	10.5
Total dose	1.00E-01	100

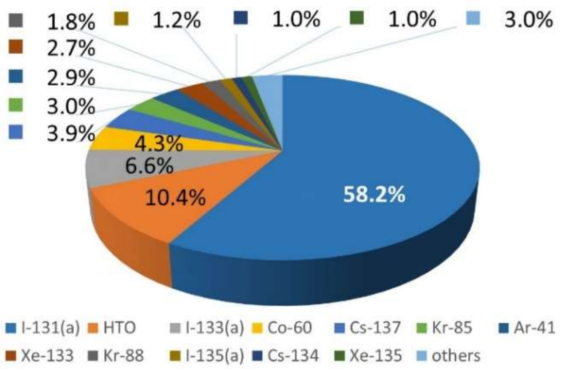

FIG. II-1. Total dose contribution per radionuclide, %. Atmospheric case A

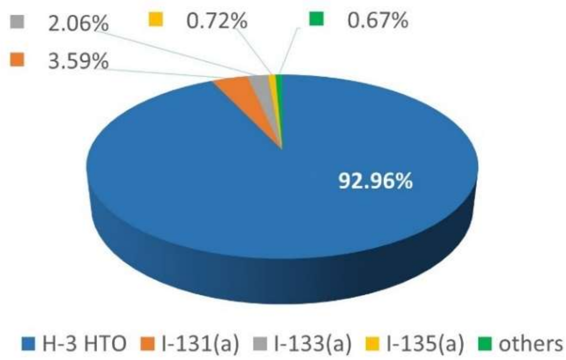

FIG. II-2. Inhalation dose contribution per radionuclide, %. Atmospheric case A

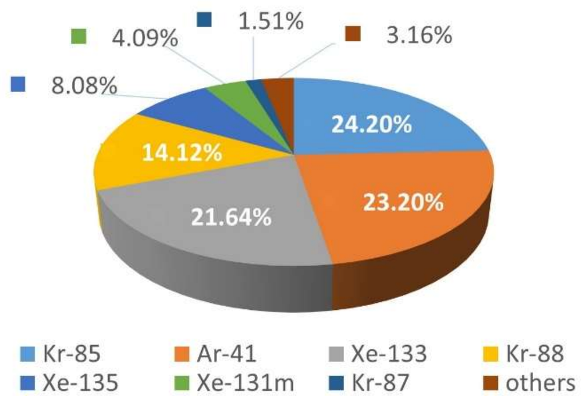

FIG. II-3. Immersion dose contribution per radionuclide, %, Atmospheric case A

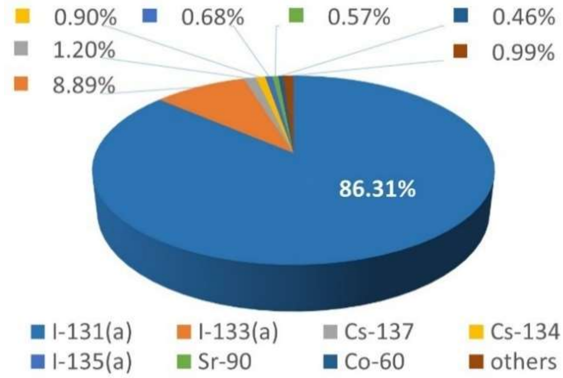

FIG. II-4. Ingestion dose contribution per radionuclide, %, Atmospheric case A

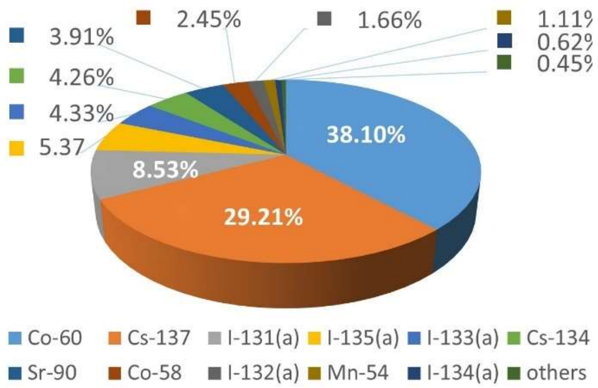

FIG. II-5. External dose contribution per radionuclide, %, Atmospheric case A

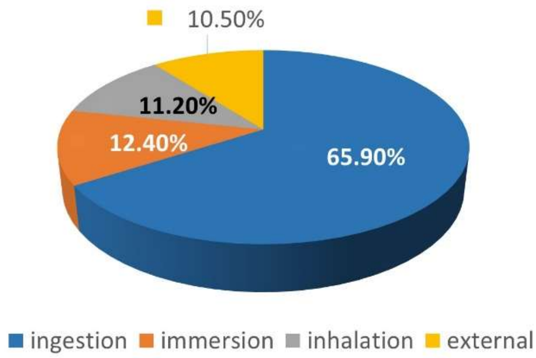

FIG. II-6. Total dose contribution per pathway, %, Atmospheric case A

TABLE II–13. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE (UP TO CUT-OFF LEVEL OF 0.5%). ATMOSPHERIC CASE A

Radionuclide	Pathway	Dose, µSv/a	Contribution to total dose, all pathways, %	Rank	Rank category
I-131(a)	Ingestion	5.84E-02	58.2	1	B_{75}
H-3 HTO	Inhalation	1.04E-02	10.4	2	E_{25}
I-133(a)	Ingestion	6.58E-03	6.6	3	F_{10}
Co-60	External	4.31E-03	4.3	4	G_5
Cs-137	External	3.86E-03	3.9	5	G_5
Kr-85	Immersion	3.02E-03	3.0	6	G_5
Ar-41	Immersion	2.89E-03	2.9	7	G_5
Xe-133	Immersion	2.70E-03	2.7	8	G_5
Kr-88	Immersion	1.76E-03	1.8	9	H_2
I-135(a)	External	1.17E-03	1.2	10	H_2
Cs-134	Ingestion	1.04E-03	1.0	11	H_2
Xe-135	Immersion	1.01E-03	1.0	12	H_2
Sr-90	External	8.01E-04	0.8	13	H_2
Xe-131m	Immersion	5.10E-04	0.5	14	H_2
Co-58	External	5.09E-04	0.5	15	H_2
Total		9.89E-02	98.7		

TABLE II–14. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE A

Rank	Inhalation pathway		Immersion pathway		Ingestion pathway		External exposure	
	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
1	H-3 HTO	92.96	Kr-85	24.20	I-131(a)	86.31	Co-60	38.10
2	I-131(a)	3.59	Ar-41	23.20	I-133(a)	8.89	Cs-137	29.21
3	I-133(a)	2.06	Xe-133	21.64	Cs-137	1.20	I-131(a)	8.53
4	I-135(a)	0.72	Kr-88	14.12	Cs-134	0.90	I-135(a)	5.37
5			Xe-135	8.08	I-135(a)	0.68	I-133(a)	4.33
6			Xe-131m	4.09	Sr-90	0.57	Cs-134	4.26
7			Kr-87	1.51	Co-60	0.46	Sr-90	3.91
8			I-135(a)	0.62			Co-58	2.45
9			Kr-85m	0.61			I-132(a)	1.66
10			I-132(a)	0.51			Mn-54	1.11
11			I-134(a)	0.51			I-134(a)	0.62

Total dose, contribution to the total dose from different radionuclides and from different pathways in the atmospheric release case B are provided in Tables II-15 to II-17. Rankings based on contribution to the total dose and contribution to the dose from a given pathway for the atmospheric release case B are presented in Tables II-18 and II-19.

TABLE II–15. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Ar-41	0.00E+00	1.33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-03
Ba-140	9.29E-09	0.00E+00	1.15E-09	6.73E-10	1.51E-08	1.70E-08	0.00E+00	2.63E-08
C-14 CO_2	1.13E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.13E-05
Ce-141	2.16E-08	0.00E+00	2.13E-11	1.28E-09	0.00E+00	1.30E-09	7.62E-08	9.91E-08
Co-57	3.57E-09	0.00E+00	3.36E-07	6.77E-10	6.97E-08	4.06E-07	0.00E+00	4.10E-07
Co-58	4.40E-07	3.74E-08	6.15E-05	1.24E-07	1.31E-05	7.48E-05	7.65E-05	1.52E-04
Co-60	1.49E-06	2.56E-08	7.25E-05	1.46E-07	1.54E-05	8.81E-05	1.18E-03	1.27E-03
Cr-51	1.57E-09	2.42E-10	1.14E-09	2.13E-07	4.80E-08	2.62E-07	1.98E-07	4.62E-07
Cs-134	1.38E-07	5.98E-09	1.45E-04	1.92E-05	1.51E-05	1.79E-04	1.33E-04	3.12E-04
Cs-136	1.72E-08	5.80E-09	7.25E-06	9.64E-07	7.59E-07	8.97E-06	2.17E-06	1.12E-05
Cs-137	1.81E-07	4.06E-09	1.85E-04	2.46E-05	1.97E-05	2.29E-04	9.09E-04	1.14E-03
Fe-59	4.90E-08	2.77E-09	3.08E-06	5.17E-07	1.90E-07	3.78E-06	3.37E-06	7.21E-06
H-3 HTO	4.35E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.35E-03
I-131(a)	1.19E-04	1.11E-06	6.65E-03	1.77E-03	8.40E-03	1.68E-02	2.66E-04	1.72E-02
I-132(a)	4.52E-06	2.06E-05	3.16E-06	1.05E-06	5.26E-06	9.47E-06	5.71E-05	9.17E-05
I-133(a)	6.87E-05	5.17E-06	9.75E-04	1.30E-04	6.57E-04	1.76E-03	1.37E-04	1.97E-03
I-134(a)	2.16E-06	2.40E-05	4.65E-07	1.55E-07	7.60E-07	1.38E-06	2.51E-05	5.26E-05
I-135(a)	2.43E-05	2.36E-05	4.50E-05	1.50E-05	7.63E-05	1.36E-04	1.73E-04	3.57E-04
Kr-85	0.00E+00	1.18E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-03
Kr-85m	0.00E+00	3.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-05
Kr-87	0.00E+00	9.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.02E-05
Kr-88	0.00E+00	7.68E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.68E-04
Mn-54	3.73E-08	3.84E-09	0.00E+00	2.22E-08	2.12E-07	2.34E-07	3.47E-05	3.50E-05
Nb-95	3.29E-08	2.60E-09	0.00E+00	4.37E-12	7.58E-08	7.58E-08	2.65E-06	2.76E-06
Ru-103	2.22E-08	6.32E-10	0.00E+00	2.89E-08	5.37E-08	8.26E-08	7.49E-07	8.54E-07
Ru-106	2.25E-08	1.46E-11	0.00E+00	1.66E-08	3.26E-08	4.92E-08	2.37E-07	3.09E-07
Sb-125	3.20E-09	2.06E-11	7.20E-11	7.59E-10	1.04E-10	9.35E-10	6.49E-07	6.53E-07
Sr-89	5.52E-07	1.16E-10	7.28E-06	4.10E-07	2.71E-06	1.04E-05	1.33E-06	1.23E-05
Sr-90	4.40E-06	1.01E-11	1.45E-03	2.18E-06	1.41E-05	1.47E-03	1.22E-04	1.59E-03
Xe-131m	0.00E+00	1.99E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E-04
Xe-133	0.00E+00	1.06E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E-03
Xe-133m	0.00E+00	1.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-05
Xe-135	0.00E+00	4.08E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E-04
Xe-135m	0.00E+00	1.39E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.39E-05
Xe-138	0.00E+00	2.71E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.71E-05
Zr-95	2.57E-08	5.68E-10	8.10E-10	5.60E-07	0.00E+00	0.00E+00	2.25E-06	2.27E-06
Total dose	4.59E-03	5.19E-03	9.60E-03	1.96E-03	9.22E-03	2.08E-02	3.13E-03	3.37E-02

TABLE II–16. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Ar-41	0.00	25.56	0.00	0.00	0.00	0.00	0.00	3.93
Ba-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-14 CO_2	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Ce-141	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Co-57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Co-58	0.01	0.00	0.00	0.01	0.14	0.36	2.44	0.45
Co-60	0.03	0.00	0.00	0.01	0.17	0.42	37.82	3.78
Cr-51	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
Cs-134	0.00	0.00	0.00	0.98	0.16	0.86	4.24	0.93
Cs-136	0.00	0.00	0.00	0.05	0.01	0.04	0.07	0.03
Cs-137	0.00	0.00	0.00	1.25	0.21	1.10	29.04	3.38
Fe-59	0.00	0.00	0.00	0.03	0.00	0.02	0.11	0.02
H-3 HTO	94.82	0.00	0.00	0.00	0.00	0.00	0.00	12.91
I-131(a)	2.59	0.02	0.00	90.08	91.10	80.91	8.50	51.07
I-132(a)	0.10	0.40	0.00	0.05	0.06	0.05	1.82	0.27
I-133(a)	1.50	0.10	0.00	6.60	7.12	8.47	4.38	5.85
I-134(a)	0.05	0.46	0.00	0.01	0.01	0.01	0.80	0.16
I-135(a)	0.53	0.45	0.00	0.76	0.83	0.66	5.52	1.06
Kr-85	0.00	22.69	0.00	0.00	0.00	0.00	0.00	3.49
Kr-85m	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.09
Kr-87	0.00	1.74	0.00	0.00	0.00	0.00	0.00	0.27
Kr-88	0.00	14.80	0.00	0.00	0.00	0.00	0.00	2.28
Mn-54	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.10
Nb-95	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01
Ru-103	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Ru-106	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Sb-125	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Sr-89	0.01	0.00	0.00	0.02	0.03	0.05	0.04	0.04
Sr-90	0.10	0.00	0.00	0.11	0.15	7.05	3.88	4.73
Xe-131m	0.00	3.84	0.00	0.00	0.00	0.00	0.00	0.59
Xe-133	0.00	20.43	0.00	0.00	0.00	0.00	0.00	3.14
Xe-133m	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.04
Xe-135	0.00	7.86	0.00	0.00	0.00	0.00	0.00	1.21
Xe-135m	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.04
Xe-138	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.08
Zr-95	0.00	0.00	0.00	0.03	0.00	0.00	0.07	0.01

TABLE II–17. CONTRIBUTION TO TOTAL DOSE FROM DIFFERENT PATHWAYS, ATMOSPHERIC CASE B.

Pathway of exposure	Adult dose from all nuclides, μSv/a	Contribution, %
Inhalation	4.59E-03	13.6
Immersion	5.19E-03	15.4
Ingestion	2.08E-02	61.7
External exposure	3.13E-03	9.3
Total dose	3.37E-02	100

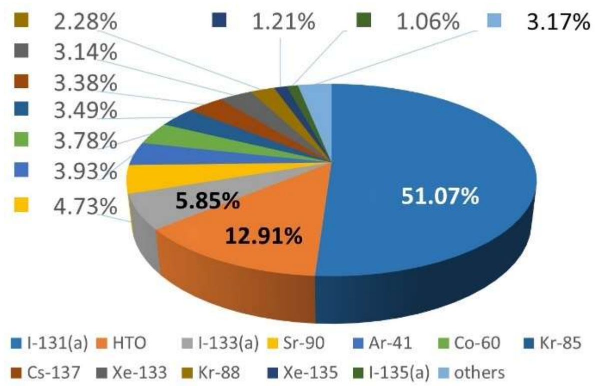

FIG. II-7. Total dose contribution per radionuclide, %. Atmospheric case B.

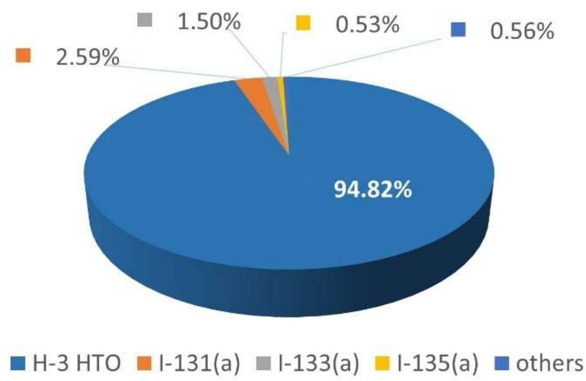

FIG. II-8. Inhalation dose contribution per radionuclide, %. Atmospheric case B.

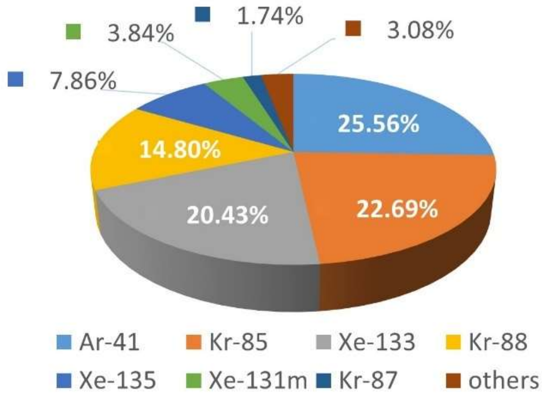

FIG. II-9. Immersion dose contribution per radionuclide, %, Atmospheric case B.

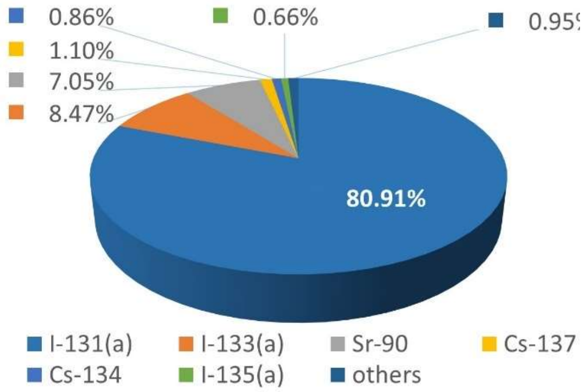

FIG. II-10. Ingestion dose contribution per radionuclide, %, Atmospheric case B.

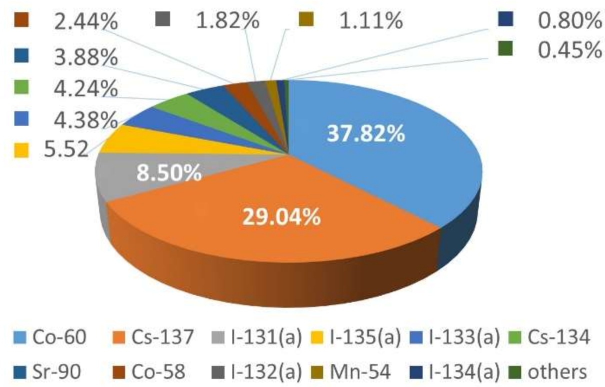

FIG. II-11. External dose contribution per radionuclide, %, Atmospheric case B.

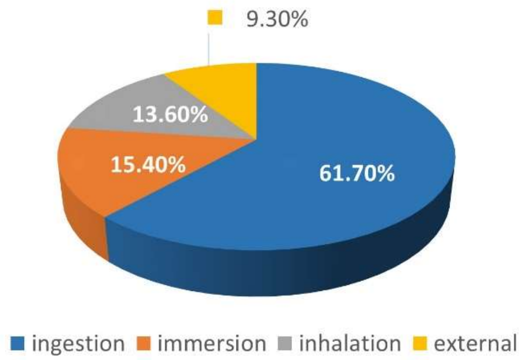

FIG. II-12. Total dose contribution per pathway, %, Atmospheric case B.

TABLE II–18. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE (UP TO CUT-OFF LEVEL OF 0.5%). ATMOSPHERIC CASE B

Radionuclide	Pathway	Dose, μSv/a	Contribution to total dose, all pathways, %	Rank	Rank category
I-131(a)	Ingestion	1.72E-02	51.07	1	B_{75}
H-3 HTO	Inhalation	4.35E-03	12.91	2	E_{25}
I-133(a)	Ingestion	1.97E-03	5.85	3	F_{10}
Sr-90	Ingestion	1.59E-03	4.73	4	G_5

TABLE II–18. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE (UP TO CUT-OFF LEVEL OF 0.5%). ATMOSPHERIC CASE B (cont.)

Radionuclide	Pathway	Dose, µSv/a	Contribution to total dose, all pathways, %	Rank	Rank category
Ar-41	Immersion	1.33E-03	3.93	5	G_5
Co-60	External	1.27E-03	3.78	6	G_5
Kr-85	Immersion	1.18E-03	3.49	7	G_5
Cs-137	External	1.14E-03	3.38	8	G_5
Xe-133	Immersion	1.06E-03	3.14	9	G_5
Kr-88	Immersion	7.68E-04	2.28	10	G_5
Xe-135	Immersion	4.08E-04	1.21	11	H_2
I-135(a)	External	3.57E-04	1.06	12	H_2
Cs-134	Ingestion	3.12E-04	0.93	13	H_2
Xe-131m	Immersion	1.99E-04	0.59	14	H_2
Co-58	External	1.52E-04	0.45	15	H_2
Total		3.33E-02	98.80		

TABLE II–19. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE B

Rank	Inhalation pathway		Immersion pathway		Ingestion pathway		External exposure	
	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
1	H-3 HTO	94.82	Ar-41	25.56	I-131 (a)	80.91	Co-60	37.82
2	I-131 (a)	2.59	Kr-85	22.69	I-133 (a)	8.47	Cs-137	29.04
3	I-133 (a)	1.50	Xe-133	20.43	Sr-90	7.05	I-131 (a)	8.50
4	I-135 (a)	0.53	Kr-88	14.80	Cs-137	1.10	I-135 (a)	5.52
5			Xe-135	7.86	Cs134	0.86	I-133 (a)	4.38
6			Xe-131m	3.84	I-135 (a)	0.66	Cs-134	4.24
7			Kr-87	1.74			Sr-90	3.88
8			Kr-85m	0.62			Co-58	2.44
9			Xe-138	0.52			I-132 (a)	1.82
10			I-134 (a)	0.46			Mn-54	1.11
11			I-135 (a)	0.45			I-134 (a)	0.80

Total dose, contribution to the total dose from different radionuclides and from different pathways in the atmospheric release case C are provided in Tables II-20 to II-22. Rankings based on contribution to the total dose and contribution to the dose from a given pathway for the atmospheric release case C are presented in Tables II-23 and II-24.

TABLE II–20. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Skin	Ingestion		Total ingestion	External	Total dose
				Mea	Vegetable			
Ar-41	0.00E+00	3.12E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.12E-03
Ba-140	3.15E-08	1.99E-10	0.00E+00	8.47E-09	2.53E-08	3.38E-08	7.62E-08	1.42E-07
C-14 CO_2	2.92E-05	3.96E-09	0.00E+00	9.08E-03	1.21E-02	2.12E-02	4.44E-05	2.12E-02
Ce-141	7.32E-08	2.48E-10	0.00E+00	2.06E-09	3.32E-08	3.52E-08	2.48E-07	3.57E-07
Co-57	1.21E-08	2.55E-10	0.00E+00	5.94E-09	9.97E-09	1.59E-08	2.03E-06	2.06E-06
Co-58	1.49E-06	1.27E-07	0.00E+00	1.09E-06	1.71E-06	2.81E-06	2.57E-04	2.61E-04
Co-60	5.04E-06	7.68E-08	0.00E+00	1.35E-06	2.73E-06	4.09E-06	3.95E-03	3.96E-03
Cr-51	5.31E-09	8.12E-10	0.00E+00	3.13E-08	1.35E-08	4.48E-08	6.58E-07	7.09E-07
Cs-134	4.69E-07	2.02E-08	0.00E+00	3.70E-05	5.97E-06	4.29E-05	4.37E-04	4.81E-04
Cs-136	5.83E-08	1.93E-08	0.00E+00	1.93E-06	2.55E-07	2.18E-06	7.16E-06	9.42E-06
Cs-137	6.15E-07	3.88E-12	0.00E+00	4.94E-05	1.53E-05	6.46E-05	1.53E-06	6.68E-05

TABLE II–20. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Skin	Ingestion		Total ingestion	External	Total dose
				Mea	Vegetable			
Fe-59	1.54E-07	9.30E-09	0.00E+00	7.72E-08	2.16E-07	2.93E-07	1.11E-05	1.16E-05
H-3 HTO	1.04E-02	0.00E+00	4.17E-03	9.32E-03	6.25E-03	1.56E-02	0.00E+00	3.02E-02
I-131(a)	4.02E-04	3.71E-06	0.00E+00	3.46E-02	1.46E-03	3.61E-02	8.84E-04	3.74E-02
I-132(a)	1.40E-05	6.23E-05	0.00E+00	1.90E-05	7.91E-07	1.98E-05	1.69E-04	2.65E-04
I-133(a)	2.31E-04	1.70E-05	0.00E+00	2.57E-03	1.07E-04	2.68E-03	4.28E-04	3.35E-03
I-134(a)	5.69E-06	6.17E-05	0.00E+00	2.34E-06	9.76E-08	2.44E-06	6.29E-05	1.33E-04
I-135(a)	8.00E-05	7.48E-05	0.00E+00	2.93E-04	1.22E-05	3.05E-04	5.44E-04	1.00E-03
Kr-85	0.00E+00	1.41E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E-03
Kr-85m	0.00E+00	8.34E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.34E-05
Kr-87	0.00E+00	1.97E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.97E-04
Kr-88	0.00E+00	1.85E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E-03
Mn-54	1.26E-07	1.29E-08	0.00E+00	1.18E-08	3.28E-07	3.39E-07	1.15E-04	1.16E-04
Nb-95	1.12E-07	8.69E-09	0.00E+00	1.14E-10	8.93E-08	8.94E-08	8.76E-06	8.97E-06
H-3 OBT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.93E-03	0.00E+00	3.93E-03
Ru-103	7.52E-08	2.11E-09	0.00E+00	2.31E-07	4.87E-08	2.80E-07	2.45E-06	2.81E-06
Ru-106+	7.62E-08	4.50E-11	0.00E+00	1.31E-07	2.95E-08	1.60E-07	4.85E-07	7.21E-07
Sb-125	4.34E-09	6.85E-11	0.00E+00	1.90E-10	4.44E-09	4.63E-09	2.09E-06	2.10E-06
Sr-89	1.44E-06	6.86E-11	0.00E+00	4.30E-06	2.43E-06	6.73E-06	1.46E-07	8.32E-06
Sr-90	3.35E-06	2.63E-12	0.00E+00	2.46E-05	3.73E-05	6.19E-05	1.05E-06	6.63E-05
Xe-131m	0.00E+00	5.35E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.35E-04
Xe-133	0.00E+00	3.03E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.03E-03
Xe-133m	0.00E+00	3.23E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E-05
Xe-135	0.00E+00	1.08E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E-03
Xe-135m	0.00E+00	2.37E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.37E-05
Xe-138	0.00E+00	4.25E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.25E-05
Zr-95	7.07E-08	1.93E-09	0.00E+00	2.43E-11	3.96E-08	3.96E-08	3.67E-06	3.78E-06
Total dose	1.13E-02	1.22E-02	4.17E-03	5.98E-02	2.01E-02	8.00E-02	7.03E-03	1.15E-01

TABLE II–21. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Skin	Ingestion		Total ingestion	External	Total dose
				Meat	Vegetables			
Ar-41	0.00	25.57	0.00	0.00	0.00	0.00	0.00	2.71
Ba-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-14 CO_2	0.26	0.00	0.00	15.18	60.05	26.50	0.63	18.43
Ce-141	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Co-57	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Co-58	0.01	0.00	0.00	0.00	0.01	0.00	3.66	0.23
Co-60	0.04	0.00	0.00	0.00	0.01	0.01	56.19	3.44
Cr-51	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Cs-134	0.00	0.00	0.00	0.06	0.03	0.05	6.22	0.42
Cs-136	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01
Cs-137	0.01	0.00	0.00	0.08	0.08	0.08	0.02	0.06
Fe-59	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.01
H-3 HTO	92.04	0.00	100.00	15.58	31.05	19.50	0.00	26.26
I-131(a)	3.56	0.03	0.00	57.86	7.26	45.13	12.57	32.52
I-132(a)	0.12	0.51	0.00	0.03	0.00	0.02	2.40	0.23
I-133(a)	2.04	0.14	0.00	4.30	0.53	3.35	6.09	2.91
I-134(a)	0.05	0.51	0.00	0.00	0.00	0.00	0.89	0.12

TABLE II–21. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Skin	Ingestion		Total ingestion	External	Total dose
				Meat	Vegetables			
I-135(a)	0.71	0.61	0.00	0.49	0.06	0.38	7.74	0.87
Kr-85	0.00	11.56	0.00	0.00	0.00	0.00	0.00	1.23
Kr-85m	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.07
Kr-87	0.00	1.61	0.00	0.00	0.00	0.00	0.00	0.17
Kr-88	0.00	15.16	0.00	0.00	0.00	0.00	0.00	1.61
Mn-54	0.00	0.00	0.00	0.00	0.00	0.00	1.64	0.10
Nb-95	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01
H-3 OBT	0.00	0.00	0.00	0.00	0.00	4.91	0.00	3.42
Ru-103	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Ru-106+	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Sb-125	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Sr-89	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01
Sr-90	0.03	0.00	0.00	0.04	0.19	0.08	0.01	0.06
Xe-131m	0.00	4.39	0.00	0.00	0.00	0.00	0.00	0.47
Xe-133	0.00	24.84	0.00	0.00	0.00	0.00	0.00	2.63
Xe-133m	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.03
Xe-135	0.00	8.85	0.00	0.00	0.00	0.00	0.00	0.94
Xe-135m	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.02
Xe-138	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.04
Zr-95	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00

TABLE II–22. CONTRIBUTION TO TOTAL DOSE FROM DIFFERENT PATHWAYS, ATMOSPHERIC CASE C

Pathway of exposure	Adult dose from all nuclides µSv/a	Contribution, %
Inhalation	1.13E-02	9.8
Immersion	1.22E-02	10.6
Skin	4.17E-03	3.6
Ingestion	8.00E-02	69.6
External exposure	7.03E-03	6.1
Total dose	1.15E-01	100.0

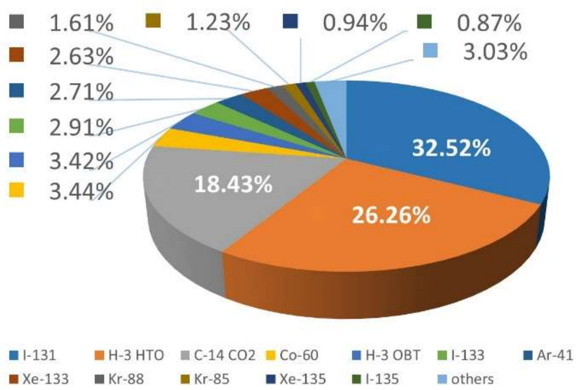

FIG. II-13. Total dose contribution per radionuclide, %, Atmospheric case C

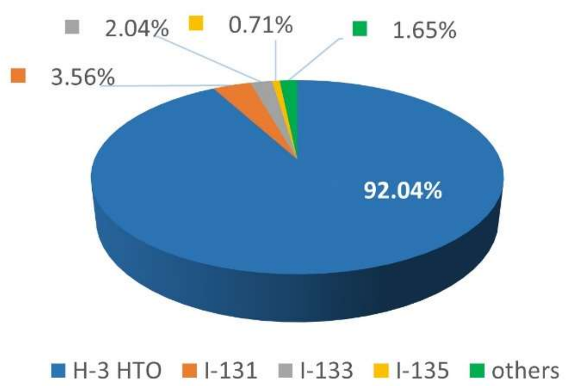

FIG. II-14. Inhalation dose contribution per radionuclide, %, Atmospheric case C

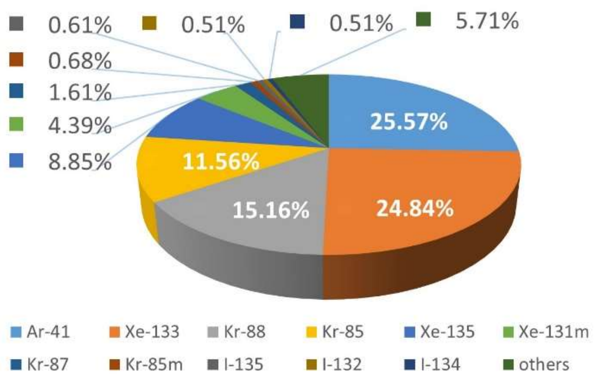

FIG. II-15. Immersion dose contribution per radionuclide, %, Atmospheric case C

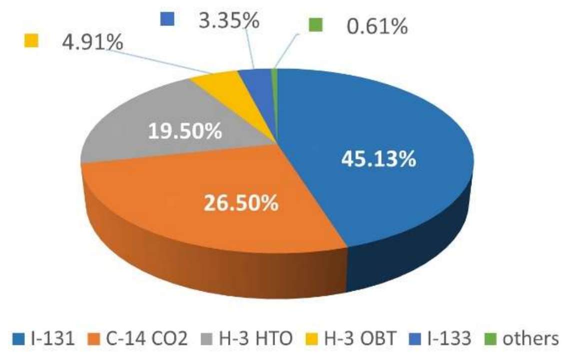

FIG. II-16. Ingestion dose contribution per radionuclide, %, Atmospheric case C

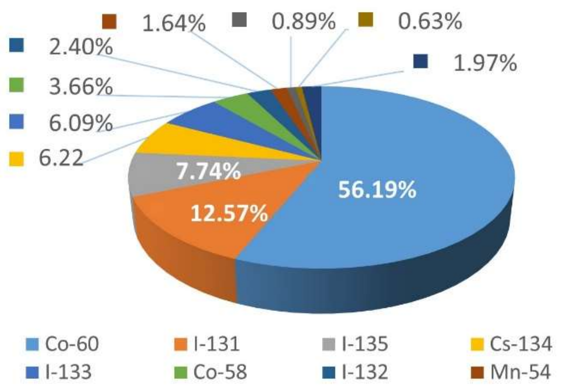

FIG. II-17. External dose contribution per radionuclide, %, Atmospheric case C

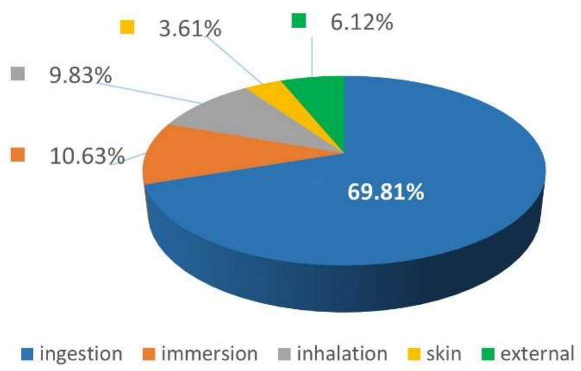

FIG. II-18. Total dose contribution per pathway, %, Atmospheric case C

TABLE II–23. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE (UP TO CUT-OFF LEVEL OF 0.5%). ATMOSPHERIC CASE C

Radionuclide	Pathway	Dose, µSv/a	Contribution to total dose, all pathways, %	Rank	Rank category
I-131(a)	Ingestion	3.61E-05	31.39	1	D_{33}
C-14 CO_2	Ingestion	2.12E-05	18.43	2	E_{25}
H-3 HTO	Ingestion	1.56E-05	13.57	3	E_{25}
H-3 HTO	Inhalation	1.04E-05	9.04	4	F_{10}
H-3 HTO	Skin	4.17E-06	3.63	5	G_5
Co-60	External	3.95E-06	3.43	6	G_5
H-3 OBT	Ingestion	3.93E-06	3.42	7	G_5
Ar-41	Immersion	3.12E-06	2.71	8	G_5
Xe-133	Immersion	3.03E-06	2.63	9	G_5
I-133(a)	Ingestion	2.68E-06	2.33	10	G_5
Kr-88	Immersion	1.85E-06	1.61	11	H_2
Kr-85	Immersion	1.41E-06	1.23	12	H_2
Xe-135	Immersion	1.08E-06	0.94	13	H_2
I-131(a)	External	8.84E-07	0.77	14	H_2
Total		1.09E-04	95.13		

TABLE II–24. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C

Rank	Inhalation pathway		Immersion pathway		Ingestion pathway		External exposure	
	Nuclide	Contrib.,%	Nuclide	Contrib.,%	Nuclide	Contrib.,%	Nuclide	Contrib.,%
1	H-3 HTO	92.04	Ar-41	25.57	I-131(a)	45.13	Co-60	56.19
2	I-131(a)	3.56	Xe-133	24.84	C-14 CO_2	26.50	I-131(a)	12.57
3	I-133(a)	2.04	Kr-88	15.16	H-3 HTO	19.50	I-135(a)	7.74
4	I-135(a)	0.71	Kr-85	11.56	H-3 OBT	4.91	Cs-134	6.22
5			Xe-135	8.85	I-133(a)	3.35	I-133(a)	6.09
6			Xe-131m	4.39			Co-58	3.66
7			Kr-87	1.61			I-132(a)	2.40
8			Kr-85m	0.68			Mn-54	1.64
9			I-135(a)	0.61			I-134(a)	0.89
10			I-132(a)	0.51			C-14 CO_2	0.63
11			I-134(a)	0.51				

Limited difference in the dose results of case A and case B is observed due to the difference in meteorological data provided by Brazil and CEA Cadarache. In every case the maximum concentration of radionuclides in the environment was evaluated and using this approach the difference in meteorological data did not influence the ranking results essentially.

Difference of results between cases A and C was stipulated by difference in input data for habits and transfer factors, difference in deposition velocities (in case C 3×10^{-3} m/s was used for H-3 and 10^{-4} m/s for C-14), difference in evaluation of H-3 effects.

Total dose and contribution to the total dose from different radionuclides in the riverine release cases A and B are provided in Table II-25 and Figures II-19, II-20. Ranking of radionuclides based on contribution to the total dose for the riverine release cases A and B are presented in Table II-26.

TABLE II–25. TOTAL DOSE. RIVERINE CASES A AND B

Riverine Case A			Riverine Case B		
Nuclide	Dose, µSv/a	Contribution, %	Nuclide	Dose, µSv/a	Contribution, %
Ag-110m	1.44E-06	0.01	Ag-110m	2.89E-07	0.01
Ce-144	5.62E-05	0.34	Ce-144	1.12E-05	0.34
Co-58	1.49E-05	0.09	Co-58	2.98E-06	0.09
Co-60	1.49E-04	0.91	Co-60	2.99E-05	0.91
Cr-51	3.83E-06	0.02	Cr-51	7.66E-07	0.02
Cs-134	6.20E-03	37.80	Cs-134	1.24E-03	37.92
Cs-137	6.86E-03	41.83	Cs-137	1.37E-03	41.90
Fe-59	4.41E-05	0.27	Fe-59	8.81E-06	0.27
H-3 HTO	6.05E-04	3.69	H-3 HTO	1.21E-04	3.70
I-131 (a)	9.08E-04	5.54	I-131 (a)	1.82E-04	5.57
Mn-54	1.98E-05	0.12	Mn-54	3.95E-06	0.12
Nb-95	2.26E-05	0.14	Nb-95	4.51E-06	0.14
Ru-106+	6.22E-05	0.38	Ru-106+	1.24E-05	0.38
Sr-90	4.44E-04	2.71	Sr-90	8.87E-05	2.71
Zn-65	9.17E-04	5.59	Zn-65	1.83E-04	5.60
Zr-95	5.68E-05	0.35	Zr-95	1.14E-05	0.35
Total	1.64E-02	100	Total	3.27E-03	100

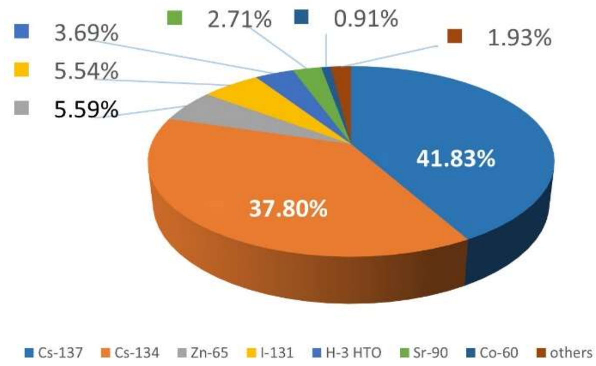

FIG. II-19. Total dose contribution per radionuclide, %, Riverine case A

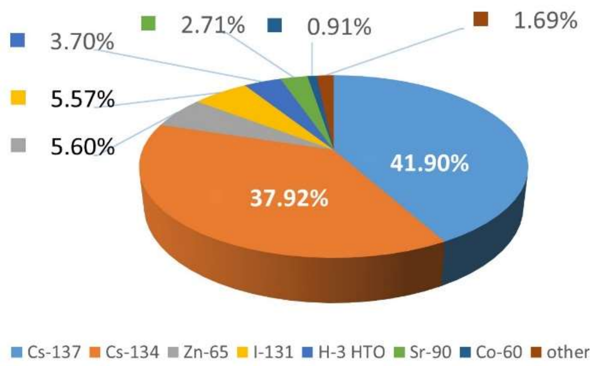

FIG. II-20. Total dose contribution per radionuclide, %, Riverine case B

TABLE II–26. RANKING OF RADIONUCLIDES BASED ON CONTRIBUTION TO THE TOTAL DOSE. RIVERINE CASES A AND B

Riverine Case A			Riverine Case B		
Nuclide	Contribution, %	Rank	Nuclide	Contribution, %	Rank
Cs-137	41.83	1	Cs-137	41.90	1
Cs-134	37.80	2	Cs-134	37.92	2
Zn-65	5.59	3	Zn-65	5.60	3
I-131 (a)	5.54	4	I-131 (a)	5.57	4
H-3 HTO	3.69	5	H-3 HTO	3.70	5
Sr-90	2.71	6	Sr-90	2.71	6
Co-60	0.91	7	Co-60	0.91	7
Ru-106+	0.38	8	Ru-106+	0.38	8
Zr-95	0.35	9	Zr-95	0.35	9
Ce-144	0.34	10	Ce-144	0.34	10
Fe-59	0.27	11	Fe-59	0.27	11
Nb-95	0.14	12	Nb-95	0.14	12
Mn-54	0.12	13	Mn-54	0.12	13
Co-58	0.09	14	Co-58	0.09	14
Cr-51	0.02	15	Cr-51	0.02	15
Ag-110m	0.01	16	Ag-110m	0.01	16

Due to the restrictions of ABRICOT model of CERES platform on the input data used, the difference of results between riverine case A and riverine case B is caused only by fish consumption rates. Case A uses a fish consumption of 30 kg/a and case B – 6 kg/a. This difference provides influence on the ingestion dose evaluation; however, it does not impact the ranking of radionuclides. Ranking for riverine releases should consider other pathways of human exposure like ingestion (via vegetables, animals etc.) and external exposure due to sediments.

REFERENCES TO ANNEX II

[II–1] MONFORT, M., PATRYL, L., ARMAND, P., Presentation of the CERES Platform used to evaluate the consequences of the emissions of radionuclides in the environment, Radioprotection, 46, 6, Société Française de Radioprotection, EDP Sciences (2011).

[II–2] DOURY, A., Une méthode de calcul pratique et générale pour la prévision numérique des pollutions véhiculées par l’atmosphère, Report of Commissariat à l'énergie atomique, CEA-R-4280 Rev.1, CEA, Saclay (1976).

[II–3] TURNER, D., Workbook of atmospheric dispersion estimates. Office of Air Programs Publication No. Ap-26, Environmental Protection Agency, Research Triangle Park, United States (1970).

[II–4] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook of parameter values for the prediction of radionuclide transfer in terrestrial and fresh water environment, Technical Report Series No 472, IAEA, Vienna (2010).

ANNEX III. INDIA

III–1. DESCRIPTION OF MODELS AND METHODOLOGIES APPLIED

The basic approach set out in SRS-19 [III–1], as modified by Indian national regulatory guide AERB.NF/SG/S-5 [III–2] was applied. For estimation of doses from tritium (H-3) and C-14, the dose conversion values based on a specific activity model recommended in regulatory guide AERB.NF/SG/S-5 [III–2] were used. The pathways considered for H-3 and C-14 were inhalation and ingestion (food crops, milk and meat). The dose contributions due to plume immersion and external exposure from ground deposited activity from these two radionuclides are negligibly small and hence were not estimated. Note that use of the specific activity model values resulted in conservative estimates.

III–2. STRUCTURE OF CONSIDERATION OF PUBLIC EXPOSURES FROM NORMAL OPERATION

In this study the annual radiological doses to an adult from atmospheric and aquatic discharges (marine and river) via a range of exposure pathways were calculated for a standardized set of radioactive releases. The generic information applied by all participants is provided in the main body of this publication. The default transfer factors were taken from TRS 472 [III–3]. The site-specific transfer factor values used in atmospheric case C, riverine case B and marine case B calculations for India are provided in this section.

For atmospheric release, in case A, a typical source term based on normal operations of a reactor in the Republic of Korea was used for the calculation. The radionuclides are assumed to be released through a 100 m tall stack. The meteorological data for atmospheric case A calculations were provided by Brazil in a form of dilution factors (s/m^3) for various wind directions and distance. To simplify the exercise, the minimum dilution value used was 4.705E-08, corresponding to the distance of 10 km. For the calculation using site-specific meteorological data, atmospheric case B, the minimum value from the Kalpakkam site was used (7.72E-08). The distance was assumed the same (10 km). Corrections due to plume rise and building wake effects were not considered. However, corrections due to dry deposition, ingrowth and radioactive decay during plume transport and dispersion were considered. Depletion due to dry deposition was based on an agreed default value suggested for the exercise. This approach was applied in line with the Indian manual for dose evaluation from atmospheric releases [III–4].

A simple, double Gaussian model assuming a flat terrain was used to estimate the downwind concentration and the effective doses due to all the major pathways: inhalation; external gamma from the plume immersion; ingestion of selected food matrices (milk, meat and vegetables); and external exposure from the ground deposited activity.

In the case of vegetable ingestion for atmospheric case C, which involved site-specific consumption values, the total consumption of vegetables was considered as one category (without separation of the different contributions of roots, leafy and non-leafy vegetables). Similarly, in the site-specific scenario considering meat, the bulk of local meat consumption is in the form of goat/sheep/lamb meat instead of beef. However, the meat consumed was considered to be beef and calculations performed accordingly. Transfer factors from TRS-472 [III–3] were applied in the absence of local values. Delay times between food production and consumption were considered in the calculation based on defaults provided in SRS-19 [III–1].

Tables III–1 and III–2 list the site-specific parameters from [III–2] used in the dose estimation for the scenarios described above (case C for atmospheric and cases B for marine and riverine releases).

TABLE III–1. SITE-SPECIFIC TRANSFER FACTORS

Chemical elements	Milk	Meat	Vegetables
Cr	2.0E-03	3.0E-02	8.0E-04
Mn	3.0E-04	1.0E-03	5.0E-01
Fe	3.0E-04	3.0E-02	7.0E-04
Co	2.0E-03	3.0E-02	3.0E-02
Sr	1.0E-03	6.0E-04	3.0E-01
Zr	3.0E-05	2.0E-02	5.0E-03
Nb	2.0E-02	3.0E-01	1.0E-02
Ru	6.0E-07	2.0E-03	8.0E-03
Ag (Ag-110m)	0.0E+00	5.0E-03	2.0E-01
Sb (Sb-125)	2.0E-05	1.0E-03	1.0E-02
I	1.0E-02	1.0E-02	2.0E-02
Cs	8.0E-03	2.0E-02	3.0E-02
Ba	4.0E-04	2.0E-04	5.0E-03
Ce	2.0E-05	2.0E-03	2.0E-03

TABLE III–2. SITE-SPECIFIC INPUT PARAMETERS USED IN THE EVALUATION OF ADULT RADIOLOGICAL DOSE

Parameters	Values
Ratio of the interception factor of forage vegetation, m^2/kg	2.0
Yield of leafy vegetables in fresh weight, m^2/kg	2.0
Yield of other food corps consumed by humans, m^2/kg	0.06
Weathering half-life (particulates), d^{-1}	0.046
Iodine on pasture vegetation, d^{-1}	0.069
Ingestion rate for beef, kg/d	16
Crop intake, kg/a	240
Water intake, m^3/a	1.09
Milk intake, kg/a	70
Meat intake, kg/a	10
Fish intake rate, kg/a	27.3

The radionuclide release to the sea used a typical data set comprising seawater concentrations of 54 radionuclides, provided by the Republic of Korea, as a source term. This data set was used to estimate annual doses to adults from the consumption of marine fish and shellfish. Two cases were considered. In marine release case A, the standard data provided for the exercise were used with all parameters fixed. In marine case B, the site-specific consumption rate and bioaccumulation factor values were used. For the site-specific calculation, the proportional ingestion rate of fish was considered as 50% fish and 50% shellfish. Doses from tritium were not estimated in the marine cases because its bioaccumulation factors were unavailable.

A typical radionuclide data set containing concentrations of sixteen radionuclides released into a river was provided by Ukraine as a source term for estimation of dose from the consumption of riverine fish. These data eliminated potential discrepancies that could arise from the models used by the various participants to estimate concentrations. Two cases were considered; case A using the standard data provided for the exercise with all parameters fixed, and case B using site-specific consumption rate and bioaccumulation factor values based on fresh weights. Doses from tritium were not estimated in the riverine cases because its bioaccumulation factors were unavailable.

III–3. RESULTS OF ASSESSMENT

Calculations were performed for all three atmospheric cases. Tables III–3, III-5 and III-7 provide the annual adult doses in µSv/a from individual radionuclides for each of the pathways for atmospheric cases A, B and C. The total adult dose estimated from all 37 radionuclides from all the pathways were 1.05E-01 µSv/a for case A, 4.90E-02 µSv/a for case B and 5.77E-02 µSv/a for case C. The difference between cases A and B was due to the meteorological data. In case C the variations were due to using site-specific parameters (consumption rates, transfer factors, breathing rate, etc.).

Tables III–4, III–6 and III–8 give the percentage contribution of each radionuclide within each pathway for atmospheric cases A, B and C. Table III–9 gives the percentage contribution of total dose from the various pathways. In all three cases the ingestion pathway contributed most of the dose (85% for cases A & B and 69% for case C), followed by plume immersion (8.5% for case A & B and 16% for case C), the inhalation pathway (6% for case A & B and 14% for case C) and ground deposition (0.5% for cases A & B and 1% for case C). Under the inhalation pathway, from amongst the 37 radionuclides considered, only 8 radionuclides contributed to 98% of the total dose. Similar trends could be seen for the cases B and C.

TABLE III–3. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE A.

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	6.36E-03	0.00E+00	1.22E-02	1.93E-07	7.80E-05	1.23E-02	0.00E+00	1.86E-02
C-14 CO2	1.87E-05	0.00E+00	7.74E-03	1.05E-07	4.61E-02	5.38E-02	0.00E+00	5.38E-02
Ar-41	0.00E+00	2.09E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.09E-03
Cr-51	1.66E-09	2.57E-10	1.35E-08	6.94E-07	2.82E-11	7.08E-07	6.93E-08	7.79E-07
Mn-54	3.97E-08	4.09E-09	2.10E-08	1.18E-07	2.41E-07	3.80E-07	1.57E-06	1.99E-06
Fe-59	5.21E-08	2.95E-09	1.76E-08	2.11E-06	5.17E-10	2.13E-06	8.53E-07	3.03E-06
Co-57	3.80E-09	0.00E+00	2.38E-09	3.54E-09	3.38E-09	9.30E-09	0.00E+00	1.31E-08
Co-58	4.68E-07	3.98E-08	4.29E-07	5.55E-07	5.54E-07	1.54E-06	1.33E-05	1.53E-05
Co-60	1.58E-06	2.73E-08	5.41E-07	8.40E-07	7.91E-07	2.17E-06	9.04E-06	1.28E-05
Kr-85	0.00E+00	2.17E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E-03
Kr-85m	0.00E+00	5.75E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.75E-05
Kr-87	0.00E+00	1.28E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-04
Kr-88	0.00E+00	1.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.32E-03
Sr-89	5.86E-07	1.24E-10	5.53E-06	1.70E-06	2.77E-06	9.99E-06	3.04E-07	1.09E-05
Sr-90	4.67E-06	1.08E-11	3.03E-05	1.21E-05	1.81E-05	6.06E-05	2.43E-07	6.55E-05
Zr-95	2.73E-08	6.07E-10	3.68E-10	4.00E-11	4.45E-10	8.53E-10	4.26E-07	4.55E-07
Nb-95	3.49E-08	2.77E-09	9.26E-11	1.61E-11	3.14E-09	3.25E-09	7.94E-07	8.35E-07
Ru-103	2.36E-08	6.75E-10	1.12E-09	1.12E-07	3.18E-09	1.16E-07	2.07E-07	3.48E-07
Ru-106	2.39E-08	1.55E-11	6.55E-10	8.87E-08	2.29E-09	9.17E-08	9.14E-09	1.25E-07
Sb-125	3.40E-09	2.19E-11	3.33E-10	4.16E-09	4.20E-12	4.50E-09	9.31E-09	1.72E-08
Xe-131m	0.00E+00	3.67E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.67E-04
Xe-133	0.00E+00	1.95E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.95E-03
Xe-133m	0.00E+00	2.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.18E-05
Xe-135	0.00E+00	7.46E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.46E-04
Xe-135m	0.00E+00	2.74E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-06
Xe-138	0.00E+00	4.88E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.88E-06
I-131	1.26E-04	1.18E-06	1.95E-02	1.86E-03	5.03E-05	2.14E-02	1.79E-04	2.17E-02
I-132(e)	4.59E-06	2.09E-05	1.09E-08	1.15E-68	1.29E-51	1.09E-08	5.75E-05	8.30E-05
I-133 (e)	7.31E-05	5.51E-06	8.55E-04	1.07E-10	2.08E-10	8.55E-04	1.36E-04	1.07E-03
I-134 (e)	1.81E-06	2.01E-05	1.05E-14	9.13E-07	5.33E-124	9.13E-07	2.14E-05	4.42E-05
I-135 (e)	2.57E-05	2.48E-05	1.81E-05	1.55E-26	8.96E-22	1.81E-05	1.78E-04	2.47E-04

TABLE III–3. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE A (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Cs-134	1.47E-07	6.37E-09	5.46E-05	1.03E-04	5.73E-07	1.58E-04	2.56E-06	1.61E-04
Cs-136	1.83E-08	6.17E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-06	1.20E-06
Cs-137	1.92E-07	4.32E-09	7.12E-05	1.36E-04	7.55E-07	2.08E-04	1.79E-06	2.10E-04
Ba-140	1.12E-08	0.00E+00	1.04E-08	1.29E-09	2.00E-10	1.19E-08	0.00E+00	2.31E-08
Ce-141	2.29E-08	0.00E+00	1.68E-09	4.47E-09	4.77E-10	6.62E-09	2.41E-08	5.36E-08
Total dose	6.62E-03	8.93E-03	4.04E-02	2.12E-03	4.62E-02	8.88E-02	6.05E-04	1.05E-01

TABLE III–4. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	9.61E+01	0.00E+00	3.02E+01	9.10E-03	1.69E-01	1.38E+01	0.00E+00	1.78E+01
C-14 CO2	2.82E-01	0.00E+00	1.91E+01	4.96E-03	9.97E+01	6.06E+01	0.00E+00	5.13E+01
Ar-41	0.00E+00	2.34E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E+00
Cr-51	2.51E-05	2.87E-06	3.34E-05	3.27E-02	6.09E-08	7.97E-04	1.15E-02	7.42E-04
Mn-54	5.99E-04	4.58E-05	5.19E-05	5.56E-03	5.21E-04	4.27E-04	2.59E-01	1.90E-03
Fe-59	7.87E-04	3.30E-05	4.36E-05	9.94E-02	1.12E-06	2.39E-03	1.41E-01	2.89E-03
Co-57	5.73E-05	0.00E+00	5.88E-06	1.67E-04	7.32E-06	1.05E-05	0.00E+00	1.25E-05
Co-58	7.07E-03	4.46E-04	1.06E-03	2.62E-02	1.20E-03	1.73E-03	2.20E+00	1.46E-02
Co-60	2.39E-02	3.06E-04	1.34E-03	3.96E-02	1.71E-03	2.45E-03	1.50E+00	1.22E-02
Kr-85	0.00E+00	2.43E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E+00
Kr-85m	0.00E+00	6.44E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.48E-02
Kr-87	0.00E+00	1.44E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-01
Kr-88	0.00E+00	1.48E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E+00
Sr-89	8.84E-03	1.38E-06	1.37E-02	8.01E-02	5.98E-03	1.13E-02	5.03E-02	1.04E-02
Sr-90	7.06E-02	1.21E-07	7.50E-02	5.71E-01	3.93E-02	6.82E-02	4.02E-02	6.24E-02
Zr-95	4.13E-04	6.79E-06	9.10E-07	1.88E-06	9.62E-07	9.61E-07	7.05E-02	4.34E-04
Nb-95	5.27E-04	3.10E-05	2.29E-07	7.60E-07	6.80E-06	3.66E-06	1.31E-01	7.96E-04
Ru-103	3.57E-04	7.56E-06	2.77E-06	5.29E-03	6.88E-06	1.31E-04	3.43E-02	3.32E-04
Ru-106	3.61E-04	1.74E-07	1.62E-06	4.18E-03	4.95E-06	1.03E-04	1.51E-03	1.19E-04
Sb-125	5.13E-05	2.45E-07	8.25E-07	1.96E-04	9.08E-09	5.06E-06	1.54E-03	1.64E-05
Xe-131m	0.00E+00	4.11E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-01
Xe-133	0.00E+00	2.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E+00
Xe-133m	0.00E+00	2.44E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.08E-02
Xe-135	0.00E+00	8.35E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.11E-01
Xe-135m	0.00E+00	3.07E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.61E-03
Xe-138	0.00E+00	5.46E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.65E-03
I-131	1.91E+00	1.32E-02	4.81E+01	8.78E+01	1.09E-01	2.41E+01	2.95E+01	2.07E+01
I-132(e)	6.93E-02	2.34E-01	2.68E-05	5.43E-64	2.79E-48	1.22E-05	9.51E+00	7.91E-02
I-133 (e)	1.10E+00	6.17E-02	2.11E+00	5.05E-06	4.51E-07	9.63E-01	2.26E+01	1.02E+00
I-134 (e)	2.73E-02	2.25E-01	2.58E-11	4.31E-02	1.15E-120	1.03E-03	3.54E+00	4.22E-02
I-135 (e)	3.87E-01	2.78E-01	4.47E-02	7.31E-22	1.94E-18	2.04E-02	2.95E+01	2.35E-01
Cs-134	2.22E-03	7.14E-05	1.35E-01	4.84E+00	1.24E-03	1.78E-01	4.23E-01	1.53E-01
Cs-136	2.76E-04	6.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.95E-01	1.14E-03
Cs-137	2.90E-03	4.84E-05	1.76E-01	6.42E+00	1.63E-03	2.34E-01	2.95E-01	2.00E-01
Ba-140	1.70E-04	0.00E+00	2.58E-05	6.10E-05	4.34E-07	1.34E-05	0.00E+00	2.21E-05
Ce-141	3.45E-04	0.00E+00	4.14E-06	2.11E-04	1.03E-06	7.46E-06	3.99E-03	5.11E-05
Total dose	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02

TABLE III–5. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	2.97E-03	0.00E+00	5.70E-03	9.02E-08	3.65E-05	5.74E-03	0.00E+00	8.71E-03
C-14 CO2	8.73E-06	0.00E+00	3.62E-03	4.92E-08	2.15E-02	2.51E-02	0.00E+00	2.52E-02
Ar-41	0.00E+00	9.78E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.78E-04
Cr-51	7.77E-10	1.20E-10	6.31E-09	3.25E-07	1.32E-11	3.31E-07	3.24E-08	3.64E-07
Mn-54	1.85E-08	1.91E-09	9.82E-09	5.51E-08	1.12E-07	1.77E-07	7.32E-07	9.30E-07
Fe-59	2.43E-08	1.38E-09	8.25E-09	9.85E-07	2.41E-10	9.93E-07	3.99E-07	1.42E-06
Co-57	1.77E-09	0.00E+00	1.11E-09	1.66E-09	1.58E-09	4.35E-09	0.00E+00	6.12E-09
Co-58	2.19E-07	1.86E-08	2.00E-07	2.59E-07	2.59E-07	7.19E-07	6.21E-06	7.17E-06
Co-60	7.39E-07	1.28E-08	2.53E-07	3.92E-07	3.70E-07	1.02E-06	4.23E-06	5.99E-06
Kr-85	0.00E+00	1.01E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-03
Kr-85m	0.00E+00	2.69E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.69E-05
Kr-87	0.00E+00	6.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.00E-05
Kr-88	0.00E+00	6.19E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.19E-04
Sr-89	2.74E-07	5.77E-11	2.58E-06	7.94E-07	1.29E-06	4.67E-06	1.42E-07	5.09E-06
Sr-90	2.18E-06	5.04E-12	1.42E-05	5.66E-06	8.48E-06	2.83E-05	1.14E-07	3.06E-05
Zr-95	1.28E-08	2.84E-10	1.72E-10	1.87E-11	2.08E-10	3.99E-10	1.99E-07	2.13E-07
Nb-95	1.63E-08	1.30E-09	4.33E-11	7.53E-12	1.47E-09	1.52E-09	3.71E-07	3.90E-07
Ru-103	1.10E-08	3.15E-10	5.23E-10	5.24E-08	1.49E-09	5.44E-08	9.70E-08	1.63E-07
Ru-106	1.12E-08	7.25E-12	3.06E-10	4.15E-08	1.07E-09	4.28E-08	4.27E-09	5.83E-08
Sb-125	1.59E-09	1.02E-11	1.56E-10	1.94E-09	1.96E-12	2.10E-09	4.35E-09	8.05E-09
Xe-131m	0.00E+00	1.72E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-04
Xe-133	0.00E+00	9.09E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.09E-04
Xe-133m	0.00E+00	1.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-05
Xe-135	0.00E+00	3.49E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.49E-04
Xe-135m	0.00E+00	1.28E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-06
Xe-138	0.00E+00	2.28E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.28E-06
I-131	5.91E-05	5.51E-07	9.09E-03	8.70E-04	2.35E-05	9.99E-03	8.35E-05	1.01E-02
I-132(e)	2.14E-06	9.78E-06	5.07E-09	5.38E-69	6.02E-52	5.07E-09	2.69E-05	3.88E-05
I-133 (e)	3.41E-05	2.57E-06	3.99E-04	5.00E-11	9.73E-11	3.99E-04	6.38E-05	5.00E-04
I-134 (e)	8.45E-07	9.39E-06	4.88E-15	4.27E-07	2.49E-124	4.27E-07	1.00E-05	2.07E-05
I-135 (e)	1.20E-05	1.16E-05	8.45E-06	7.24E-27	4.19E-22	8.45E-06	8.33E-05	1.15E-04
Cs-134	6.88E-08	2.98E-09	2.55E-05	4.80E-05	2.68E-07	7.38E-05	1.19E-06	7.51E-05
Cs-136	8.55E-09	2.88E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.50E-07	5.61E-07
Cs-137	8.97E-08	2.02E-09	3.33E-05	6.36E-05	3.53E-07	9.72E-05	8.35E-07	9.81E-05
Ba-140	5.25E-09	0.00E+00	4.87E-09	6.04E-10	9.37E-11	5.57E-09	0.00E+00	1.08E-08
Ce-141	1.07E-08	0.00E+00	7.83E-10	2.09E-09	2.23E-10	3.10E-09	1.13E-08	2.51E-08
Total dose	3.09E-03	4.17E-03	1.89E-02	9.91E-04	2.16E-02	4.15E-02	2.83E-04	4.90E-02

TABLE III–6. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	9.61E+01	0.00E+00	3.02E+01	9.10E-03	1.69E-01	1.38E+01	0.00E+00	1.78E+01
C-14 CO_2	2.82E-01	0.00E+00	1.91E+01	4.96E-03	9.97E+01	6.06E+01	0.00E+00	5.13E+01
Ar-41	0.00E+00	2.34E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E+00
Cr-51	2.51E-05	2.87E-06	3.34E-05	3.27E-02	6.09E-08	7.97E-04	1.15E-02	7.42E-04
Mn-54	5.99E-04	4.58E-05	5.19E-05	5.56E-03	5.21E-04	4.27E-04	2.59E-01	1.90E-03
Fe-59	7.87E-04	3.30E-05	4.36E-05	9.94E-02	1.12E-06	2.39E-03	1.41E-01	2.89E-03

TABLE III–6. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Co-57	5.73E-05	0.00E+00	5.88E-06	1.67E-04	7.32E-06	1.05E-05	0.00E+00	1.25E-05
Co-58	7.07E-03	4.46E-04	1.06E-03	2.62E-02	1.20E-03	1.73E-03	2.20E+00	1.46E-02
Co-60	2.39E-02	3.06E-04	1.34E-03	3.96E-02	1.71E-03	2.45E-03	1.50E+00	1.22E-02
Kr-85	0.00E+00	2.43E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E+00
Kr-85m	0.00E+00	6.44E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.48E-02
Kr-87	0.00E+00	1.44E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-01
Kr-88	0.00E+00	1.48E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E+00
Sr-89	8.84E-03	1.38E-06	1.37E-02	8.01E-02	5.98E-03	1.13E-02	5.03E-02	1.04E-02
Sr-90	7.06E-02	1.21E-07	7.50E-02	5.71E-01	3.93E-02	6.82E-02	4.02E-02	6.24E-02
Zr-95	4.13E-04	6.79E-06	9.10E-07	1.88E-06	9.62E-07	9.61E-07	7.05E-02	4.34E-04
Nb-95	5.27E-04	3.10E-05	2.29E-07	7.60E-07	6.80E-06	3.66E-06	1.31E-01	7.96E-04
Ru-103	3.57E-04	7.56E-06	2.77E-06	5.29E-03	6.88E-06	1.31E-04	3.43E-02	3.32E-04
Ru-106	3.61E-04	1.74E-07	1.62E-06	4.18E-03	4.95E-06	1.03E-04	1.51E-03	1.19E-04
Sb-125	5.13E-05	2.45E-07	8.25E-07	1.96E-04	9.08E-09	5.06E-06	1.54E-03	1.64E-05
Xe-131m	0.00E+00	4.11E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-01
Xe-133	0.00E+00	2.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E+00
Xe-133m	0.00E+00	2.44E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.08E-02
Xe-135	0.00E+00	8.35E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.11E-01
Xe-135m	0.00E+00	3.07E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.61E-03
Xe-138	0.00E+00	5.46E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.65E-03
I-131	1.91E+00	1.32E-02	4.81E+01	8.78E+01	1.09E-01	2.41E+01	2.95E+01	2.07E+01
I-132(e)	6.93E-02	2.34E-01	2.68E-05	5.43E-64	2.79E-48	1.22E-05	9.51E+00	7.91E-02
I-133 (e)	1.10E+00	6.17E-02	2.11E+00	5.05E-06	4.51E-07	9.63E-01	2.26E+01	1.02E+00
I-134 (e)	2.73E-02	2.25E-01	2.58E-11	4.31E-02	1.15E-120	1.03E-03	3.54E+00	4.22E-02
I-135 (e)	3.87E-01	2.78E-01	4.47E-02	7.31E-22	1.94E-18	2.04E-02	2.95E+01	2.35E-01
Cs-134	2.22E-03	7.14E-05	1.35E-01	4.84E+00	1.24E-03	1.78E-01	4.23E-01	1.53E-01
Cs-136	2.76E-04	6.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.95E-01	1.14E-03
Cs-137	2.90E-03	4.84E-05	1.76E-01	6.42E+00	1.63E-03	2.34E-01	2.95E-01	2.00E-01
Ba-140	1.70E-04	0.00E+00	2.58E-05	6.10E-05	4.34E-07	1.34E-05	0.00E+00	2.21E-05
Ce-141	3.45E-04	0.00E+00	4.14E-06	2.11E-04	1.03E-06	7.46E-06	3.99E-03	5.11E-05
Total dose	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02

TABLE III–7. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3	7.96E-03	0.00E+00	3.42E-03	6.24E-06	4.75E-05	3.47E-03	0.00E+00	1.14E-02
C-14 CO_2	2.34E-05	0.00E+00	0.00E+00	1.59E-03	2.76E-02	2.91E-02	0.00E+00	2.92E-02
Ar-41	0.00E+00	2.09E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.09E-03
Cr-51	2.08E-09	2.57E-10	1.17E-08	1.54E-08	1.46E-11	2.72E-08	6.93E-08	9.88E-08
Mn-54	4.96E-08	4.09E-09	2.87E-08	1.31E-08	2.02E-07	2.43E-07	1.57E-06	1.86E-06
Fe-59	6.52E-08	2.95E-09	2.82E-08	3.01E-07	2.34E-10	3.29E-07	8.53E-07	1.25E-06
Co-57	4.75E-09	0.00E+00	8.07E-09	1.65E-08	5.08E-10	2.51E-08	0.00E+00	2.98E-08
Co-58	5.86E-07	3.98E-08	1.45E-06	2.58E-06	8.32E-08	4.12E-06	1.33E-05	1.80E-05
Co-60	1.98E-06	2.73E-08	1.84E-06	3.91E-06	1.19E-07	5.86E-06	9.04E-06	1.69E-05
Kr-85	0.00E+00	2.17E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E-03
Kr-85m	0.00E+00	5.75E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.75E-05
Kr-87	0.00E+00	1.28E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-04

TABLE III–7. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Kr-88	0.00E+00	1.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+0 0	0.00E+00	1.32E-03
Sr-89	7.33E-07	1.24E-10	7.94E-07	5.23E-08	8.63E-07	1.71E-06	3.04E-07	2.75E-06
Sr-90	5.85E-06	1.08E-11	4.35E-06	3.73E-07	5.66E-06	1.04E-05	2.43E-07	1.65E-05
Zr-95	3.42E-08	6.07E-10	5.73E-10	4.44E-08	3.60E-10	4.53E-08	4.26E-07	5.06E-07
Nb-95	4.37E-08	2.77E-09	8.43E-07	1.24E-06	1.41E-09	2.08E-06	7.94E-07	2.93E-06
Ru-103	2.96E-08	6.75E-10	1.33E-11	4.53E-09	6.12E-10	5.16E-09	2.07E-07	2.43E-07
Ru-106	2.99E-08	1.55E-11	7.80E-12	3.59E-09	4.41E-10	4.03E-09	9.14E-09	4.31E-08
Sb-125	4.25E-09	2.19E-11	3.28E-11	2.31E-10	7.05E-11	3.34E-10	9.31E-09	1.39E-08
Xe-131m	0.00E+00	3.67E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.67E-04
Xe-133	0.00E+00	1.95E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.95E-03
Xe-133m	0.00E+00	2.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.18E-05
Xe-135	0.00E+00	7.46E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.46E-04
Xe-135m	0.00E+00	2.74E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-06
Xe-138	0.00E+00	4.88E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.88E-06
I-131	1.58E-04	1.18E-06	6.73E-03	1.85E-04	1.89E-05	6.93E-03	1.79E-04	7.27E-03
I-132(e)	5.74E-06	2.09E-05	3.75E-09	1.15E-69	4.85E-52	3.75E-09	5.75E-05	8.41E-05
I-133 (e)	9.14E-05	5.51E-06	2.95E-04	1.06E-11	7.84E-11	2.95E-04	1.36E-04	5.29E-04
I-134 (e)	2.26E-06	2.01E-05	3.61E-15	1.11E-172	2.01E-124	3.61E-15	2.14E-05	4.38E-05
I-135 (e)	3.21E-05	2.48E-05	6.25E-06	1.54E-27	3.37E-22	6.25E-06	1.78E-04	2.41E-04
Cs-134	1.84E-07	6.37E-09	1.77E-05	6.23E-06	2.85E-07	2.43E-05	2.56E-06	2.70E-05
Cs-136	2.29E-08	6.17E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-06	1.21E-06
Cs-137	2.40E-07	4.32E-09	2.31E-05	8.25E-06	3.76E-07	3.17E-05	1.79E-06	3.38E-05
Ba-140	1.41E-08	0.00E+00	4.86E-09	1.23E-10	1.30E-10	5.12E-09	0.00E+00	1.92E-08
Ce-141	2.86E-08	0.00E+00	3.13E-10	2.98E-09	1.03E-10	3.40E-09	2.41E-08	5.61E-08
Total dose	8.29E-03	8.93E-03	1.05E-02	1.80E-03	2.76E-02	3.99E-02	6.05E-04	5.77E-02

TABLE III–8. CONTRIBUTION TO THE TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Depositio n	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	9.61E+01	0.00E+00	3.26E+01	3.46E-01	1.72E-01	8.69E+00	0.00E+00	1.98E+01
C-14 CO_2	2.82E-01	0.00E+00	0.00E+00	8.81E+01	9.97E+01	7.30E+01	0.00E+00	5.05E+01
Ar-41	0.00E+00	2.34E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.62E+00
Cr-51	2.51E-05	2.87E-06	1.12E-04	8.57E-04	5.28E-08	6.81E-05	1.15E-02	1.71E-04
Mn-54	5.99E-04	4.58E-05	2.73E-04	7.27E-04	7.30E-04	6.10E-04	2.59E-01	3.23E-03
Fe-59	7.87E-04	3.30E-05	2.69E-04	1.67E-02	8.47E-07	8.25E-04	1.41E-01	2.17E-03
Co-57	5.73E-05	0.00E+00	7.69E-05	9.14E-04	1.84E-06	6.27E-05	0.00E+00	5.16E-05
Co-58	7.07E-03	4.46E-04	1.39E-02	1.43E-01	3.01E-04	1.03E-02	2.20E+00	3.12E-02
Co-60	2.39E-02	3.06E-04	1.75E-02	2.17E-01	4.30E-04	1.47E-02	1.50E+00	2.93E-02
Kr-85	0.00E+00	2.43E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.75E+00
Kr-85m	0.00E+00	6.44E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.96E-02
Kr-87	0.00E+00	1.44E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.22E-01
Kr-88	0.00E+00	1.48E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.29E+00
Sr-89	8.84E-03	1.38E-06	7.56E-03	2.90E-03	3.12E-03	4.28E-03	5.03E-02	4.76E-03
Sr-90	7.06E-02	1.21E-07	4.15E-02	2.07E-02	2.05E-02	2.60E-02	4.02E-02	2.85E-02
Zr-95	4.13E-04	6.79E-06	5.46E-06	2.46E-03	1.30E-06	1.14E-04	7.05E-02	8.77E-04
Nb-95	5.27E-04	3.10E-05	8.03E-03	6.88E-02	5.12E-06	5.22E-03	1.31E-01	5.07E-03
Ru-103	3.57E-04	7.56E-06	1.27E-07	2.51E-04	2.22E-06	1.29E-05	3.43E-02	4.21E-04

TABLE III–8. CONTRIBUTION TO THE TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Ru-106	3.61E-04	1.74E-07	7.43E-08	1.99E-04	1.59E-06	1.01E-05	1.51E-03	7.46E-05
Sb-125	5.13E-05	2.45E-07	3.12E-07	1.28E-05	2.55E-07	8.37E-07	1.54E-03	2.41E-05
Xe-131m	0.00E+00	4.11E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.36E-01
Xe-133	0.00E+00	2.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.37E+00
Xe-133m	0.00E+00	2.44E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E-02
Xe-135	0.00E+00	8.35E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.29E+00
Xe-135m	0.00E+00	3.07E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.75E-03
Xe-138	0.00E+00	5.46E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.45E-03
I-131	1.91E+00	1.32E-02	6.41E+01	1.03E+01	6.85E-02	1.74E+01	2.95E+01	1.26E+01
I-132(e)	6.93E-02	2.34E-01	3.57E-05	6.36E-65	1.76E-48	9.40E-06	9.51E+00	1.46E-01
I-133 (e)	1.10E+00	6.17E-02	2.81E+00	5.91E-07	2.84E-07	7.40E-01	2.26E+01	9.16E-01
I-134 (e)	2.73E-02	2.25E-01	3.44E-11	6.16E-16	7.27E-121	9.05E-12	3.54E+00	7.58E-02
I-135 (e)	3.87E-01	2.78E-01	5.95E-02	8.56E-23	1.22E-18	1.57E-02	2.95E+01	4.18E-01
Cs-134	2.22E-03	7.14E-05	1.69E-01	3.46E-01	1.03E-03	6.07E-02	4.23E-01	4.67E-02
Cs-136	2.76E-04	6.91E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.95E-01	2.09E-03
Cs-137	2.90E-03	4.84E-05	2.20E-01	4.58E-01	1.36E-03	7.95E-02	2.95E-01	5.85E-02
Ba-140	1.70E-04	0.00E+00	4.63E-05	6.84E-06	4.70E-07	1.28E-05	0.00E+00	3.32E-05
Ce-141	3.45E-04	0.00E+00	2.98E-06	1.65E-04	3.72E-07	8.51E-06	3.99E-03	9.72E-05
Total dose	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.00E+02

TABLE III–9. ANNUAL DOSE FROM VARIOUS PATHWAYS. ATMOSPHERIC CASES A, B AND C

Pathway		Atmospheric case A		Atmospheric case B		Atmospheric case C	
		Dose, µSv/a	Contrib., %	Dose, µSv/a	Contrib., %	Dose, µSv/a	Contrib., %
Inhalation		6.62E-03	6.31	3.09E-03	6.31	8.29E-03	14.35
Immersion		8.93E-03	8.51	4.17E-03	8.51	8.93E-03	15.47
Ingestion	Milk	4.04E-02	38.54	1.89E-02	38.54	1.05E-02	18.18
	Veggies	4.62E-02	44.04	2.16E-02	44.04	2.76E-02	47.84
	Meat	2.12E-03	2.02	9.91E-04	2.02	1.80E-03	3.12
	Total	8.88E-02	84.60	4.15E-02	84.60	3.99E-02	69.14
Ground deposition		6.05E-04	0.58	2.83E-04	0.58	6.05E-04	1.05
Total		1.05E-01	100.00	4.90E-02	100.00	5.77E-02	100.00

TABLE III–10. RANKING OF RADIONUCLIDES BASED ON TOTAL ANNUAL DOSE. ATMOSPHERIC CASES A, B AND C

Rank	Atmospheric case A			Atmospheric case B			Atmospheric case C		
	Nuclide	Dose,µSv/a	Contr.,%	Nuclide	Dose,µSv/a	Contr.,%	Nuclide	Dose,µSv/a	Contr.,%
1	C-14 CO_2	5.38E-02	51.29	C-14 CO_2	2.52E-02	51.29	C-14 CO_2	2.92E-02	50.50
2	I-131	2.17E-02	20.66	I-131	1.01E-02	20.66	H-3 HTO	1.14E-02	19.80
3	H-3 HTO	1.86E-02	17.77	H-3 HTO	8.71E-03	17.77	I-131	7.27E-03	12.59
4	Kr-85	2.17E-03	2.07	Kr-85	1.01E-03	2.07	Kr-85	2.17E-03	3.75
5	Ar-41	2.09E-03	1.99	Ar-41	9.78E-04	1.99	Ar-41	2.09E-03	3.62
6	Xe-133	1.95E-03	1.85	Xe-133	9.09E-04	1.85	Xe-133	1.95E-03	3.37
7	Kr-88	1.32E-03	1.26	Kr-88	6.19E-04	1.26	Kr-88	1.32E-03	2.29
8	I-133(e)	1.07E-03	1.02	I-133(e)	5.00E-04	1.02	Xe-135	7.46E-04	1.29
9	Xe-135	7.46E-04	0.71	Xe-135	3.49E-04	0.71	I-133(e)	5.29E-04	0.92
10	Xe-131m	3.67E-04	0.35	Xe-131m	1.72E-04	0.35	Xe-131m	3.67E-04	0.64
11	I-135(e)	2.47E-04	0.24	I-135(e)	1.15E-04	0.24	I-135(e)	2.41E-04	0.42

TABLE III–10. RANKING OF RADIONUCLIDES BASED ON TOTAL ANNUAL DOSE. ATMOSPHERIC CASES A, B AND C (cont.)

Rank	Atmospheric case A			Atmospheric case B			Atmospheric case C		
	Nuclide	Dose,µSv/a	Contr.,%	Nuclide	Dose,µSv/a	Contr.,%	Nuclide	Dose,µSv/a	Contr.,%
12	Cs-137	2.10E-04	0.20	Cs-137	9.81E-05	0.20	Kr-87	1.28E-04	0.22
13	Cs-134	1.61E-04	0.15	Cs-134	7.51E-05	0.15	I-132(e)	8.41E-05	0.15
14	Kr-87	1.28E-04	0.12	Kr-87	6.00E-05	0.12	Kr-85m	5.75E-05	0.10
15	I-132(e)	8.30E-05	0.08	I-132(e)	3.88E-05	0.08	I-134(e)	4.38E-05	0.08
16	Sr-90	6.55E-05	0.06	Sr-90	3.06E-05	0.06	Cs-137	3.38E-05	0.06
17	Kr-85m	5.75E-05	0.05	Kr-85m	2.69E-05	0.05	Cs-134	2.70E-05	0.05
18	I-134(e)	4.42E-05	0.04	I-134(e)	2.07E-05	0.04	Xe-133m	2.18E-05	0.04
19	Xe-133m	2.18E-05	0.02	Xe-133m	1.02E-05	0.02	Co-58	1.80E-05	0.03
20	Co-58	1.53E-05	0.01	Co-58	7.17E-06	0.01	Co-60	1.69E-05	0.03
21	Co-60	1.28E-05	0.01	Co-60	5.99E-06	0.01	Sr-90	1.65E-05	0.03
22	Sr-89	1.09E-05	0.01	Sr-89	5.09E-06	0.01	Xe-138	4.88E-06	0.01
23	Xe-138	4.88E-06	0.00	Xe-138	2.28E-06	0.00	Nb-95	2.93E-06	0.01
24	Fe-59	3.03E-06	0.00	Fe-59	1.42E-06	0.00	Sr-89	2.75E-06	0.00
25	Xe-135m	2.74E-06	0.00	Xe-135m	1.28E-06	0.00	Xe-135m	2.74E-06	0.00
26	Mn-54	1.99E-06	0.00	Mn-54	9.30E-07	0.00	Mn-54	1.86E-06	0.00
27	Cs-136	1.20E-06	0.00	Cs-136	5.61E-07	0.00	Fe-59	1.25E-06	0.00
28	Nb-95	8.35E-07	0.00	Nb-95	3.90E-07	0.00	Cs-136	1.21E-06	0.00
29	Cr-51	7.79E-07	0.00	Cr-51	3.64E-07	0.00	Zr-95	5.06E-07	0.00
30	Zr-95	4.55E-07	0.00	Zr-95	2.13E-07	0.00	Ru-103	2.43E-07	0.00
31	Ru-103	3.48E-07	0.00	Ru-103	1.63E-07	0.00	Cr-51	9.88E-08	0.00
32	Ru-106	1.25E-07	0.00	Ru-106	5.83E-08	0.00	Ce-141	5.61E-08	0.00
33	Ce-141	5.36E-08	0.00	Ce-141	2.51E-08	0.00	Ru-106	4.31E-08	0.00
34	Ba-140	2.31E-08	0.00	Ba-140	1.08E-08	0.00	Co-57	2.98E-08	0.00
35	Sb-125	1.72E-08	0.00	Sb-125	8.05E-09	0.00	Ba-140	1.92E-08	0.00
36	Co-57	1.31E-08	0.00	Co-57	6.12E-09	0.00	Sb-125	1.39E-08	0.00
	Total	1.05E-01	100.00	Total	4.90E-02	100.00	Total	5.77E-02	100.00

Table III–10 provides the ranking of radionuclides based on the total dose contributed through all pathways. The ranking for case A demonstrates that C-14, I-131 and H-3 are ranked as the top three, together contributing about 90% of the total adult dose. A similar trend was seen in case B. For case C, whilst C-14 remained at rank 1, the ranks of H-3 and I-131 were interchanged. The total adult dose contribution of the three radionuclides in case C reduced to 83% (a reduction of about 8% compared to cases A and B).

Figures III–1 to III–18 help to compare contributions from different radionuclides and different pathways in atmospheric cases A, B and C.

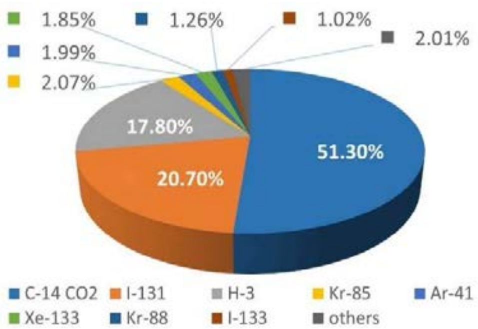

FIG. III-1. Total dose contribution per radionuclide, %. Atmospheric case A

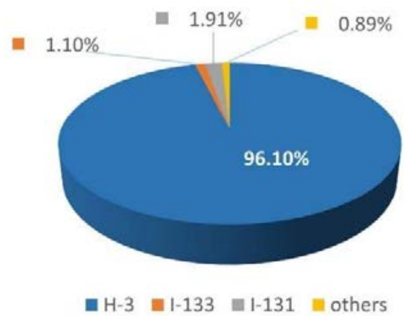

FIG. III-2. Inhalation dose contribution per radionuclide, %. Atmospheric case A

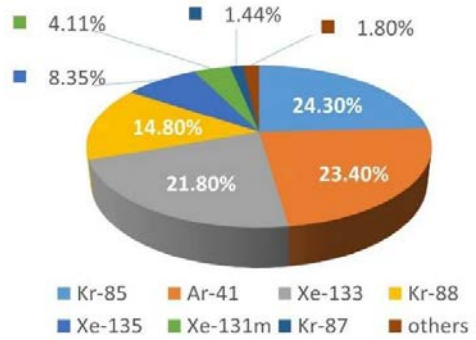

FIG. III-3. Immersion dose contribution per radionuclide, %, Atmospheric case A

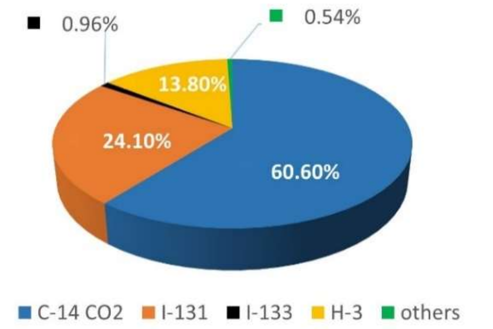

FIG. III-4. Ingestion dose contribution per radionuclide, %, Atmospheric case A

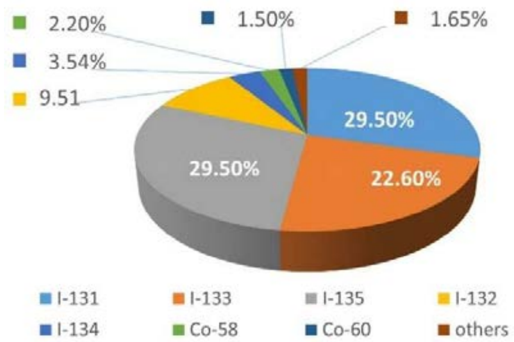

FIG. III-5. Ground deposition contribution per radionuclide, %, Atmospheric case A

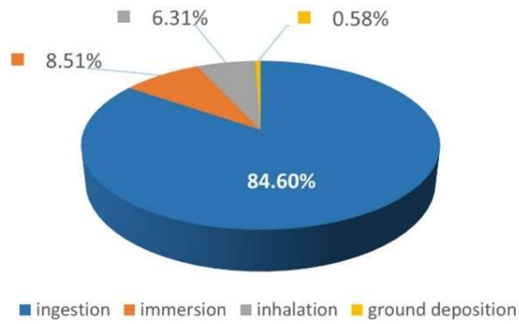

FIG. III-6. Total dose contribution per pathway, %, Atmospheric case A

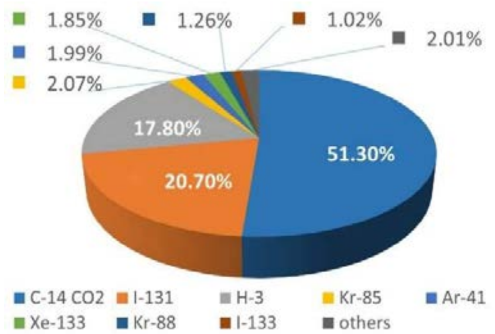

FIG. III-7. Total dose contribution per radionuclide, %. Atmospheric case B

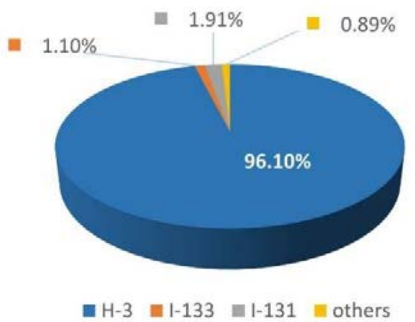

FIG. III-8. Inhalation dose contribution per radionuclide, %. Atmospheric case B

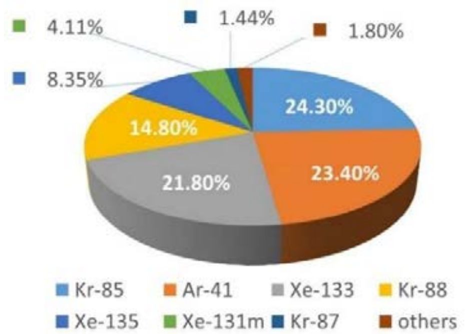

FIG. III-9. Immersion dose contribution per radionuclide, %, Atmospheric case B

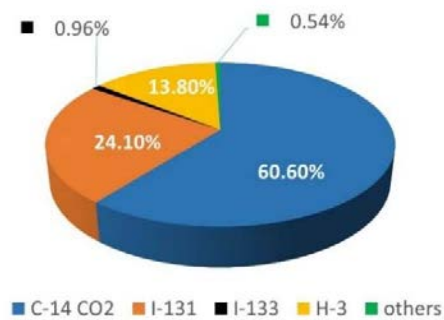

FIG. III-10. Ingestion dose contribution per radionuclide, %, Atmospheric case B

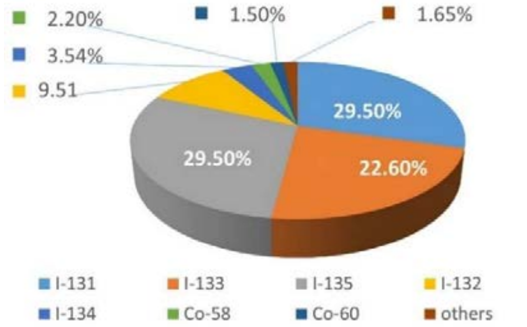

FIG. III-11. Ground deposition contribution per radionuclide, %, Atmospheric case B

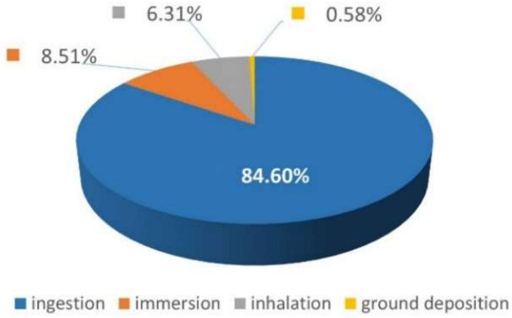

FIG. III-12. Total dose contribution per pathway, %, Atmospheric case B

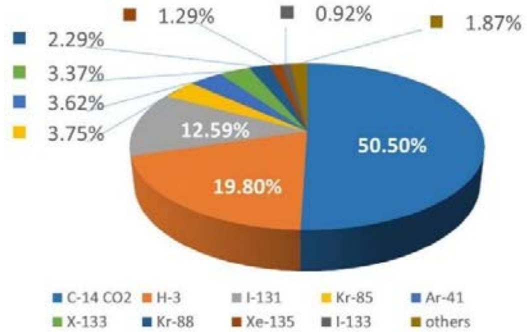

FIG. III-13. Total dose contribution per radionuclide, %. Atmospheric case C

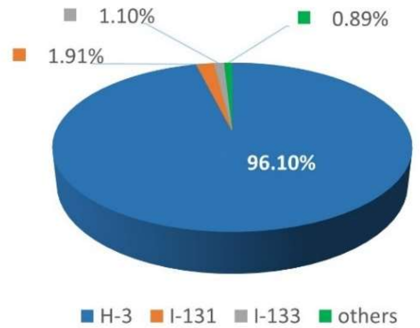

FIG. III-14. Inhalation dose contribution per radionuclide, %. Atmospheric case C

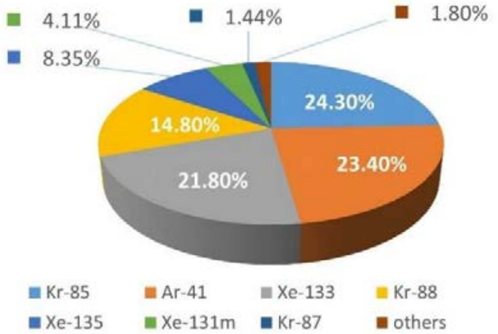

FIG. III-15. Immersion dose contribution per radionuclide, %, Atmospheric case C

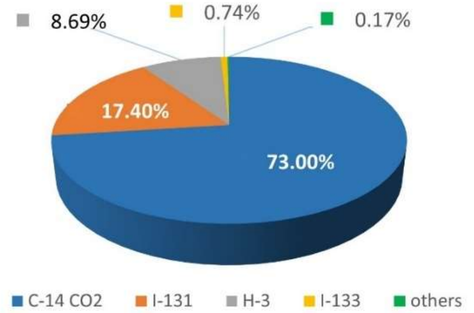

FIG. III-16. Ingestion dose contribution per radionuclide, %, Atmospheric case C

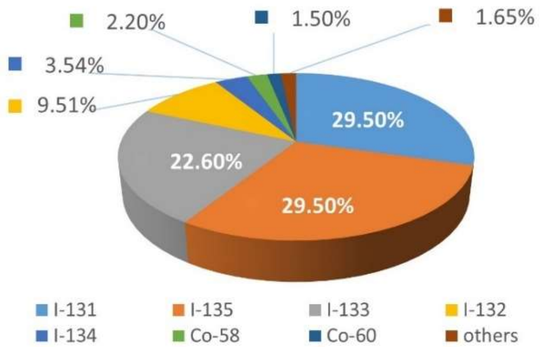

FIG. III-17. Ground deposition contribution per radionuclide, %, Atmospheric case C

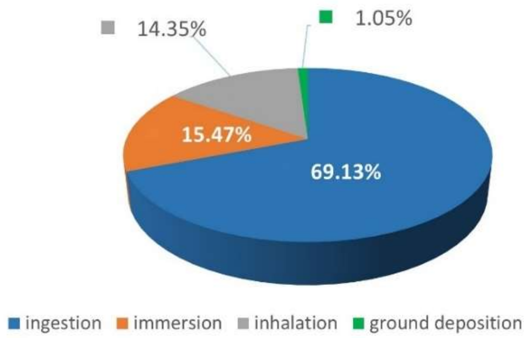

FIG. III-18. Total dose contribution per pathway, %, Atmospheric case C

Table III–11 gives the results of calculations for marine discharges. All 54 radionuclides were considered in the evaluation of the doses for both case A and B. The estimated total annual dose for case A was 4.75E-02 μSv and for case B – 1.54E-02 μSv. The use of site-specific factors resulted in a reduction of dose by about a factor of 3 which can essentially be attributed to the difference in the bioaccumulation factors and, to some extent, to the food consumption rate. The dose contribution from marine fish is less than that of shellfish in both cases, by a factor of about 5 to 12.

TABLE III–11. ANNUAL DOSE FROM MARINE DISCHARGES (μSv/a). MARINE CASES A AND B

Nuclide	Case A			Case B		
	Ingestion of fish	Ingestion of shellfish	Total dose from ingestion	Ingestion of fish	Ingestion of shellfish	Total dose from ingestion
H-3 (HTO)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na-24	9.02E-09	8.12E-09	1.71E-08	2.46E-08	2.46E-08	4.92E-08
P-32	3.57E-04	7.13E-05	4.28E-04	3.25E-05	3.25E-05	6.49E-05
Cr-51	2.51E-06	3.02E-06	5.53E-06	1.37E-06	1.72E-07	1.54E-06
Mn-54	6.04E-05	2.26E-04	2.87E-04	2.06E-05	4.12E-04	4.33E-04
Fe-55	2.73E-04	9.02E-04	1.17E-03	2.49E-05	2.49E-05	4.97E-05
Fe-59	4.31E-04	1.42E-03	1.85E-03	3.92E-05	3.92E-05	7.84E-05
Co-58	3.88E-04	5.82E-04	9.69E-04	1.06E-05	1.06E-04	1.16E-04
Co-60	1.41E-03	2.11E-03	3.52E-03	3.84E-05	3.84E-04	4.23E-04
Ni-63	7.04E-06	4.22E-06	1.13E-05	9.61E-07	1.92E-07	1.15E-06
Zn-65	1.29E-04	1.94E-03	2.07E-03	7.05E-05	1.41E-04	2.12E-04
Br-84	4.20E-11	4.20E-11	8.40E-11	0.00E+00	0.00E+00	0.00E+00
Rb-88	2.15E-10	1.29E-11	2.28E-10	0.00E+00	0.00E+00	0.00E+00
Sr-89	5.89E-08	1.77E-08	7.66E-08	8.04E-09	8.04E-08	8.84E-08
Sr-90	6.47E-08	1.94E-08	8.42E-08	8.84E-09	8.84E-08	9.72E-08
Sr-91	3.01E-09	9.03E-10	3.92E-09	4.11E-10	4.11E-09	4.52E-09
Y-90	2.50E-08	3.74E-07	3.99E-07	3.41E-09	3.41E-07	3.44E-07
Y-91m	1.04E-10	1.56E-09	1.66E-09	1.42E-11	1.42E-09	1.43E-09
Y-91	1.32E-07	1.99E-06	2.12E-06	1.81E-08	1.81E-06	1.82E-06
Y-93	2.52E-07	3.78E-06	4.03E-06	3.44E-08	3.44E-06	3.47E-06
Zr-95	1.05E-06	7.86E-05	7.96E-05	1.43E-06	1.43E-06	2.86E-06
Nb-95	1.25E-06	1.25E-05	1.37E-05	1.13E-06	1.13E-06	2.27E-06
Mo-99	9.79E-07	2.94E-06	3.92E-06	0.00E+00	0.00E+00	0.00E+00
Tc-99m	8.38E-08	8.38E-07	9.22E-07	7.63E-09	7.63E-07	7.70E-07
Ru-103	6.84E-07	2.05E-04	2.06E-04	9.34E-08	5.60E-05	5.61E-05
Ru-106	8.88E-05	2.67E-02	2.67E-02	1.21E-05	7.28E-03	7.29E-03
Rh-103m	1.78E-07	5.35E-07	7.13E-07	0.00E+00	0.00E+00	0.00E+00
Rh-106m	9.45E-05	2.84E-04	3.78E-04	0.00E+00	0.00E+00	0.00E+00
Ag-110	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag-110m	1.66E-04	9.96E-04	1.16E-03	0.00E+00	0.00E+00	0.00E+00
Sb-124	1.19E-05	3.56E-06	1.54E-05	8.09E-06	2.43E-06	1.05E-05
Te-129m	1.07E-06	1.07E-05	1.17E-05	9.70E-06	9.70E-06	1.94E-05
Te-129	7.70E-09	7.70E-08	8.47E-08	7.00E-08	7.00E-08	1.40E-07
Te-131	7.73E-10	7.73E-09	8.51E-09	7.04E-09	7.04E-09	1.41E-08
Te-131m	9.43E-07	9.43E-06	1.04E-05	8.58E-06	8.58E-06	1.72E-05
Te-132	5.59E-06	5.59E-05	6.15E-05	5.09E-05	5.09E-05	1.02E-04
I-131	1.15E-03	3.44E-04	1.49E-03	3.13E-04	3.13E-03	3.45E-03
I-132	4.47E-07	1.34E-07	5.81E-07	1.22E-07	1.22E-06	1.34E-06
I-133	1.13E-04	3.40E-05	1.47E-04	3.09E-05	3.09E-04	3.40E-04
I-134	1.91E-08	5.72E-09	2.48E-08	5.20E-09	5.20E-08	5.72E-08
I-135	9.76E-06	2.93E-06	1.27E-05	2.67E-06	2.67E-05	2.93E-05
Cs-134	1.79E-03	1.61E-04	1.95E-03	2.44E-04	1.46E-03	1.71E-03

TABLE III–11. ANNUAL DOSE FROM MARINE DISCHARGES (µSv/a). MARINE CASES A AND B (cont.)

Nuclide	Case A			Case B		
	Ingestion of fish	Ingestion of shellfish	Total dose from ingestion	Ingestion of fish	Ingestion of shellfish	Total dose from ingestion
Cs-136	1.73E-05	1.56E-06	1.89E-05	2.37E-06	1.42E-05	1.66E-05
Cs-137	1.69E-03	1.52E-04	1.84E-03	2.30E-04	1.38E-04	3.68E-04
Ba-135m	4.24E-16	1.27E-17	4.37E-16	1.16E-16	1.16E-15	1.27E-15
Ba-140	1.86E-05	5.58E-07	1.92E-05	5.08E-06	5.08E-05	5.58E-05
La-140	0.00E+00	0.00E+00	0.00E+00	1.46E-05	4.85E-04	5.00E-04
Ce-141	5.47E-07	1.64E-05	1.70E-05	2.99E-08	2.99E-08	5.98E-08
Ce-143	1.92E-06	5.75E-05	5.94E-05	1.05E-07	1.05E-07	2.09E-07
Ce-144	9.33E-05	2.80E-03	2.89E-03	5.09E-06	5.09E-06	1.02E-05
Pr-143	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pr-144	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
W-187	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Np-239	3.91E-07	4.69E-06	5.08E-06	1.07E-07	1.07E-06	1.17E-06
Total	8.30E-03	3.91E-02	4.75E-02	1.18E-03	1.42E-02	1.54E-02

The radionuclides considered in the marine scenarios were ranked based on their contribution to total adult dose. Only eleven contributed to about 99% of the total dose. Hence, only the top eleven radionuclides were considered in the ranking exercise.

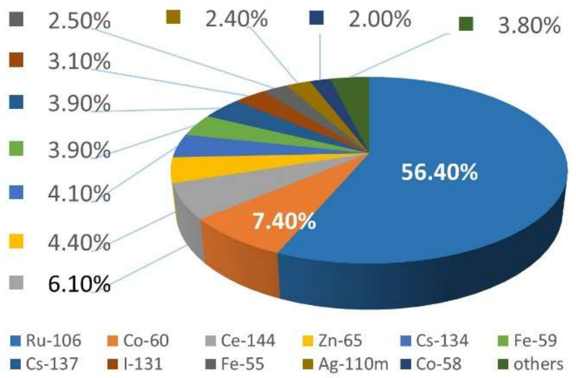

FIG. III-19. Ingestion dose contribution per radionuclide, %, Marine case A.

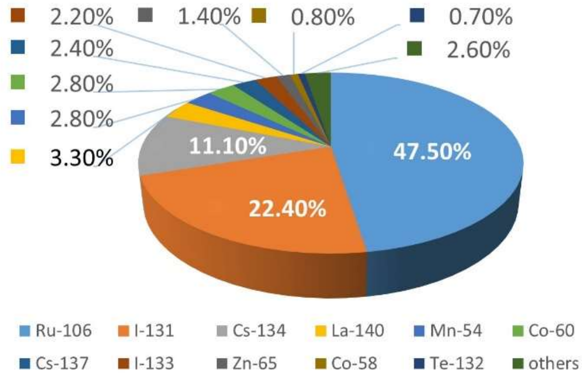

FIG. III-20. Ingestion dose contribution per radionuclide, %, Marine case B.

TABLE III–12. ANNUAL DOSE AND RANKING OF RADIONUCLIDES BASED ON TOTAL DOSE CONTRIBUTION. MARINE DISCHARGE CASES A AND B

Rank	Case A			Case B		
	Nuclide	Dose, µSv/a	Contribution, %	Nuclide	Dose, µSv/a	Contribution, %
1	Ru-106	2.67E-02	56.4	Ru-106	7.29E-03	47.5
2	Co-60	3.52E-03	7.4	I-131	3.45E-03	22.4
3	Ce-144	2.89E-03	6.1	Cs-134	1.71E-03	11.1
4	Zn-65	2.07E-03	4.4	La-140	5.00E-04	3.3
5	Cs-134	1.95E-03	4.1	Mn-54	4.33E-04	2.8
6	Fe-59	1.85E-03	3.9	Co-60	4.23E-04	2.8
7	Cs-137	1.84E-03	3.9	Cs-137	3.68E-04	2.4
8	I-131	1.49E-03	3.1	I-133	3.40E-04	2.2
9	Fe-55	1.17E-03	2.5	Zn-65	2.12E-04	1.4
10	Ag-110m	1.16E-03	2.4	Co-58	1.16E-04	0.8
11	Co-58	9.69E-04	2.0	Te-132	1.02E-04	0.7
	Total	4.75E-02	100.0	Total	1.54E-02	100.0

Table III–12 lists the results of the ranked dose contributions for both cases. Ru-106 was the highest dose contributor in both cases while there was a small change in the ranking order of the other radionuclides.

Table III–13 gives the estimated doses for the riverine discharge scenario cases A and B. Total annual adult dose estimate for case A was 0.1 µSv while for case B – 0.0355 µSv. Amongst 16 radionuclides considered in the riverine scenario, five contributed ca. 95% to the total dose. It should be noted that the consumption rates of freshwater fish were assumed almost equal in the standard data (30 kg/a [III–1]) and in the site-specific case B (27.3 kg/a). Hence, the difference in the dose between case A and case B is essentially due to the differences in the bioaccumulation factors (note the variation in the values for iodine: 40 l/kg based on Indian data [III–2] and 650 l/kg in the case of standardized data set [III–3]).

TABLE III–13. ANNUAL DOSE AND RANKING OF RADIONUCLIDES BASED ON TOTAL DOSE CONTRIBUTION. RIVERINE DISCHARGE CASES A AND B.

Rank	Case A			Case B		
	Nuclide	Dose, µSv/a	Contribution, %	Nuclide	Dose, µSv/a	Contribution, %
1	I-131	3.65E-02	36.4	Cs-137	1.55E-02	43.6
2	Cs-137	2.55E-02	25.4	Cs-134	1.40E-02	39.4
3	Cs-134	2.31E-02	23.0	Zn-65	2.07E-03	5.8
4	Zn-65	1.07E-02	10.7	I-131	2.04E-03	5.8
5	Sr-90	3.48E-03	3.5	Sr-90	1.00E-03	2.8
6	Co-60	4.94E-04	0.5	Co-60	3.37E-04	0.9
7	Ru-106	1.54E-04	0.2	Ru-106	1.40E-04	0.4
8	Ag-110m	7.88E-05	0.1	Zr-95	1.28E-04	0.4
9	Fe-59	7.65E-05	0.1	Ce-144	1.27E-04	0.4
10	Nb-95	5.59E-05	0.1	Nb-95	5.09E-05	0.1
11	Ce-144	5.57E-05	0.1	Fe-59	4.97E-05	0.1
12	Mn-54	5.51E-05	0.1	Mn-54	4.46E-05	0.1
13	Co-58	4.93E-05	0.0	Co-58	3.37E-05	0.1
14	Zr-95	4.46E-05	0.0	Cr-51	8.64E-06	0.0
15	Cr-51	9.49E-06	0.0	Ag-110m	1.30E-06	0.0
16	H-3	0.00E+00	0.0	H-3	0.00E+00	0.0
	Total	1.00E-01		Total	3.55E-02	

In riverine scenario the radionuclides have been ranked based on their proportional contribution to the total adult dose (Table III–13). It is seen from the list that iodine ranked first in case A but is ranked fourth in case B, with a substantial reduction in its contribution to the dose (the percentage reduced from 36% to 6%). This is in line with the changes in transfer factor for this radionuclide, noted above.

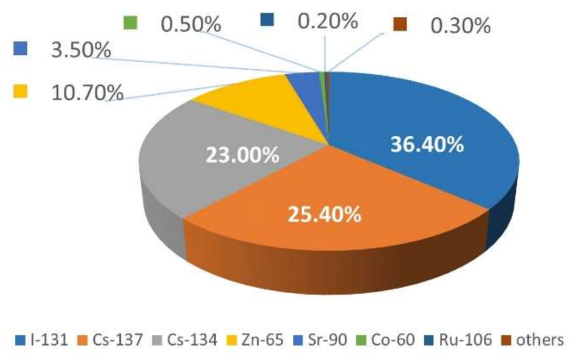

FIG. III-21. Ingestion dose contribution per radionuclide, %, Riverine case A.

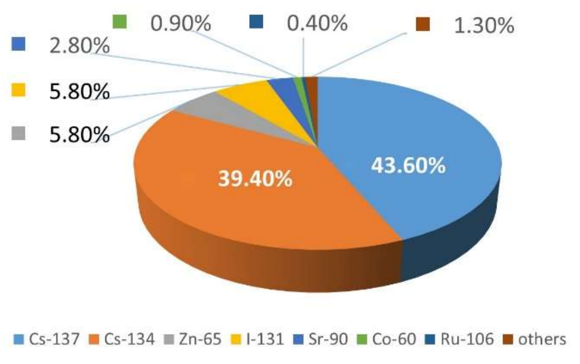

FIG. III-22. Ingestion dose contribution per radionuclide, %, Riverine case B.

Discussions were held among the project participants on the schemes to be adopted for ranking the radionuclides for atmospheric, marine and riverine discharges. A suggestion was also made to group the radionuclides under various percentage bands (ranges) in addition to ranking of the radionuclides based on their contribution to the total dose. Table III–14 provides the ranking for atmospheric cases based on all pathways combined and rankings for the individual atmospheric pathways for each case.

TABLE III–14. RANKING OF RADIONUCLIDES BASED ON CONTRIBUTION TO TOTAL DOSE FROM DIFFERENT PATHWAYS. ATMOSPHERIC CASES A, B AND C.

Rank	Inhalation			Immersion			Ingestion			Ground deposition			All pathways		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
A_{100}	H-3	H-3	H-3												
B_{75}							C-14	C-14	C-14				C-14	C-14	C-14
C_{50}															
D_{33}										I-131 I-135	I-131 I-135	I-131 I-135			
F_{25}				Ar-41 Kr-85 Kr-88 Xe-133	Ar-41 Kr-85 Kr-88 Xe-133	Ar-41 Kr-85 Kr-88 Xe-133	I-131 H-3	I-131 H-3	I-131	I-133	I-133	I-133	I-131 H-3	I-131 H-3	I-131 H-3
G_{10}				Xe-135	Xe-135	Xe-135			H-3	I-132	I-132	I-132			
H_5	I-131 I-133	I-131 I-133	I-131 I-133	Kr-85m Kr-87 Xe-131m	Kr-85m Kr-87 Xe-131m	Kr-85m Kr-87 Xe-131m	I-133	I-133	I-133	I-134 Co-58 Co-60	I-134 Co-58 Co-60	I-134 Co-58 Co-60	Kr-85, Ar-41, Xe-133 Kr-88, I-133, Xe-135	Kr-85, Ar-41, Xe-133 Kr-88, I-133, Xe-135	Kr-85, Ar-41, Xe-133, Kr-88, I-133, Xe-135, Xe-133m

Table III–15 gives the ranking of radionuclides based on the doses estimated for the marine and riverine discharges.

TABLE III–15. RANKING OF RADIONUCLIDES BASED ON CONTRIBUTION TO TOTAL DOSE FROM INGESTION. MARINE AND RIVERINE DISCHARGES

Range	Marine discharges[a]		Riverine discharges[b]	
	Case A	Case B	Case A	Case B
A_{100}				
B_{75}	Ru-106			
C_{50}		Ru-106	I-131, Cs-137	Cs-137, Cs-134
D_{33}			Cs-134, Zn-65	
F_{25}		I-131, Cs-134		
G_{10}	Co-60, Ce-144			Zn-65, I-131
H_5	Zn-65, Cs-134, Fe-59, Cs-137, I-131, Fe-55, Ag-110m, Co-58	La-140, Mn-54, Co-60, Cs-137, I-133, Zn-65, Co-58, Te-132	Sr-90, Co-60	Sr-90, Co-60

a - ingestion of sea fish and shellfish considered
b - ingestion of riverine fish considered

REFERENCES TO ANNEX III

[III–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances, IAEA Safety Reports Series No. 19, IAEA, Vienna (2001).

[III–2] INDIA ATOMIC ENERGY REGULATORY BOARD, Methodologies for Environmental Radiation Dose Assessment, Guide AERB/NF/SG/S-5, AERB, Mumbai (2005).

[III–3] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Fresh Water Environment, Technical Report Series No 472, IAEA, Vienna (2010).

[III–4] HUKOO, R.K., BAPAT, V.N., SHIRVAIKAR, V.V., Manual of Dose Evaluation from Atmospheric Releases, BARC – 1412, Mumbai (1988).

ANNEX IV. INDONESIA

IV–1. DESCRIPTION OF MODELS AND METHODOLOGIES APPLIED

The generic model from SRS-19 [IV–1] was used for the calculations by Indonesia to assess the radiological impact of releases of radioactive substances into the environment. Special considerations of SRS-19 for assessment of dose from discharges of H-3 and C-14 were not used. Some parameters in the SRS-19 model were changed considering updated data from TRS-422 [IV–2] and TRS-472 [IV–3].

All calculations were performed assuming 50 years duration of the normal operational discharge of radioactive material. Annual doses were calculated for adults only.

The most of results in this study are presented to 2 significant digits which may create little uncertainties in summing up of relative contributions to the total dose from different radionuclides and/or different pathways.

IV–2. STRUCTURE OF CONSIDERATION OF PUBLIC EXPOSURES FROM NORMAL OPERATION

In this study the annual radiological doses to an adult from atmospheric discharges were assessed in the three different cases (A, B and C) using the same source term agreed among all participants. Case A uses input data common to all participants; however, the analytical models and methodologies used for calculations could be different. Case B differs from case A due to using Indonesian meteorological data [IV–4]. Case C differs from case A due to using local consumption rates.

Four pathways for human exposure were considered in atmospheric scenarios including the exposure from plume immersion, ground deposition, inhalation and ingestion of contaminated foodstuff (meat, milk, and vegetables).

TABLE IV–1. SITE-SPECIFIC DILUTION VALUES (s/m^3) FROM THE SERPONG RESEARCH REACTOR SITE

Sector	Distance, km									
	0.31	1	2	5	7	10	15	25	35	45
N	5.05E-10	5.05E-08	9.78E-08	7.57E-08	1.04E-07	6.31E-08	3.15E-08	1.86E-08	9.46E-09	5.05E-09
NNE	3.47E-10	2.4E-08	4.73E-08	3.47E-08	3.47E-08	2.11E-08	1.14E-08	6.62E-09	3.47E-09	1.86E-09
NE	2.02E-10	1.61E-08	3.47E-08	2.78E-08	2.55E-08	1.55E-08	8.2E-09	3.78E-09	1.99E-09	1.14E-09
ENE	2.49E-10	1.83E-08	3.78E-08	2.71E-08	2.4E-08	1.48E-08	7.88E-09	3.78E-09	1.96E-09	1.1E-09
E	5.99E-10	3.78E-08	5.99E-08	3.78E-08	2.84E-08	1.73E-08	9.46E-09	4.42E-09	2.24E-09	1.32E-09
ESE	1.32E-09	3.47E-08	4.42E-08	2.59E-08	2.08E-08	1.26E-08	6.62E-09	2.96E-09	1.51E-09	8.83E-10
SE	1.42E-09	3.15E-08	3.47E-08	1.86E-08	1.55E-08	9.15E-09	4.73E-09	2.14E-09	1.1E-09	6.31E-10
SSE	1.61E-09	3.47E-08	3.15E-08	1.8E-08	1.45E-08	8.83E-09	4.73E-09	2.14E-09	1.1E-09	6.31E-10
S	1.92E-09	4.1E-08	4.1E-08	2.33E-08	1.99E-08	1.17E-08	6.31E-09	2.78E-09	1.39E-09	7.88E-10
SSW	2.71E-10	1.48E-08	2.08E-08	1.32E-08	1.1E-08	6.62E-09	3.47E-09	1.67E-09	8.51E-10	4.73E-10
SW	2.87E-10	1.77E-08	2.96E-08	2.11E-08	1.67E-08	1.01E-08	5.36E-09	2.55E-09	1.32E-09	7.57E-10
WSW	1.23E-10	1.17E-08	2.4E-08	1.77E-08	1.7E-08	1.04E-08	5.36E-09	2.81E-09	1.42E-09	7.88E-10
W	1.64E-10	9.46E-09	1.61E-08	1.39E-08	2.11E-08	1.23E-08	5.99E-09	3.12E-09	1.51E-09	7.57E-10
WNW	1.42E-10	7.25E-09	9.78E-09	8.83E-09	1.77E-08	1.01E-08	4.73E-09	2.27E-09	1.04E-09	5.36E-10
NW	1.99E-10	1.01E-08	1.39E-08	1.04E-08	1.73E-08	1.01E-08	4.73E-09	2.3E-09	1.1E-09	5.68E-10
NNW	1.23E-10	1.17E-08	2.74E-08	2.24E-08	2.87E-08	1.7E-08	8.51E-09	4.1E-09	2.08E-09	1.14E-09

Parameters for case A were taken from the SRS-19 [IV–1] with any changes described in the report. Meteorological data were provided by Brazil (see main body of the report). The pre-calculated χ/Q value for case A (10 km distance from the source) is $4.705 \cdot 10^{-8}$ s/m^3.

In the atmospheric case B, site-specific meteorological data from the Serpong multi-purpose 30 MW research reactor (RSG-GAS) were used [IV–4]. Table IV–1 shows dilution values (χ/Q) taken from the Serpong site.

In Table IV–1 maximum dilution value, $1.04 \cdot 10^{-7}$ s/m^3, corresponds to 7 km to the North. The dilution value at 10 km to the North, $6.31 \cdot 10^{-8}$ s/m^3, was used in case B to compare with the same distance for case A. The real stack height of Serpong reactor is 60 m. In case B calculation the stack height was assumed 100 m like in case A; the wind speed correction for this stack height was made accordingly. In this study case B differs from case A only by dilution value ($6.31 \cdot 10^{-8}$ vs $4.705 \cdot 10^{-8}$ s/m^3) yielding shorter transit times and hence less radioactive decays during the transit. Doses in case B are higher but the radionuclide ranking is the same as in case A.

In the atmospheric case C, meteorological data (dilution value $4.705 \cdot 10^{-8}$ s/m^3) and source term are the same as in case A. The consumption rate data for an adult were taken from the data set of the Serpong multi-purpose research reactor site. Consumption rate data are provided in Table IV–2.

TABLE IV–2. ADULT CONSUMPTION RATE DATA. FRESH WEIGHTS. SERPONG RESEARCH REACTOR SITE

Commodity	Consumption, kg per capita per week
Milk[a]	0.00316
Meat	0.29347
Fresh water fish	0.0779
Leafy vegetables	0.33175
Non-leafy vegetables including fruits and grain	2.74559
Root vegetables	0.20855

a – local fresh milk consumption is low. Powdered milk is mostly consumed but it was not considered in this assessment.

In the marine discharge scenarios only the dose from ingestion of contaminated fish and shellfish was considered. Pre-calculated concentrations of radionuclides in the water at 1 km from discharge location were used as input data in marine cases A and B. Country specific data for transfer coefficients for marine discharges were not available for this study. Country specific data for the consumption rate in marine case B have introduced some changes to the doses compared to the marine case A, however they couldn't change the ranking of radionuclides since doses were scaled uniformly for all radionuclides.

In the riverine discharge scenarios only the dose from ingestion of contaminated fish was considered. Pre-calculated concentrations of radionuclides in the water at 1 km from discharge were used for the dose estimations in riverine cases A and B. Country specific or site specific transfer coefficients for riverine discharges were not available for this study. In riverine case A the transfer coefficients and consumption rates were used as agreed among the project participants. In riverine case B the site specific consumption rate of fresh water fish was used.

IV–3. RESULTS OF ASSESSMENT

Calculations were performed for all three atmospheric cases. Tables IV–3, IV-5 and IV-7 provide the annual adult doses in μSv/a from individual radionuclides for each of the pathways for atmospheric cases A, B and C. The total adult doses from all the pathways are 3.6E-02 μSv for case A, 4.9E-02 μSv for case B and 3.53E-02 μSv for case C.

Tables IV–4, IV–6 and IV–8 give the percentage contribution of each radionuclide within each pathway for atmospheric cases A, B and C. Table IV–9 gives the percentage contribution to the total dose from the different pathways. Figures IV–1 to IV–18 help to compare contributions from different radionuclides and different pathways in atmospheric cases A, B and C.

TABLE IV–3. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3	7.8E-03	na	na	na	na	0.0E+00	0.0E+00	7.8E-03
C-14	2.1E-05	na	na	na	na	0.0E+00	0.0E+00	2.1E-05
Ar-41	na	3.6E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.6E-03
Cr-51	1.7E-09	2.6E-10	5.6E-10	2.9E-08	2.3E-07	2.6E-07	2.1E-07	4.7E-07
Mn-54	4.0E-08	4.1E-09	1.7E-09	9.7E-09	5.0E-06	5.0E-06	3.7E-05	4.2E-05
Fe-59	5.2E-08	2.9E-09	7.3E-10	8.7E-08	4.1E-06	4.2E-06	3.6E-06	7.9E-06
Co-57	3.8E-09	na	1.3E-10	1.9E-10	2.1E-07	2.1E-07	na	2.1E-07
Co-58	4.7E-07	4.0E-08	1.9E-08	2.5E-08	3.4E-05	3.4E-05	8.1E-05	1.2E-04
Co-60	1.6E-06	2.7E-08	5.0E-08	7.8E-08	4.9E-05	4.9E-05	1.3E-03	1.3E-03
Kr-85	na	2.2E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-03
Kr-85m	na	7.1E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.1E-05
Kr-87	na	2.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.7E-04
Kr-88	na	1.9E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-03
Sr-89	5.9E-07	1.2E-10	2.7E-07	8.2E-08	3.6E-05	3.6E-05	1.4E-06	3.8E-05
Sr-90	4.7E-06	1.1E-11	9.6E-05	3.8E-05	2.8E-04	4.2E-04	5.8E-05	4.8E-04
Zr-95	2.7E-08	6.1E-10	1.6E-11	1.7E-12	8.9E-07	8.9E-07	2.4E-06	3.3E-06
Nb-95	3.5E-08	2.8E-09	3.8E-12	6.6E-13	1.8E-06	1.8E-06	2.8E-06	4.6E-06
Ru-103	2.4E-08	6.8E-10	4.6E-11	4.7E-09	9.6E-07	9.6E-07	8.0E-07	1.8E-06
Ru-106	2.4E-08	1.6E-11	3.1E-11	4.3E-09	6.7E-07	6.7E-07	2.6E-07	9.5E-07
Ag-110m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-125	3.4E-09	2.2E-11	1.6E-11	2.0E-10	8.5E-08	8.5E-08	6.9E-07	7.7E-07
Xe-131m	na	3.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E-04
Xe-133	na	2.0E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-03
Xe-133m	na	2.2E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-05
Xe-135	na	8.3E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.3E-04
Xe-135m	na	1.3E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-04
Xe-138	na	2.8E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.8E-04
I-131	1.3E-04	1.2E-06	8.4E-04	8.1E-05	1.2E-02	1.3E-02	2.8E-04	1.3E-02
I-132(e)	7.0E-06	3.2E-05	7.1E-10	5.4E-70	3.7E-49	7.1E-10	8.8E-05	1.3E-04
I-133 (e)	7.7E-05	5.8E-06	3.9E-05	4.9E-12	5.2E-08	3.9E-05	1.5E-04	2.7E-04
I-134 (e)	5.4E-06	6.0E-05	1.3E-15	8.5E-173	2.6E-121	1.3E-15	6.3E-05	1.3E-04
I-135 (e)	3.0E-05	2.9E-05	9.0E-07	5.7E-28	2.0E-19	9.0E-07	2.1E-04	2.7E-04
Cs-134	1.5E-07	6.4E-09	3.2E-06	6.0E-06	1.2E-04	1.2E-04	1.2E-04	2.5E-04
Cs-136	1.8E-08	6.2E-09	1.2E-07	8.2E-08	3.1E-06	3.3E-06	2.3E-06	5.7E-06
Cs-137	1.9E-07	4.3E-09	2.6E-05	5.0E-05	1.5E-04	2.3E-04	4.3E-04	6.6E-04
Ba-140	9.9E-09	na	4.4E-10	5.5E-11	3.3E-07	3.3E-07	0.0E+00	3.4E-07
Ce-141	2.3E-08	na	6.9E-11	1.8E-10	4.7E-07	4.7E-07	8.1E-08	5.8E-07
Total	8.0E-03	1.2E-02	1.0E-03	1.8E-04	1.3E-02	1.4E-02	2.8E-03	3.6E-02

TABLE IV–4. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3	9.7E+01	na	na	na	na	0.0E+00	0.0E+00	2.1E+01
C-14	2.6E-01	na	na	na	na	0.0E+00	0.0E+00	5.8E-02
Ar-41	na	3.1E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.8E+00
Cr-51	2.1E-05	2.2E-06	5.5E-05	1.7E-02	1.8E-03	1.9E-03	7.5E-03	1.3E-03
Mn-54	4.9E-04	3.5E-05	1.7E-04	5.5E-03	3.9E-02	3.6E-02	1.3E+00	1.1E-01
Fe-59	6.5E-04	2.5E-05	7.3E-05	5.0E-02	3.2E-02	3.0E-02	1.3E-01	2.2E-02
Co-57	4.7E-05	na	1.2E-05	1.1E-04	1.6E-03	1.5E-03	na	5.8E-04
Co-58	5.8E-03	3.4E-04	1.9E-03	1.4E-02	2.7E-01	2.5E-01	2.9E+00	3.2E-01
Co-60	2.0E-02	2.3E-04	5.0E-03	4.4E-02	3.8E-01	3.5E-01	4.5E+01	3.6E+00
Kr-85	na	1.9E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.9E+00
Kr-85m	na	6.1E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-01
Kr-87	na	2.3E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.5E-01
Kr-88	na	1.6E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.1E+00
Sr-89	7.3E-03	1.1E-06	2.6E-02	4.7E-02	2.8E-01	2.6E-01	5.0E-02	1.0E-01
Sr-90	5.8E-02	9.2E-08	9.5E+00	2.2E+01	2.2E+00	3.0E+00	2.1E+00	1.3E+00
Zr-95	3.4E-04	5.2E-06	1.6E-06	9.7E-07	6.9E-03	6.4E-03	8.6E-02	9.1E-03
Nb-95	4.4E-04	2.4E-05	3.8E-07	3.8E-07	1.4E-02	1.3E-02	1.0E-01	1.3E-02
Ru-103	2.9E-04	5.8E-06	4.6E-06	2.7E-03	7.5E-03	6.9E-03	2.8E-02	4.9E-03
Ru-106	3.0E-04	1.3E-07	3.1E-06	2.4E-03	5.2E-03	4.8E-03	9.1E-03	2.6E-03
Ag-110m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-125	4.2E-05	1.9E-07	1.6E-06	1.2E-04	6.6E-04	6.1E-04	2.4E-02	2.1E-03
Xe-131m	na	3.2E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00
Xe-133	na	1.7E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.4E+00
Xe-133m	na	1.9E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.1E-02
Xe-135	na	7.1E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E+00
Xe-135m	na	1.1E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.5E-01
Xe-138	na	2.4E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.8E-01
I-131	1.6E+00	1.0E-02	8.4E+01	4.6E+01	9.5E+01	9.3E+01	1.0E+01	3.7E+01
I-132(e)	8.7E-02	2.7E-01	7.0E-05	3.1E-64	2.9E-45	5.1E-06	3.1E+00	3.5E-01
I-133 (e)	9.5E-01	4.9E-02	3.9E+00	2.8E-06	4.1E-04	2.8E-01	5.4E+00	7.5E-01
I-134 (e)	6.8E-02	5.2E-01	1.3E-10	4.8E-167	2.0E-117	9.3E-12	2.2E+00	3.5E-01
I-135 (e)	3.7E-01	2.5E-01	8.9E-02	3.2E-22	1.5E-15	6.4E-03	7.5E+00	7.4E-01
Cs-134	1.8E-03	5.5E-05	3.1E-01	3.4E+00	9.0E-01	8.9E-01	4.4E+00	6.8E-01
Cs-136	2.3E-04	5.3E-05	1.2E-02	4.7E-02	2.4E-02	2.4E-02	8.2E-02	1.6E-02
Cs-137	2.4E-03	3.7E-05	2.6E+00	2.9E+01	1.2E+00	1.6E+00	1.5E+01	1.8E+00
Ba-140	1.2E-04	na	4.4E-05	3.1E-05	2.6E-03	2.4E-03	0.0E+00	9.3E-04
Ce-141	2.9E-04	na	6.8E-06	1.0E-04	3.7E-03	3.4E-03	2.9E-03	1.6E-03
Total	2.2E+01	3.2E+01	2.8E+00	4.8E-01	3.5E+01	3.8E+01	7.7E+00	1.0E+02

TABLE IV–5. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3	1.0E-02	na	na	na	na	0.0E+00	0.0E+00	1.0E-02
C-14	2.8E-05	na	na	na	na	0.0E+00	0.0E+00	2.8E-05
Ar-41	na	4.8E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.8E-03
Cr-51	2.2E-09	3.4E-10	7.5E-10	3.9E-08	3.1E-07	3.5E-07	2.8E-07	6.4E-07
Mn-54	5.3E-08	5.5E-09	2.3E-09	1.3E-08	6.6E-06	6.7E-06	4.9E-05	5.6E-05

TABLE IV–5. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Fe-59	7.0E-08	4.0E-09	9.8E-10	1.2E-07	5.5E-06	5.7E-06	4.8E-06	1.1E-05
Co-57	5.1E-09	na	1.7E-10	2.5E-10	2.8E-07	2.8E-07	na	2.8E-07
Co-58	6.3E-07	5.3E-08	2.6E-08	3.3E-08	4.6E-05	4.6E-05	1.1E-04	1.6E-04
Co-60	2.1E-06	3.7E-08	6.7E-08	1.0E-07	6.6E-05	6.6E-05	1.7E-03	1.8E-03
Kr-85	na	2.9E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.9E-03
Kr-85m	na	9.5E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.5E-05
Kr-87	na	3.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E-04
Kr-88	na	2.5E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.5E-03
Sr-89	7.9E-07	1.7E-10	3.6E-07	1.1E-07	4.8E-05	4.9E-05	1.9E-06	5.1E-05
Sr-90	6.3E-06	1.4E-11	1.3E-04	5.1E-05	3.8E-04	5.6E-04	7.7E-05	6.4E-04
Zr-95	3.7E-08	8.1E-10	2.1E-11	2.3E-12	1.2E-06	1.2E-06	3.2E-06	4.4E-06
Nb-95	4.7E-08	3.7E-09	5.1E-12	8.9E-13	2.4E-06	2.4E-06	3.8E-06	6.2E-06
Ru-103	3.2E-08	9.1E-10	6.2E-11	6.3E-09	1.3E-06	1.3E-06	1.1E-06	2.4E-06
Ru-106	3.2E-08	2.1E-11	4.2E-11	5.7E-09	8.9E-07	9.0E-07	3.4E-07	1.3E-06
Ag-110m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-125	4.6E-09	2.9E-11	2.2E-11	2.7E-10	1.1E-07	1.1E-07	9.2E-07	1.0E-06
Xe-131m	na	4.9E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.9E-04
Xe-133	na	2.6E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E-03
Xe-133m	na	3.0E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-05
Xe-135	na	1.1E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-03
Xe-135m	na	1.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-04
Xe-138	na	3.8E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E-04
I-131	1.7E-04	1.6E-06	1.1E-03	1.1E-04	1.6E-02	1.7E-02	3.8E-04	1.8E-02
I-132(e)	9.3E-06	4.3E-05	9.5E-10	7.3E-70	4.9E-49	9.5E-10	1.2E-04	1.7E-04
I-133 (e)	1.0E-04	7.7E-06	5.2E-05	6.6E-12	6.9E-08	5.3E-05	2.0E-04	3.7E-04
I-134 (e)	7.3E-06	8.1E-05	1.7E-15	1.1E-172	3.5E-121	1.7E-15	8.4E-05	1.7E-04
I-135 (e)	4.0E-05	3.8E-05	1.2E-06	7.6E-28	2.6E-19	1.2E-06	2.8E-04	3.6E-04
Cs-134	2.0E-07	8.5E-09	4.2E-06	8.0E-06	1.5E-04	1.7E-04	1.6E-04	3.3E-04
Cs-136	2.5E-08	8.3E-09	1.6E-07	1.1E-07	4.2E-06	4.5E-06	3.1E-06	7.6E-06
Cs-137	2.6E-07	5.8E-09	3.5E-05	6.7E-05	2.1E-04	3.1E-04	5.8E-04	8.8E-04
Ba-140	1.3E-08	na	5.9E-10	7.3E-11	4.4E-07	4.4E-07	0.0E+00	4.6E-07
Ce-141	3.1E-08	na	9.2E-11	2.5E-10	6.3E-07	6.4E-07	1.1E-07	7.7E-07
Total	1.1E-02	1.6E-02	1.4E-03	2.4E-04	1.7E-02	1.9E-02	3.8E-03	4.9E-02

TABLE IV–6. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B.

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3	9.7E+01	na	na	na	na	0.0E+00	0.0E+00	2.4E+01
C-14	2.6E-01	na	na	na	na	0.0E+00	0.0E+00	6.5E-02
Ar-41	na	3.1E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.7E+00
Cr-51	2.1E-05	2.2E-06	5.5E-05	1.7E-02	1.8E-03	6.1E-03	7.5E-03	3.4E-03
Mn-54	4.9E-04	3.5E-05	1.7E-04	5.5E-03	3.9E-02	1.5E-02	1.3E+00	3.3E-01
Fe-59	6.5E-04	2.5E-05	7.3E-05	5.0E-02	3.2E-02	2.7E-02	1.3E-01	3.9E-02
Co-57	4.7E-05		1.2E-05	1.1E-04	1.6E-03	5.8E-04	na	1.6E-04
Co-58	5.8E-03	3.4E-04	1.9E-03	1.4E-02	2.7E-01	9.5E-02	2.9E+00	7.5E-01
Co-60	2.0E-02	2.3E-04	5.0E-03	4.4E-02	3.8E-01	1.4E-01	4.5E+01	1.1E+01
Kr-85	na	1.9E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.6E+00

TABLE IV–6. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Kr-85m	na	6.1E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E-01
Kr-87	na	2.3E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.9E-01
Kr-88	na	1.6E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.0E+00
Sr-89	7.3E-03	1.1E-06	2.6E-02	4.7E-02	2.8E-01	1.2E-01	5.0E-02	4.4E-02
Sr-90	5.8E-02	9.2E-08	9.5E+00	2.2E+01	2.2E+00	1.1E+01	2.1E+00	3.3E+00
Zr-95	3.4E-04	5.2E-06	1.6E-06	9.7E-07	6.9E-03	2.3E-03	8.6E-02	2.2E-02
Nb-95	4.4E-04	2.4E-05	3.8E-07	3.8E-07	1.4E-02	4.6E-03	1.0E-01	2.6E-02
Ru-103	2.9E-04	5.8E-06	4.6E-06	2.7E-03	7.5E-03	3.4E-03	2.8E-02	8.0E-03
Ru-106	3.0E-04	1.3E-07	3.1E-06	2.4E-03	5.2E-03	2.5E-03	9.1E-03	3.0E-03
Ag-110m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-125	4.2E-05	1.9E-07	1.6E-06	1.2E-04	6.6E-04	2.6E-04	2.4E-02	6.2E-03
Xe-131m	na	3.2E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.9E-01
Xe-133	na	1.7E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.2E+00
Xe-133m	na	1.9E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.8E-02
Xe-135	na	7.1E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.8E+00
Xe-135m	na	1.1E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.8E-01
Xe-138	na	2.4E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.1E-01
I-131	1.6E+00	1.0E-02	8.4E+01	4.6E+01	9.5E+01	7.5E+01	1.0E+01	2.2E+01
I-132(e)	8.7E-02	2.7E-01	7.0E-05	3.1E-64	2.9E-45	2.3E-05	3.1E+00	8.7E-01
I-133 (e)	9.5E-01	4.9E-02	3.9E+00	2.8E-06	4.1E-04	1.3E+00	5.4E+00	1.9E+00
I-134 (e)	6.8E-02	5.2E-01	1.3E-10	4.8E-167	2.0E-117	4.3E-11	2.2E+00	7.1E-01
I-135 (e)	3.7E-01	2.5E-01	8.9E-02	3.2E-22	1.5E-15	3.0E-02	7.5E+00	2.0E+00
Cs-134	1.8E-03	5.5E-05	3.1E-01	3.4E+00	9.0E-01	1.5E+00	4.4E+00	1.5E+00
Cs-136	2.3E-04	5.3E-05	1.2E-02	4.7E-02	2.4E-02	2.8E-02	8.2E-02	2.8E-02
Cs-137	2.4E-03	3.7E-05	2.6E+00	2.9E+01	1.2E+00	1.1E+01	1.5E+01	6.5E+00
Ba-140	1.2E-04	na	4.4E-05	3.1E-05	2.6E-03	8.9E-04	0.0E+00	2.5E-04
Ce-141	2.9E-04	na	6.8E-06	1.0E-04	3.7E-03	1.3E-03	2.9E-03	1.1E-03
Total	2.2E+01	3.2E+01	2.8E+00	4.9E-01	3.5E+01	3.9E+01	7.7E+00	1.0E+02

TABLE IV–7. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3	7.76E-03	na	na	na	na	0.00E+00	0.00E+00	7.76E-03
C-14	2.10E-05	na	na	na	na	0.00E+00	0.00E+00	2.10E-05
Ar-41	na	3.57E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.57E-03
Cr-51	1.66E-09	2.57E-10	3.67E-13	4.44E-09	2.32E-07	2.37E-07	2.10E-07	4.49E-07
Mn-54	3.97E-08	4.09E-09	1.14E-12	1.48E-09	4.95E-06	4.96E-06	3.69E-05	4.19E-05
Fe-59	5.21E-08	2.95E-09	4.82E-13	1.33E-08	4.13E-06	4.14E-06	3.59E-06	7.78E-06
Co-57	3.80E-09	na	8.24E-14	2.85E-11	2.06E-07	2.06E-07	na	2.10E-07
Co-58	4.68E-07	3.98E-08	1.26E-11	3.79E-09	3.43E-05	3.43E-05	8.14E-05	1.16E-04
Co-60	1.58E-06	2.73E-08	3.29E-11	1.19E-08	4.91E-05	4.92E-05	1.26E-03	1.31E-03
Kr-85	na	2.17E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E-03
Kr-85m	na	7.12E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.12E-05
Kr-87	na	2.74E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-04
Kr-88	na	1.86E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.86E-03
Sr-89	5.86E-07	1.24E-10	1.74E-10	1.25E-08	3.59E-05	3.60E-05	1.40E-06	3.79E-05
Sr-90	4.67E-06	1.08E-11	6.28E-08	5.82E-06	2.82E-04	2.88E-04	5.77E-05	3.51E-04

TABLE IV–7. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Zr-95	2.74E-08	6.07E-10	1.03E-14	2.61E-13	8.88E-07	8.88E-07	2.40E-06	3.31E-06
Nb-95	3.50E-08	2.78E-09	2.51E-15	1.01E-13	1.76E-06	1.76E-06	2.80E-06	4.60E-06
Ru-103	2.36E-08	6.76E-10	3.06E-14	7.12E-10	9.56E-07	9.57E-07	7.97E-07	1.78E-06
Ru-106	2.39E-08	1.55E-11	2.06E-14	6.49E-10	6.67E-07	6.68E-07	2.56E-07	9.48E-07
Sb-125	3.40E-09	2.19E-11	1.08E-14	3.12E-11	8.49E-08	8.49E-08	6.86E-07	7.74E-07
Xe-131m	na	3.68E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.68E-04
Xe-133	na	1.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.96E-03
Xe-133m	na	2.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.22E-05
Xe-135	na	8.30E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.30E-04
Xe-135m	na	1.29E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.29E-04
Xe-138	na	2.85E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.85E-04
I-131	1.27E-04	1.19E-06	5.54E-07	1.24E-05	1.21E-02	1.21E-02	2.84E-04	1.25E-02
I-132	6.97E-06	3.18E-05	4.65E-13	8.25E-71	3.65E-49	4.65E-13	8.77E-05	1.27E-04
I-133	7.65E-05	5.77E-06	2.57E-08	7.46E-13	5.18E-08	7.76E-08	1.52E-04	2.34E-04
I-134	5.43E-06	6.03E-05	8.55E-19	1.30E-173	2.59E-121	8.55E-19	6.27E-05	1.28E-04
I-135	2.97E-05	2.87E-05	5.89E-10	8.68E-29	1.97E-19	5.89E-10	2.09E-04	2.68E-04
Cs-134	1.47E-07	6.37E-09	2.08E-09	9.09E-07	1.15E-04	1.16E-04	1.23E-04	2.39E-04
Cs-136	1.83E-08	6.19E-09	7.71E-11	1.26E-08	3.12E-06	3.14E-06	2.31E-06	5.47E-06
Cs-137	1.92E-07	4.32E-09	1.72E-08	7.65E-06	1.53E-04	1.61E-04	4.30E-04	5.90E-04
Ba-140	9.91E-09	na	2.89E-13	8.37E-12	3.30E-07	3.30E-07	0.00E+00	3.40E-07
Ce-141	2.29E-08	na	4.53E-14	2.81E-11	4.73E-07	4.74E-07	8.08E-08	5.77E-07
Total	8.03E-03	1.17E-02	6.63E-07	2.68E-05	1.28E-02	1.28E-02	2.80E-03	3.53E-02

TABLE IV–8. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3	9.7E+01	na	na	na	na	0.0E+00	0.0E+00	2.2E+01
C-14	2.6E-01	na	na	na	na	0.0E+00	0.0E+00	5.9E-02
Ar-41	na	3.1E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+01
Cr-51	2.1E-05	2.2E-06	5.5E-05	1.7E-02	1.8E-03	1.9E-03	7.5E-03	1.3E-03
Mn-54	4.9E-04	3.5E-05	1.7E-04	5.5E-03	3.9E-02	3.9E-02	1.3E+00	1.2E-01
Fe-59	6.5E-04	2.5E-05	7.3E-05	5.0E-02	3.2E-02	3.2E-02	1.3E-01	2.2E-02
Co-57	4.7E-05	na	1.2E-05	1.1E-04	1.6E-03	1.6E-03	na	5.9E-04
Co-58	5.8E-03	3.4E-04	1.9E-03	1.4E-02	2.7E-01	2.7E-01	2.9E+00	3.3E-01
Co-60	2.0E-02	2.3E-04	5.0E-03	4.4E-02	3.8E-01	3.8E-01	4.5E+01	3.7E+00
Kr-85	na	1.9E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.1E+00
Kr-85m	na	6.1E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-01
Kr-87	na	2.3E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.8E-01
Kr-88	na	1.6E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.3E+00
Sr-89	7.3E-03	1.1E-06	2.6E-02	4.7E-02	2.8E-01	2.8E-01	5.0E-02	1.1E-01
Sr-90	5.8E-02	9.2E-08	9.5E+00	2.2E+01	2.2E+00	2.3E+00	2.1E+00	9.9E-01
Zr-95	3.4E-04	5.2E-06	1.6E-06	9.7E-07	6.9E-03	6.9E-03	8.6E-02	9.4E-03
Nb-95	4.4E-04	2.4E-05	3.8E-07	3.8E-07	1.4E-02	1.4E-02	1.0E-01	1.3E-02
Ru-103	2.9E-04	5.8E-06	4.6E-06	2.7E-03	7.5E-03	7.5E-03	2.8E-02	5.0E-03
Ru-106	3.0E-04	1.3E-07	3.1E-06	2.4E-03	5.2E-03	5.2E-03	9.1E-03	2.7E-03
Sb-125	4.2E-05	1.9E-07	1.6E-06	1.2E-04	6.6E-04	6.6E-04	2.4E-02	2.2E-03
Xe-131m	na	3.2E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00

TABLE IV–8. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Xe-133	na	1.7E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.6E+00
Xe-133m	na	1.9E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.3E-02
Xe-135	na	7.1E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E+00
Xe-135m	na	1.1E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E-01
Xe-138	na	2.4E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.1E-01
I-131	1.6E+00	1.0E-02	8.4E+01	4.6E+01	9.5E+01	9.5E+01	1.0E+01	3.5E+01
I-132	8.7E-02	2.7E-01	7.0E-05	3.1E-64	2.9E-45	3.6E-09	3.1E+00	3.6E-01
I-133	9.5E-01	4.9E-02	3.9E+00	2.8E-06	4.1E-04	6.1E-04	5.4E+00	6.6E-01
I-134	6.8E-02	5.2E-01	1.3E-10	4.8E-167	2.0E-117	6.7E-15	2.2E+00	3.6E-01
I-135	3.7E-01	2.5E-01	8.9E-02	3.2E-22	1.5E-15	4.6E-06	7.5E+00	7.6E-01
Cs-134	1.8E-03	5.5E-05	3.1E-01	3.4E+00	9.0E-01	9.1E-01	4.4E+00	6.8E-01
Cs-136	2.3E-04	5.3E-05	1.2E-02	4.7E-02	2.4E-02	2.4E-02	8.2E-02	1.5E-02
Cs-137	2.4E-03	3.7E-05	2.6E+00	2.9E+01	1.2E+00	1.3E+00	1.5E+01	1.7E+00
Ba-140	1.2E-04	na	4.4E-05	3.1E-05	2.6E-03	2.6E-03	0.0E+00	9.6E-04
Ce-141	2.9E-04	na	6.8E-06	1.0E-04	3.7E-03	3.7E-03	2.9E-03	1.6E-03
Total	2.3E+01	3.3E+01	1.9E-03	7.6E-02	3.6E+01	3.6E+01	7.9E+00	1.0E+02

TABLE IV–9. ANNUAL DOSE FROM VARIOUS PATHWAYS. ATMOSPHERIC CASES A, B AND C

Pathway	Atmospheric case A		Atmospheric case B		Atmospheric case C	
	Dose, µSv/a	Contrib., %	Dose, µSv/a	Contrib., %	Dose, µSv/a	Contrib., %
Inhalation	8.03E-03	22	1.1E-02	22	8.03E-03	23
Immersion	1.17E-02	32	1.6E-02	32	1.17E-02	33
Ingestion	1.40E-02	38	1.9E-02	39	1.28E-02	36
Ground deposition	2.80E-03	7.7	3.8E-03	7.7	2.80E-03	8
Total	3.65E-02		4.9E-02		3.53E-02	

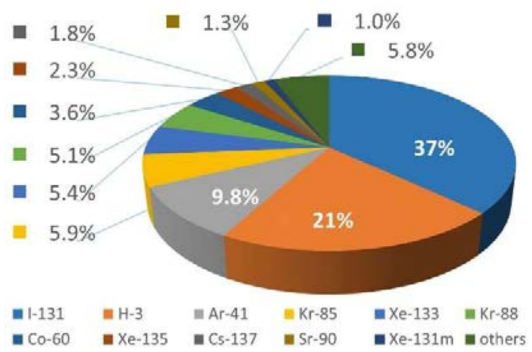

FIG. IV-1. Total dose contribution per radionuclide, %. Atmospheric case A

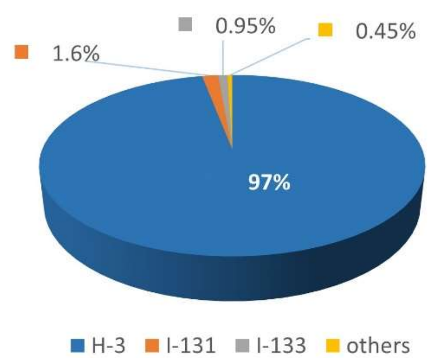

FIG. IV-2. Inhalation dose contribution per radionuclide, %. Atmospheric case A

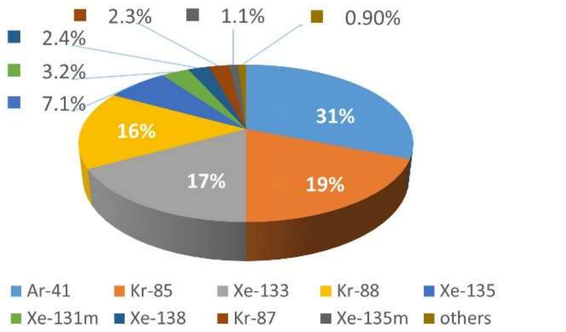

FIG. IV-3. Immersion dose contribution per radionuclide, %, Atmospheric case A

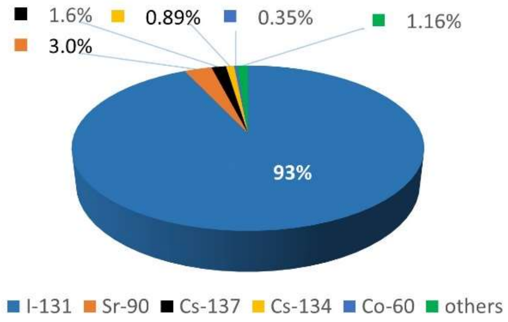

FIG. IV-4. Ingestion dose contribution per radionuclide, %, Atmospheric case A

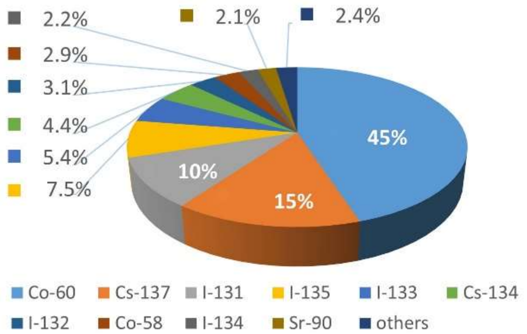

FIG. IV-5. Ground deposition contribution per radionuclide, %, Atmospheric case A

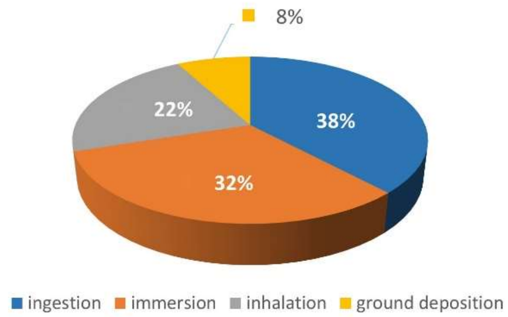

FIG. IV-6. Total dose contribution per pathway, %, Atmospheric case A

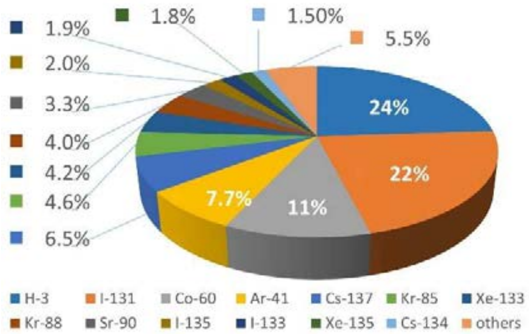

FIG. IV-7. Total dose contribution per radionuclide, %. Atmospheric case B

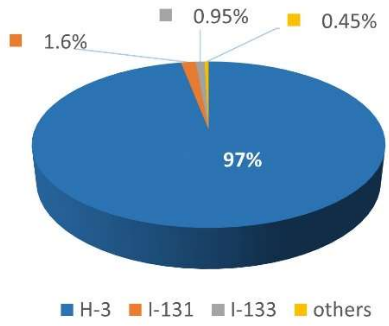

FIG. IV-8. Inhalation dose contribution per radionuclide, %. Atmospheric case B

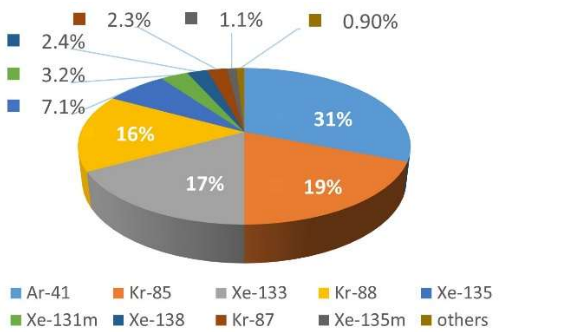

FIG. IV-9. Immersion dose contribution per radionuclide, %, Atmospheric case B

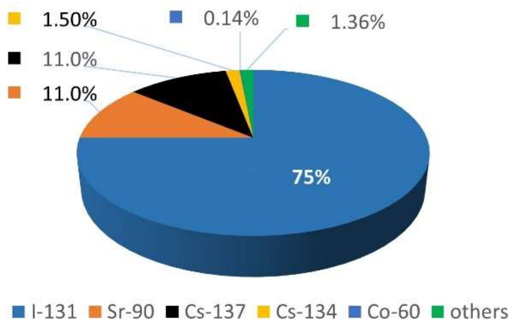

FIG. IV-10. Ingestion dose contribution per radionuclide, %, Atmospheric case B

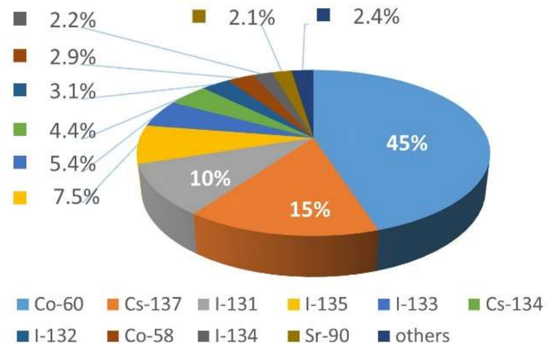

FIG. IV-11. Ground deposition contribution per radionuclide, %, Atmospheric case B

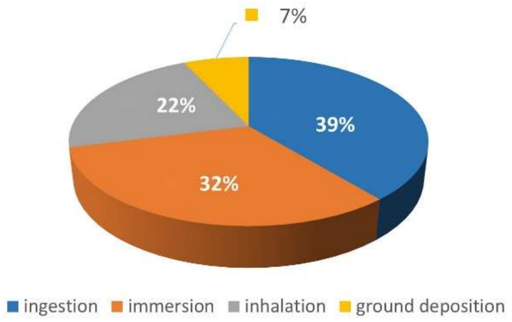

FIG. IV-12. Total dose contribution per pathway, %, Atmospheric case B

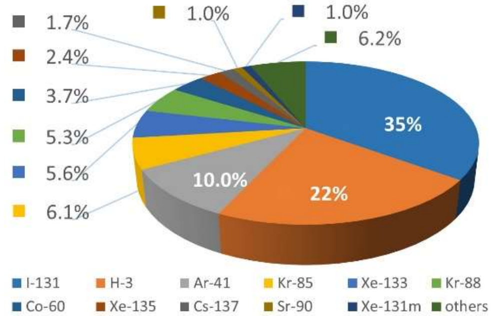

FIG. IV-13. Total dose contribution per radionuclide, %. Atmospheric case C

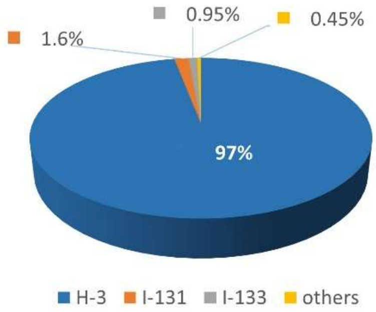

FIG. IV-14. Inhalation dose contribution per radionuclide, %. Atmospheric case C

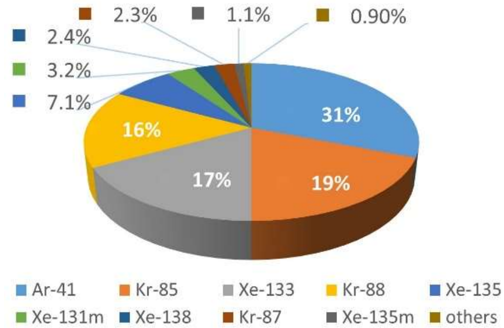

FIG. IV-15. Immersion dose contribution per radionuclide, %, Atmospheric case C

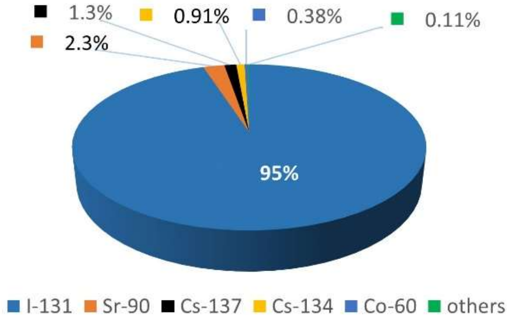

FIG. IV-16. Ingestion dose contribution per radionuclide, %, Atmospheric case C

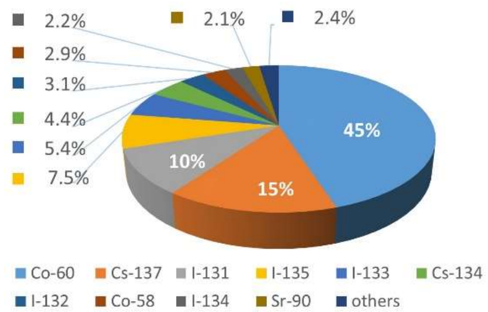

FIG. IV-17. Ground deposition contribution per radionuclide, %, Atmospheric case C

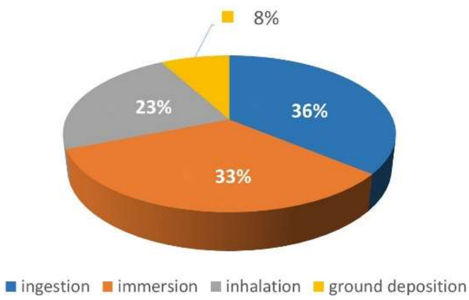

FIG. IV-18. Total dose contribution per pathway, %, Atmospheric case C

Tables IV–10, IV–11 and IV–12 provide the rankings of radionuclides based on the total dose contributed through all pathways in atmospheric cases A, B and C. Table IV–13 provides a comparison of ranking results among atmospheric cases. In all three atmospheric cases, A, B and C, the ingestion of food was the most notable contributor to the doses among all considered pathways. In atmospheric case B, the dilution factor (adapted to match the stack parameters used in case A) is 1.33 higher than in case A which is reflected in the dose results. Total annual dose for all pathways in case B and case A, 0.049 μSv/a and 0.036 μSv/a respectively, differ with a factor of 1.36. This difference is mostly determined by the dilution factor. In atmospheric case C, only the food consumption rates differ from case A. This food consumption rate difference determines the dose difference. Indonesian meat consumption rate is much lower than the rate assumed in case A. The difference in milk consumption is even higher. The contribution of radionuclides from milk to the total dose is 0.001 μSv/a in case A and only 0.00007 μSv/a in case C.

TABLE IV–10. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE A

Rank	Inhalation		Immersion		Ingestion		Ground deposition		All pathways	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.7E+01	Ar-41	3.1E+01	I-131	9.3E+01	Co-60	4.5E+01	I-131	3.7E+01
2	I-131	1.6E+00	Kr-85	1.9E+01	Sr-90	3.0E+00	Cs-137	1.5E+01	H-3	2.1E+01
3	I-133	9.5E-01	Xe-133	1.7E+01	Cs-137	1.6E+00	I-131	1.0E+01	Ar-41	9.8E+00
4	I-135	3.7E-01	Kr-88	1.6E+01	Cs-134	8.9E-01	I-135	7.5E+00	Kr-85	5.9E+00
5	C-14	2.6E-01	Xe-135	7.1E+00	Co-60	3.5E-01	I-133	5.4E+00	Xe-133	5.4E+00
6	I-132	8.7E-02	Xe-131m	3.2E+00	I-133	2.8E-01	Cs-134	4.4E+00	Kr-88	5.1E+00
7	I-134	6.8E-02	Xe-138	2.4E+00	Sr-89	2.6E-01	I-132	3.1E+00	Co-60	3.6E+00
8	Sr-90	5.8E-02	Kr-87	2.3E+00	Co-58	2.5E-01	Co-58	2.9E+00	Xe-135	2.3E+00
9	Co-60	2.0E-02	Xe-135m	1.1E+00	Mn-54	3.6E-02	I-134	2.2E+00	Cs-137	1.8E+00
10	Sr-89	7.3E-03	Kr-85m	6.1E-01	Fe-59	3.0E-02	Sr-90	2.1E+00	Sr-90	1.3E+00
11	Co-58	5.8E-03	I-134	5.2E-01	Cs-136	2.4E-02	Mn-54	1.3E+00	Xe-131m	1.0E+00
12	Cs-137	2.4E-03	I-132	2.7E-01	Nb-95	1.3E-02	Fe-59	1.3E-01	Xe-138	7.8E-01
13	Cs-134	1.8E-03	I-135	2.5E-01	Ru-103	6.9E-03	Nb-95	1.0E-01	Kr-87	7.5E-01
14	Fe-59	6.5E-04	Xe-133m	1.9E-01	I-135	6.4E-03	Zr-95	8.6E-02	I-133	7.5E-01
15	Mn-54	4.9E-04	I-133	4.9E-02	Zr-95	6.4E-03	Cs-136	8.2E-02	I-135	7.4E-01
16	Nb-95	4.4E-04	I-131	1.0E-02	Ru-106	4.8E-03	Sr-89	5.0E-02	Cs-134	6.8E-01
17	Zr-95	3.4E-04	Co-58	3.4E-04	Ce-141	3.4E-03	Ru-103	2.8E-02	Xe-135m	3.5E-01
18	Ru-106	3.0E-04	Co-60	2.3E-04	Ba-140	2.4E-03	Sb-125	2.4E-02	I-134	3.5E-01
19	Ru-103	2.9E-04	Cs-134	5.5E-05	Cr-51	1.9E-03	Ru-106	9.1E-03	I-132	3.5E-01
20	Ce-141	2.9E-04	Cs-136	5.3E-05	Co-57	1.5E-03	Cr-51	7.5E-03	Co-58	3.2E-01
21	Cs-136	2.3E-04	Cs-137	3.7E-05	Sb-125	6.1E-04	Ce-141	2.9E-03	Kr-85m	2.0E-01
22	Ba-140	1.2E-04	Mn-54	3.5E-05	I-132	5.1E-06	Co-57	6.0E-13	Mn-54	1.1E-01
23	Co-57	4.7E-05	Fe-59	2.5E-05	I-134	9.3E-12			Sr-89	1.0E-01
24	Sb-125	4.2E-05	Nb-95	2.4E-05					Xe-133m	6.1E-02
25	Cr-51	2.1E-05	Ru-103	5.8E-06					C-14	5.8E-02
26			Zr-95	5.2E-06					Fe-59	2.2E-02
27			Cr-51	2.2E-06					Cs-136	1.6E-02
28			Sr-89	1.1E-06					Nb-95	1.3E-02
29			Sb-125	1.9E-07					Zr-95	9.1E-03
30			Ru-106	1.3E-07					Ru-103	4.9E-03
31			Sr-90	9.2E-08					Ru-106	2.6E-03
32									Sb-125	2.1E-03
33									Ce-141	1.6E-03
34									Cr-51	1.3E-03
35									Ba-140	9.3E-04
36									Co-57	5.8E-04

TABLE IV–11. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE B

Rank	Inhalation		Immersion		Ingestion		Ground deposition		All pathways	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.7E+01	Ar-41	3.1E+01	I-131	9.3E+01	Co-60	4.5E+01	I-131	3.7E+01
2	I-131	1.6E+00	Kr-85	1.9E+01	Sr-90	3.0E+00	Cs-137	1.5E+01	H-3	2.1E+01
3	I-133	9.5E-01	Xe-133	1.7E+01	Cs-137	1.6E+00	I-131	1.0E+01	Ar-41	9.8E+00
4	I-135	3.7E-01	Kr-88	1.6E+01	Cs-134	8.9E-01	I-135	7.5E+00	Kr-85	5.9E+00
5	C-14	2.6E-01	Xe-135	7.1E+00	Co-60	3.5E-01	I-133	5.4E+00	Xe-133	5.4E+00
6	I-132	8.7E-02	Xe-131m	3.2E+00	I-133	2.8E-01	Cs-134	4.4E+00	Kr-88	5.1E+00
7	I-134	6.8E-02	Xe-138	2.4E+00	Sr-89	2.6E-01	I-132	3.1E+00	Co-60	3.6E+00
8	Sr-90	5.8E-02	Kr-87	2.3E+00	Co-58	2.5E-01	Co-58	2.9E+00	Xe-135	2.3E+00
9	Co-60	2.0E-02	Xe-135m	1.1E+00	Mn-54	3.6E-02	I-134	2.2E+00	Cs-137	1.8E+00
10	Sr-89	7.3E-03	Kr-85m	6.1E-01	Fe-59	3.0E-02	Sr-90	2.1E+00	Sr-90	1.3E+00
11	Co-58	5.8E-03	I-134	5.2E-01	Cs-136	2.4E-02	Mn-54	1.3E+00	Xe-131m	1.0E+00
12	Cs-137	2.4E-03	I-132	2.7E-01	Nb-95	1.3E-02	Fe-59	1.3E-01	Xe-138	7.8E-01
13	Cs-134	1.8E-03	I-135	2.5E-01	Ru-103	6.9E-03	Nb-95	1.0E-01	Kr-87	7.5E-01
14	Fe-59	6.5E-04	Xe-133m	1.9E-01	I-135	6.4E-03	Zr-95	8.6E-02	I-133	7.5E-01
15	Mn-54	4.9E-04	I-133	4.9E-02	Zr-95	6.4E-03	Cs-136	8.2E-02	I-135	7.4E-01
16	Nb-95	4.4E-04	I-131	1.0E-02	Ru-106	4.8E-03	Sr-89	5.0E-02	Cs-134	6.8E-01
17	Zr-95	3.4E-04	Co-58	3.4E-04	Ce-141	3.4E-03	Ru-103	2.8E-02	Xe-135m	3.5E-01
18	Ru-106	3.0E-04	Co-60	2.3E-04	Ba-140	2.4E-03	Sb-125	2.4E-02	I-134	3.5E-01
19	Ru-103	2.9E-04	Cs-134	5.5E-05	Cr-51	1.9E-03	Ru-106	9.1E-03	I-132	3.5E-01
20	Ce-141	2.9E-04	Cs-136	5.3E-05	Co-57	1.5E-03	Cr-51	7.5E-03	Co-58	3.2E-01
21	Cs-136	2.3E-04	Cs-137	3.7E-05	Sb-125	6.1E-04	Ce-141	2.9E-03	Kr-85m	2.0E-01
22	Ba-140	1.2E-04	Mn-54	3.5E-05	I-132	5.1E-06			Mn-54	1.1E-01
23	Co-57	4.7E-05	Fe-59	2.5E-05	I-134	9.3E-12			Sr-89	1.0E-01
24	Sb-125	4.2E-05	Nb-95	2.4E-05					Xe-133m	6.1E-02
25	Cr-51	2.1E-05	Ru-103	5.8E-06					C-14	5.8E-02
26			Zr-95	5.2E-06					Fe-59	2.2E-02
27			Cr-51	2.2E-06					Cs-136	1.6E-02
28			Sr-89	1.1E-06					Nb-95	1.3E-02
29			Sb-125	1.9E-07					Zr-95	9.1E-03
30			Ru-106	1.3E-07					Ru-103	4.9E-03
31			Sr-90	9.2E-08					Ru-106	2.6E-03
32									Sb-125	2.1E-03
33									Ce-141	1.6E-03
34									Cr-51	1.3E-03
35									Ba-140	9.3E-04
36									Co-57	5.8E-04

TABLE IV–12. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C

Rank	Inhalation		Immersion		Ingestion		Ground deposition		All pathways	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.7E+01	Ar-41	3.1E+01	I-131	9.5E+01	Co-60	4.5E+01	I-131	3.5E+01
2	I-131	1.6E+00	Kr-85	1.9E+01	Sr-90	2.3E+00	Cs-137	1.5E+01	H-3	2.2E+01
3	I-133	9.5E-01	Xe-133	1.7E+01	Cs-137	1.3E+00	I-131	1.0E+01	Ar-41	1.0E+01
4	I-135	3.7E-01	Kr-88	1.6E+01	Cs-134	9.1E-01	I-135	7.5E+00	Kr-85	6.1E+00
5	C-14	2.6E-01	Xe-135	7.1E+00	Co-60	3.8E-01	I-133	5.4E+00	Xe-133	5.6E+00
6	I-132	8.7E-02	Xe-131m	3.2E+00	Sr-89	2.8E-01	Cs-134	4.4E+00	Kr-88	5.3E+00

TABLE IV–12. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C (cont.)

Rank	Inhalation		Immersion		Ingestion		Ground deposition		All pathways	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
7	I-134	6.8E-02	Xe-138	2.4E+00	Co-58	2.7E-01	I-132	3.1E+00	Co-60	3.7E+00
8	Sr-90	5.8E-02	Kr-87	2.3E+00	Mn-54	3.9E-02	Co-58	2.9E+00	Xe-135	2.4E+00
9	Co-60	2.0E-02	Xe-135m	1.1E+00	Fe-59	3.2E-02	I-134	2.2E+00	Cs-137	1.7E+00
10	Sr-89	7.3E-03	Kr-85m	6.1E-01	Cs-136	2.4E-02	Sr-90	2.1E+00	Xe-131m	1.0E+00
11	Co-58	5.8E-03	I-134	5.2E-01	Nb-95	1.4E-02	Mn-54	1.3E+00	Sr-90	9.9E-01
12	Cs-137	2.4E-03	I-132	2.7E-01	Ru-103	7.5E-03	Fe-59	1.3E-01	Xe-138	8.1E-01
13	Cs-134	1.8E-03	I-135	2.5E-01	Zr-95	6.9E-03	Nb-95	1.0E-01	Kr-87	7.8E-01
14	Fe-59	6.5E-04	Xe-133m	1.9E-01	Ru-106	5.2E-03	Zr-95	8.6E-02	I-135	7.6E-01
15	Mn-54	4.9E-04	I-133	4.9E-02	Ce-141	3.7E-03	Cs-136	8.2E-02	Cs-134	6.8E-01
16	Nb-95	4.4E-04	I-131	1.0E-02	Ba-140	2.6E-03	Sr-89	5.0E-02	I-133	6.6E-01
17	Zr-95	3.4E-04	Co-58	3.4E-04	Cr-51	1.9E-03	Ru-103	2.8E-02	Xe-135m	3.7E-01
18	Ru-106	3.0E-04	Co-60	2.3E-04	Co-57	1.6E-03	Sb-125	2.4E-02	I-134	3.6E-01
19	Ru-103	2.9E-04	Cs-134	5.5E-05	Sb-125	6.6E-04	Ru-106	9.1E-03	I-132	3.6E-01
20	Ce-141	2.9E-04	Cs-136	5.3E-05	I-133	6.1E-04	Cr-51	7.5E-03	Co-58	3.3E-01
21	Cs-136	2.3E-04	Cs-137	3.7E-05	I-135	4.6E-06	Ce-141	2.9E-03	Kr-85m	2.0E-01
22	Ba-140	1.2E-04	Mn-54	3.5E-05	I-132	3.6E-09			Mn-54	1.2E-01
23	Co-57	4.7E-05	Fe-59	2.5E-05	I-134	6.7E-15			Sr-89	1.1E-01
24	Sb-125	4.2E-05	Nb-95	2.4E-05					Xe-133m	6.3E-02
25	Cr-51	2.1E-05	Ru-103	5.8E-06					C-14	5.9E-02
26			Zr-95	5.2E-06					Fe-59	2.2E-02
27			Cr-51	2.2E-06					Cs-136	1.5E-02
28			Sr-89	1.1E-06					Nb-95	1.3E-02
29			Sb-125	1.9E-07					Zr-95	9.4E-03
30			Ru-106	1.3E-07					Ru-103	5.0E-03
31			Sr-90	9.2E-08					Ru-106	2.7E-03
32									Sb-125	2.2E-03
33									Ce-141	1.6E-03
34									Cr-51	1.3E-03
35									Ba-140	9.6E-04
36									Co-57	5.9E-04

TABLE IV–13. RANKING OF RADIONUCLIDES BASED ON TOTAL ANNUAL DOSE. ATMOSPHERIC CASES A, B AND C

Rank	Atmospheric case A			Atmospheric case B			Atmospheric case C		
	Nuclide[a]	Dose, μSv/a	Contr., %	Nuclide[a]	Dose, μSv/a	Contr., %	Nuclide[a]	Dose, μSv/a	Contr., %
1	I-131	1.3E-02	37	I-131	1.8E-02	37	I-131	1.25E-02	35
2	H-3	7.8E-03	21	H-3	1.0E-02	21	H-3	7.76E-03	22
3	Ar-41	3.6E-03	9.8	Ar-41	4.8E-03	9.8	Ar-41	3.57E-03	10
4	Kr-85	2.2E-03	5.9	Kr-85	2.9E-03	5.9	Kr-85	2.17E-03	6.1
5	Xe-133	2.0E-03	5.4	Xe-133	2.6E-03	5.4	Xe-133	1.96E-03	5.6
6	Kr-88	1.9E-03	5.1	Kr-88	2.5E-03	5.1	Kr-88	1.86E-03	5.3
7	Co-60	1.3E-03	3.6	Co-60	1.8E-03	3.6	Co-60	1.31E-03	3.7
8	Xe-135	8.3E-04	2.3	Xe-135	1.1E-03	2.3	Xe-135	8.30E-04	2.4
9	Cs-137	6.6E-04	1.8	Cs-137	8.8E-04	1.8	Cs-137	5.90E-04	1.7
10	Sr-90	4.8E-04	1.3	Sr-90	6.4E-04	1.3	Xe-131m	3.68E-04	1.0
11	Xe-131m	3.7E-04	1.0	Xe-131m	4.9E-04	1.0			

a – Inhalation is a major pathway for H-3; Ground deposition – for Co-60; Ingestion – for I-131, Cs-137 and Sr-90; Immersion – for Ar-41, Kr-85, Kr-88, Xe-133, Xe-135 and Xe-131m.

TABLE IV–14. ANNUAL DOSE FROM MARINE DISCHARGES (μSv/a). MARINE CASE A

Nuclide	Dose from ingestion of		Total	Nuclide	Dose from ingestion of		Total
	fish	shellfish			fish	shellfish	
H-3	na	na	0.00E+00	Rh-106m	9.45E-05	2.84E-04	3.78E-04
Na-24	9.02E-09	8.12E-09	1.71E-08	Ag-110	na	na	0.00E+00
P-32	3.57E-04	7.13E-05	4.28E-04	Ag-110m	1.66E-04	9.96E-04	1.16E-03
Cr-51	2.51E-06	3.02E-06	5.53E-06	Sb-124	1.19E-05	3.56E-06	1.54E-05
Mn-54	6.04E-05	2.26E-04	2.87E-04	Te-129m	1.07E-06	1.07E-05	1.17E-05
Fe-55	2.73E-04	9.02E-04	1.17E-03	Te-129	7.70E-09	7.70E-08	8.47E-08
Fe-59	4.31E-04	1.42E-03	1.85E-03	Te-131	7.73E-10	7.73E-09	8.51E-09
Co-58	3.88E-04	5.82E-04	9.69E-04	Te-131m	9.43E-07	9.43E-06	1.04E-05
Co-60	1.41E-03	2.11E-03	3.52E-03	Te-132	5.59E-06	5.59E-05	6.15E-05
Ni-63	7.04E-06	4.22E-06	1.13E-05	I-131	1.15E-03	3.44E-04	1.49E-03
Zn-65	1.29E-04	1.94E-03	2.07E-03	I-132	4.47E-07	1.34E-07	5.81E-07
Br-84	4.20E-11	4.20E-11	8.40E-11	I-133	1.13E-04	3.40E-05	1.47E-04
Rb-88	2.15E-10	1.29E-11	2.28E-10	I-134	1.91E-08	5.72E-09	2.48E-08
Sr-89	5.89E-08	1.77E-08	7.66E-08	I-135	9.76E-06	2.93E-06	1.27E-05
Sr-90	6.47E-08	1.94E-08	8.42E-08	Cs-134	1.79E-03	1.61E-04	1.95E-03
Sr-91	3.01E-09	9.03E-10	3.92E-09	Cs-136	1.73E-05	1.56E-06	1.89E-05
Y-90	2.50E-08	3.74E-07	3.99E-07	Cs-137	1.69E-03	1.52E-04	1.84E-03
Y-91m	1.04E-10	1.56E-09	1.66E-09	Ba-135m	4.24E-16	1.27E-17	4.37E-16
Y-91	1.32E-07	1.99E-06	2.12E-06	Ba-140	1.86E-05	5.58E-07	1.92E-05
Y-93	2.52E-07	3.78E-06	4.03E-06	La-140	na	na	0.00E+00
Zr-95	1.05E-06	7.86E-05	7.96E-05	Ce-141	5.47E-07	1.64E-05	1.70E-05
Nb-95	1.25E-06	1.25E-05	1.37E-05	Ce-143	1.92E-06	5.75E-05	5.94E-05
Mo-99	9.79E-07	2.94E-06	3.92E-06	Ce-144	9.33E-05	2.80E-03	2.89E-03
Tc-99m	8.38E-08	8.38E-07	9.22E-07	Pr-143	na	na	0.00E+00
Ru-103	6.84E-07	2.05E-04	2.06E-04	Pr-144	na	na	0.00E+00
Ru-106	8.88E-05	2.67E-02	2.67E-02	W-187	na	na	0.00E+00
Rh-103m	1.78E-07	5.35E-07	7.13E-07	Np-239	3.91E-07	4.69E-06	5.08E-06
				Total	8.30E-03	3.91E-02	4.75E-02

TABLE IV–15. CONTRIBUTION TO DOSE FROM MARINE DISCHARGES. MARINE CASE A

Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
H-3	0.0E+00	Sr-90	1.8E-04	Ag-110	0.0E+00	Cs-136	4.0E-02
Na-24	3.6E-05	Sr-91	8.3E-06	Ag-110m	2.4E+00	Cs-137	3.9E+00
P-32	9.0E-01	Y-90	8.4E-04	Sb-124	3.2E-02	Ba-135m	9.2E-13
Cr-51	1.2E-02	Y-91m	3.5E-06	Te-129m	2.5E-02	Ba-140	4.0E-02
Mn-54	6.0E-01	Y-91	4.5E-03	Te-129	1.8E-04	La-140	0.0E+00
Fe-55	2.5E+00	Y-93	8.5E-03	Te-131	1.8E-05	Ce-141	3.6E-02
Fe-59	3.9E+00	Zr-95	1.7E-01	Te-131m	2.2E-02	Ce-143	1.3E-01
Co-58	2.0E+00	Nb-95	2.9E-02	Te-132	1.3E-01	Ce-144	6.1E+00
Co-60	7.4E+00	Mo-99	8.3E-03	I-131	3.1E+00	Pr-143	0.0E+00
Ni-63	2.4E-02	Tc-99m	1.9E-03	I-132	1.2E-03	Pr-144	0.0E+00
Zn-65	4.4E+00	Ru-103	4.3E-01	I-133	3.1E-01	W-187	0.0E+00
Br-84	1.8E-07	Ru-106	5.6E+01	I-134	5.2E-05	Np-239	1.1E-02
Rb-88	4.8E-07	Rh-103m	1.5E-03	I-135	2.7E-02		
Sr-89	1.6E-04	Rh-106m	8.0E-01	Cs-134	4.1E+00	Total	100

Table IV–14 gives the results of dose calculations (absolute values) and Table IV–15 gives the percentage contribution of each radionuclide for the marine case A. Figure IV–19 illustrates results provided in Table IV–15. Table IV–16 provides the ranking of radionuclides based on their contribution to the total dose in the marine case A. Table IV–17 gives the results of dose calculations (absolute values), percentage contribution of radionuclides and their ranking based on contribution to the total dose in the marine case B.

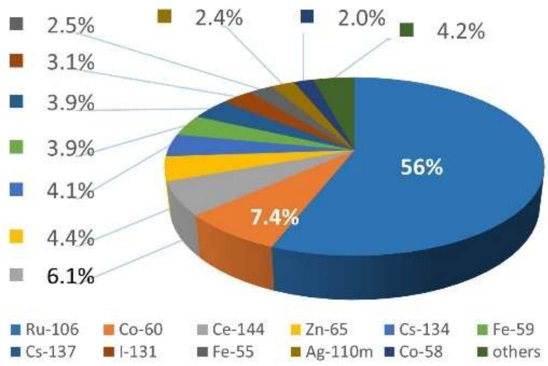

FIG. IV-19. Ingestion dose contribution per radionuclide, %, Marine case A.

Ru-106 provides dominant dose contribution (68% in shellfish) due to the very high bioaccumulation factor of Ru in shellfish (67 times higher than for Cs). At the same time, the proportion of Ru-106 in the discharge is the second largest after H-3.

TABLE IV–16. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, MARINE CASE A

Rank	Ingestion of fish		Ingestion of shellfish		Total ingestion	
	Nuclide	Contribution, %	Nuclide	Contribution, %	Nuclide	Contribution, %
1	Cs-134	2.2E+01	Ru-106	6.8E+01	Ru-106	5.6E+01
2	Cs-137	2.0E+01	Ce-144	7.1E+00	Co-60	7.4E+00
3	Co-60	1.7E+01	Co-60	5.4E+00	Ce-144	6.1E+00
4	I-131	1.4E+01	Zn-65	4.9E+00	Zn-65	4.4E+00
5	Fe-59	5.2E+00	Fe-59	3.6E+00	Cs-134	4.1E+00
6	Co-58	4.7E+00	Ag-110m	2.5E+00	Fe-59	3.9E+00
7	P-32	4.3E+00	Fe-55	2.3E+00	Cs-137	3.9E+00
8	Fe-55	3.3E+00	Co-58	1.5E+00	I-131	3.1E+00
9	Ag-110m	2.0E+00	I-131	8.8E-01	Fe-55	2.5E+00
10	Zn-65	1.6E+00	Rh-106m	7.2E-01	Ag-110m	2.4E+00
11	I-133	1.4E+00	Mn-54	5.8E-01	Co-58	2.0E+00
12	Rh-106m	1.1E+00	Ru-103	5.2E-01	P-32	9.0E-01
13	Ce-144	1.1E+00	Cs-134	4.1E-01	Rh-106m	8.0E-01
14	Ru-106	1.1E+00	Cs-137	3.9E-01	Mn-54	6.0E-01
15	Mn-54	7.3E-01	Zr-95	2.0E-01	Ru-103	4.3E-01
16	Ba-140	2.2E-01	P-32	1.8E-01	I-133	3.1E-01
17	Cs-136	2.1E-01	Ce-143	1.5E-01	Zr-95	1.7E-01
18	Sb-124	1.4E-01	Te-132	1.4E-01	Te-132	1.3E-01
19	I-135	1.2E-01	I-133	8.7E-02	Ce-143	1.3E-01
20	Ni-63	8.5E-02	Ce-141	4.2E-02	Ba-140	4.0E-02
21	Te-132	6.7E-02	Nb-95	3.2E-02	Cs-136	4.0E-02
22	Cr-51	3.0E-02	Te-129m	2.7E-02	Ce-141	3.6E-02
23	Ce-143	2.3E-02	Te-131m	2.4E-02	Sb-124	3.2E-02
24	Nb-95	1.5E-02	Np-239	1.2E-02	Nb-95	2.9E-02
25	Te-129m	1.3E-02	Ni-63	1.1E-02	I-135	2.7E-02
26	Zr-95	1.3E-02	Y-93	9.7E-03	Te-129m	2.5E-02
27	Mo-99	1.2E-02	Sb-124	9.1E-03	Ni-63	2.4E-02

TABLE IV–16. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, MARINE CASE A (cont.)

Rank	Ingestion of fish		Ingestion of shellfish		Total ingestion	
	Nuclide	Contribution, %	Nuclide	Contribution, %	Nuclide	Contribution, %
28	Te-131m	1.1E-02	Cr-51	7.7E-03	Te-131m	2.2E-02
29	Ru-103	8.2E-03	Mo-99	7.5E-03	Cr-51	1.2E-02
30	Ce-141	6.6E-03	I-135	7.5E-03	Np-239	1.1E-02
31	I-132	5.4E-03	Y-91	5.1E-03	Y-93	8.5E-03
32	Np-239	4.7E-03	Cs-136	4.0E-03	Mo-99	8.3E-03
33	Y-93	3.0E-03	Tc-99m	2.1E-03	Y-91	4.5E-03
34	Rh-103m	2.1E-03	Ba-140	1.4E-03	Tc-99m	1.9E-03
35	Y-91	1.6E-03	Rh-103m	1.4E-03	Rh-103m	1.5E-03
36	Tc-99m	1.0E-03	Y-90	9.6E-04	I-132	1.2E-03
37	Sr-90	7.8E-04	I-132	3.4E-04	Y-90	8.4E-04
38	Sr-89	7.1E-04	Te-129	2.0E-04	Te-129	1.8E-04
39	Y-90	3.0E-04	Sr-90	5.0E-05	Sr-90	1.8E-04
40	I-134	2.3E-04	Sr-89	4.5E-05	Sr-89	1.6E-04
41	Na-24	1.1E-04	Na-24	2.1E-05	I-134	5.2E-05
42	Te-129	9.3E-05	Te-131	2.0E-05	Na-24	3.6E-05
43	Sr-91	3.6E-05	I-134	1.5E-05	Te-131	1.8E-05
44	Te-131	9.3E-06	Y-91m	4.0E-06	Sr-91	8.3E-06
45	Rb-88	2.6E-06	Sr-91	2.3E-06	Y-91m	3.5E-06
46	Y-91m	1.2E-06	Br-84	1.1E-07	Rb-88	4.8E-07
47	Br-84	5.1E-07	Rb-88	3.3E-08	Br-84	1.8E-07
48	Ba-135m	5.1E-12	Ba-135m	3.3E-14	Ba-135m	9.2E-13
49	H-3	0.0E+00	H-3	0.0E+00	H-3	0.0E+00
50	Ag-110	0.0E+00	Ag-110	0.0E+00	Ag-110	0.0E+00
51	La-140	0.0E+00	La-140	0.0E+00	La-140	0.0E+00
52	Pr-143	0.0E+00	Pr-143	0.0E+00	Pr-143	0.0E+00
53	Pr-144	0.0E+00	Pr-144	0.0E+00	Pr-144	0.0E+00
54	W-187	0.0E+00	W-187	0.0E+00	W-187	0.0E+00

TABLE IV–17. ANNUAL DOSES FROM INGESTION. MARINE CASE B

Radionuclide	Dose from ingestion of		Total dose, µSv/a	Contribution to total dose, %	Rank
	Fish, µSv/a	Shellfish, µSv/a			
Ru-106	8.9E-05	2.7E-02	2.7E-02	5.6E+01	1
Co-60	1.4E-03	2.1E-03	3.5E-03	7.4E+00	2
Ce-144	9.3E-05	2.8E-03	2.9E-03	6.1E+00	3
Zn-65	1.3E-04	1.9E-03	2.1E-03	4.4E+00	4
Cs-134	1.8E-03	1.6E-04	1.9E-03	4.1E+00	5
Fe-59	4.3E-04	1.4E-03	1.9E-03	3.9E+00	6
Cs-137	1.7E-03	1.5E-04	1.8E-03	3.9E+00	7
I-131	1.1E-03	3.4E-04	1.5E-03	3.1E+00	8
Fe-55	2.7E-04	9.0E-04	1.2E-03	2.5E+00	9
Ag-110m	1.7E-04	1.0E-03	1.2E-03	2.4E+00	10
Co-58	3.9E-04	5.8E-04	9.7E-04	2.0E+00	11
P-32	3.6E-04	7.1E-05	4.3E-04	9.0E-01	12
Rh-106m	9.5E-05	2.8E-04	3.8E-04	8.0E-01	13
Mn-54	6.0E-05	2.3E-04	2.9E-04	6.0E-01	14
Ru-103	6.8E-07	2.1E-04	2.1E-04	4.3E-01	15
Total dose	8.30E-03	3.91E-02	4.75E-02		

Tables IV–18 and IV–19 give the results of dose calculations (absolute values), percentage contribution of radionuclides and their ranking based on contribution to the total dose in the riverine cases A and B. Figures IV–20 and IV–21 illustrate results provided in Table IV–18.

TABLE IV–18. ANNUAL DOSES AND CONTRIBUTIONS TO THE TOTAL DOSE FROM RADIONUCLIDES. RIVERINE CASES A AND B

Radionuclide	Riverine case A		Riverine case B	
	Dose, μSv/a	Contribution, %	Dose, μSv/a	Contribution, %
H-3	0.0E+00	0.0E+00	0.00E+00	0.0E+00
Cr-51	9.5E-06	9.5E-03	1.28E-06	9.5E-03
Mn-54	5.5E-05	5.5E-02	7.45E-06	5.5E-02
Fe-59	7.6E-05	7.6E-02	1.03E-05	7.6E-02
Co-58	4.9E-05	4.9E-02	6.66E-06	4.9E-02
Co-60	4.9E-04	4.9E-01	6.67E-05	4.9E-01
Zn-65	1.1E-02	1.1E+01	1.44E-03	1.1E+01
Sr-90	3.5E-03	3.5E+00	4.70E-04	3.5E+00
Zr-95	4.5E-05	4.4E-02	6.02E-06	4.4E-02
Nb-95	5.6E-05	5.6E-02	7.55E-06	5.6E-02
Ru-106	1.5E-04	1.5E-01	2.08E-05	1.5E-01
Ag-110m	7.9E-05	7.9E-02	1.06E-05	7.9E-02
I-131	3.7E-02	3.6E+01	4.93E-03	3.6E+01
Cs-134	2.3E-02	2.3E+01	3.11E-03	2.3E+01
Cs-137	2.6E-02	2.5E+01	3.45E-03	2.5E+01
Ce-144	5.6E-05	5.6E-02	7.52E-06	5.6E-02
Total	1.0E-01	1.0E+02	1.36E-02	1.0E+02

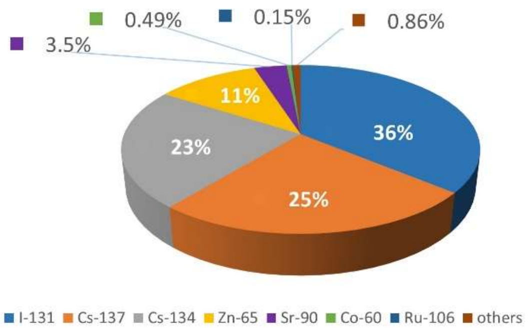

FIG. IV-20. Ingestion dose contribution per radionuclide, %, Riverine case A

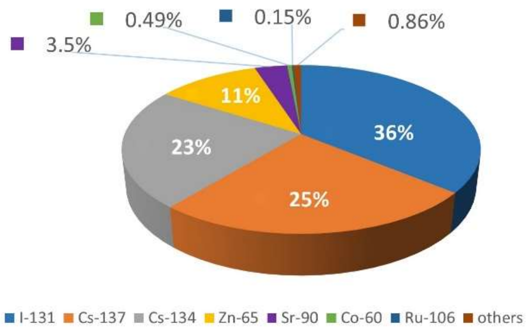

FIG. IV-21. Ingestion dose contribution per radionuclide, %, Riverine case B

In both riverine discharge scenarios, riverine case A and riverine case B, the same parameters were used except the fresh water fish consumption rates. The total annual adult dose changed from 0.10 μSv/a to 0.01 μSv/a as the consumption rate changed from 30 kg/a in riverine case A to ca. 4.1 kg/a in case B. There was no difference in percentage dose contribution of radionuclides between riverine case A and case B.

The radionuclides ranking in these exercises demonstrates that the first five to ten ranked radionuclides usually provide more than 95% of the dose, irrespective of the pathway considered.

TABLE IV–19. RANKING BASED ON TOTAL DOSE CONTRIBUTION. RIVERINE CASES A AND B

Rank	Riverine case A		Riverine case B	
	Radionuclide	Contribution, %	Radionuclide	Contribution, %
1	I-131	3.6E+01	I-131	3.6E+01
2	Cs-137	2.5E+01	Cs-137	2.5E+01
3	Cs-134	2.3E+01	Cs-134	2.3E+01
4	Zn-65	1.1E+01	Zn-65	1.1E+01
5	Sr-90	3.5E+00	Sr-90	3.5E+00
6	Co-60	4.9E-01	Co-60	4.9E-01
7	Ru-106	1.5E-01	Ru-106	1.5E-01
8	Ag-110m	7.9E-02	Ag-110m	7.9E-02
9	Fe-59	7.6E-02	Fe-59	7.6E-02
10	Nb-95	5.6E-02	Nb-95	5.6E-02
11	Ce-144	5.6E-02	Ce-144	5.6E-02
12	Mn-54	5.5E-02	Mn-54	5.5E-02
13	Co-58	4.9E-02	Co-58	4.9E-02
14	Zr-95	4.4E-02	Zr-95	4.4E-02
15	Cr-51	9.5E-03	Cr-51	9.5E-03

REFERENCES TO ANNEX IV

[IV–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment, Safety Reports Series No. 19, IAEA, Vienna (2001).

[IV–2] INTERNATIONAL ATOMIC ENERGY AGENCY, Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment, Technical Reports Series No 422, IAEA, Vienna (2004).

[IV–3] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Fresh Water Environment, Technical Report Series No 472, IAEA, Vienna (2010).

[IV–4] BIRO PUSAT STATISTIK INDONESIA, Pemutakhiran Data Lingkungan Kawasan Nuklir Serpong Radius 5 km, 2000-2004, Tangerang (2005).

ANNEX V. REPUBLIC OF KOREA

V–1. DESCRIPTION OF MODELS AND METHODOLOGIES APPLIED

Korea applies the PWR-GALE code (NUREG-0017) [V–1], a computerized mathematical model, for calculating the releases of radioactive material in gaseous and liquid effluents from pressurized water reactors (PWRs). The method for calculating the radionuclide concentrations for reactor coolant and steam generator fluid in the PWR-GALE code is based on the American National Standard, ANSI/ANS-18.1-1984 [V–2]. The outcomes of these calculations were provided to all the participants as standard input data (case A) for the atmospheric and marine discharge dose assessments.

The code used by Korea to calculate dose was INDAC (Integrated Dose Assessment Code Package for KINS) [V–3]. It was developed by KINS (Korea Institute of Nuclear Safety) in 1999, incorporating the ICRP Publication 60 [V–4] concepts into GASDOS/LIQDOS which was, in turn developed by modifying the food chain model from GASPAR-II/ LADTAP-II in 1989 [V–5, V–6]. The GASPAR-II/ LADTAP-II Codes were developed by the USNRC based on the model in USNRC Regulatory Guide 1.109 [V–7].

The code used to calculate the atmospheric diffusion factor was XOQDOQ, developed by USNRC based on the model in USNRC Regulatory Guide 1.111 [V–8].

For the oceanic dilution factors POM (Princeton Ocean Model) [V–9], a 3-dimensional numerical model developed by Princeton University in USA, was applied. The POM Code was tested and fitted to the near field and far field of the Korean Sea.

V–2. STRUCTURE OF CONSIDERATION OF PUBLIC EXPOSURES FROM NORMAL OPERATION

In this study the annual radiological doses to an adult from atmospheric and marine discharges are estimated. The riverine pathway was not considered as all new NPPs in Korea are located directly on the coast.

Due to default settings in INDAC [V–3], some of the pre-agreed settings for modeling dose were adapted or applied differently by Korea. The foliar interception factors provided in the fixed parameter data set were not applicable in the INDAC Code. Hence, the retention factors from US NRC Regulatory Guide 1.109 [V–7] were used.

Root vegetables are integrated into leafy vegetables in the INDAC code. In the fixed parameter data set the transfer factors are provided for dry weights. The Korean vegetable consumption data were transformed from wet weight to dry weight. Table V–1 provides the consumption rates and dry matter contents considered.

TABLE V–1. ANNUAL ADULT CONSUMPTION RATES FOR VEGETABLES IN INDAC

Vegetables	Consumption, fresh weight, kg/a	Average dry matter content [V–10], %
Leafy and root vegetables	302	7.6
Non-leafy vegetables (including fruits)	108	13.5
Total vegetables	410	

Similarly, the ingestion rate of grass by cow, 16 kg (dry)/day, in INDAC was converted to 80 kg (fresh)/day. This was based on the dry/fresh ratio of pasture being 0.2, from SRS-19 [V–11].

Specific activity models are used in the atmospheric release dose assessments. The participants using SRS-19 approach agreed not to apply the special conditions for tritium and C-14 dose calculations. Tritium dose was calculated only from HTO. The relative deposition factor, D/Q, of 5.446E-10 m^{-2} was derived from the pre-defined χ/Q value of 4.705E-08 s/m^3 with a given deposition velocity of 1000 m/d. Default values used as input parameters for INDAC specific activity models are provided in Table V–2.

TABLE V–2. DEFAULT VALUES USED AS INPUT PARAMETERS FOR INDAC SPECIFIC ACTIVITY MODELS

Factors	Values
Natural carbon fraction of total plant mass	0.11
Concentration of natural carbon in the atmosphere	0.16 g/m^3
Water fraction of total plant mass	0.75
Ratio of H-3 concentration in plant water to that in atmospheric water	0.5
Absolute humidity	8 g/m^3

The following pathways were considered under atmospheric release: internal exposure from inhalation; external exposure from plume immersion; internal exposure from ingestion of contaminated foodstuff (meat, milk and vegetables); and external exposure from ground deposition.

A pre-calculated χ/Q value for the cases A and C (providing dilutions at 10 km distance from the source) is 4.705E-08 s/m^3, based on Brazilian meteorological data. Korean site meteorological data (and corresponding χ/Q value) were used for Case B. Site-specific one year (January to December 2009) meteorological data for Shin-Ulchin NPP located on the East coast of the Korean peninsula were used for this assessment.

TABLE V–3. ATMOSPHERIC DISPERSION FACTORS AND DEPOSITION FACTORS

Atmospheric case	χ/Q, s/m^3	$[\chi/Q]^d$, s/m^3	$[\chi/Q]^{dd}$, s/m^3	D/Q, m^{-2}
A	4.705E-08	4.622E-08	4.622E-08	5.446E-10
B	4.286E-08	4.171E-08	4.112E-08	6.172E-10

The measured wind speed and direction was divided into 9 classes of maxima (0.6, 0.9, 1.5, 3, 5, 8, 11, 15, and 40 m/sec) to provide frequency data as input to the XOQDOQ code [V–12]. The directional distribution of 'Calm' was dealt with by assigning it to the direction of the next, non-calm wind-speed class. The XOQDOQ code was then applied to calculate relative atmospheric dispersion factors, χ/Q (not corrected, and corrected for decay and deposition), and deposition factors, *D/Q* (see Table V–3). Atmospheric dispersion factors and deposition factors (output of XOQDOQ) are used as an input to INDAC for atmospheric case B.

In atmospheric case C the same basic approach as in case A was used. Country specific data for adult breathing rate, 7400 m^3/a, transfer coefficients (Table V–4) and adult consumption data (Table V–5) were applied. The agricultural products, rice and green vegetables (used to make traditional Korean food kimchi) were added to represent the food chain of Korean. Similarly, delay between harvest and consumption (Table V–5) is a default inclusion in the INDAC code. Delay calculations for cases A and B used values from SRS-19, Table VIII [V–11].

In marine case A the INDAC code [V–3] was applied to calculate exposure dose to the public via the marine release pathway using pre-defined fixed input parameters. Ingestion of contaminated fish and shellfish were considered only according to the pre-defined pathway scenario. In marine case B the same methodology and source term were adopted as for case A but using country specific data for bioaccumulation factors (Table V–6) and consumption rates (Table V–7). The ingestion pathway of seaweed was also added, as a typical food chain of Korea.

TABLE V–4. TRANSFER COEFFICIENTS. WET WEIGHT (FROM INDAC LIBRARIES [V–3])

Element	Rice	Fruit	Kimchi	Vegetables	Milk	Beef	Pork	Poultry
H	4.80E+00	4.80E+00	4.80E+00	4.80E+00	1.00E-02	1.20E-02	1.20E-02	1.20E-02
Be	4.20E-04	4.20E-04	4.20E-04	4.20E-04	1.00E-04	1.00E-03	1.00E-03	1.00E-03
C	5.50E+00	5.50E+00	5.50E+00	5.50E+00	1.20E-02	3.10E-02	3.10E-02	3.10E-02
N	7.50E+00	7.50E+00	7.50E+00	7.50E+00	2.20E-02	7.70E-02	7.70E-02	7.70E-02
O	1.60E+00	1.60E+00	1.60E+00	1.60E+00	2.00E-02	1.60E-02	1.60E-02	1.60E-02
F	6.50E-04	6.50E-04	6.50E-04	6.50E-04	1.40E-02	1.50E-01	1.50E-01	1.50E-01
Ne	1.40E-01	1.40E-01	1.40E-01	1.40E-01	2.00E-02	2.00E-02	2.00E-02	2.00E-02
Na	5.00E-02	5.00E-02	5.00E-02	5.00E-02	3.80E-02	5.00E-02	1.00E-01	1.00E-02
Mg	1.30E-01	1.30E-01	1.30E-01	1.30E-01	1.00E-02	5.00E-03	5.00E-03	5.00E-03
Al	1.80E-04	1.80E-04	1.80E-04	1.80E-04	5.00E-04	1.50E-03	1.50E-03	1.50E-03
Si	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.00E-04	4.00E-05	4.00E-05	4.00E-05
P	1.10E+00	1.10E+00	1.10E+00	1.10E+00	1.90E-02	5.40E-01	5.40E-01	1.90E-01
S	5.90E-01	5.90E-01	5.90E-01	5.90E-01	1.80E-02	1.00E-01	1.00E-01	1.00E-01
Cl	5.00E+00	5.00E+00	5.00E+00	5.00E+00	5.00E-02	8.00E-02	8.00E-02	8.00E-02
Ar	6.00E-01	6.00E-01	6.00E-01	6.00E-01	2.00E-02	2.00E-02	2.00E-02	2.00E-02
K	3.70E-01	3.70E-01	3.70E-01	3.70E-01	1.00E-02	1.20E-02	1.20E-02	1.20E-02

TABLE V–5. ADULT CONSUMPTION RATES AND TIMING FOR KOREA

Food	Adult consumption rate, kg/a FW	Time from harvest to consumption, days
Grains	188.5	14
Vegetables (leafy and root)	126.7	1
Kimchi (additional vegetables)	97.9	1
Fruit	66.3	14
Milk	63.0	1
Beef	20.7	7
Pork	12.4	7
Poultry	22.0	3

TABLE V–6. SEAFOOD BIOACCUMULATION FACTORS, l/kg WET WEIGHT (FROM INDAC LIBRARIES [V–3])

Element	Fish	Shellfish	Algae
H	9.00E-01	9.30E-01	9.30E-01
C	1.80E+03	1.40E+03	1.80E+03
Cr	4.00E+02	2.00E+03	2.00E+03
P	2.90E+04	3.00E+04	3.00E+03
Mn	6.00E+02	1.00E+04	2.00E+04
Fe	3.00E+03	2.00E+04	5.00E+04
Co	1.00E+02	2.00E+03	1.00E+03
Zn	2.00E+03	1.00E+05	1.00E+03
Rb	8.30E+00	1.70E+01	1.70E+01
Sr	5.00E-01	6.30E+00	1.30E+01
Nb	3.00E+04	1.00E+02	5.00E+02
Ag	3.30E+03	3.30E+03	2.00E+02
Te	1.00E+01	1.00E+05	1.00E+03
I	1.00E+01	5.00E+01	4.00E+03
Ru	1.00E+01	2.00E+03	2.00E+03

TABLE V–7. ADULT SEAFOOD CONSUMPTION RATES AND TIMING FOR KOREA

Food	Adult consumption rate, kg/a WW	Time from harvest to consumption, days
Fish	79.3	1
Shellfish	17.6	1
Seaweed (Algae)	15.8	1

V–3. RESULTS OF ASSESSMENT

Tables V–8, V-10 and V-12 provide the annual adult doses for atmospheric cases A, B and C from every considered pathway and from specific radionuclides. The total annual adult doses from all pathways in case A are 1.40E-01 μSv/a, B – 9.55E-02 μSv/a, in C – 1.73E-01 μSv/a.

TABLE V–8. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	1.15E-02	0.00E+00	8.35E-03	2.75E-03	1.63E-02	2.74E-02	0.00E+00	3.89E-02
C-14 CO2	2.07E-05	0.00E+00	1.98E-02	2.92E-02	2.26E-02	7.16E-02	0.00E+00	7.16E-02
Ar-41	0.00E+00	1.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.47E-03
Cr-51	1.64E-09	1.79E-10	2.89E-09	1.47E-07	1.32E-07	2.82E-07	2.10E-07	4.94E-07
Mn-54	3.92E-08	2.86E-09	4.23E-09	1.68E-08	2.88E-06	2.90E-06	3.69E-05	3.98E-05
Fe-59	5.14E-08	2.06E-09	3.62E-09	3.69E-07	2.34E-06	2.71E-06	3.59E-06	6.35E-06
Co-57	3.72E-05	0.00E+00	4.61E-06	4.89E-06	1.17E-03	1.18E-03	5.97E-03	7.19E-03
Co-58	4.62E-07	2.79E-08	8.66E-08	8.86E-08	1.95E-05	1.97E-05	8.13E-05	1.01E-04
Co-60	1.56E-06	1.92E-08	1.15E-07	1.23E-07	2.97E-05	2.99E-05	1.26E-03	1.29E-03
Kr-85	0.00E+00	1.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-03
Kr-85m	0.00E+00	4.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.02E-05
Kr-87	0.00E+00	8.97E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.97E-05
Kr-88	0.00E+00	9.25E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.25E-04
Sr-89	5.78E-07	8.65E-11	1.15E-06	2.96E-07	2.05E-05	2.19E-05	1.42E-06	2.39E-05
Sr-90	4.61E-06	7.54E-12	1.78E-05	4.89E-06	3.11E-04	3.34E-04	1.30E-04	4.68E-04
Zr-95	2.70E-08	4.25E-10	7.43E-11	6.45E-12	5.04E-07	5.04E-07	2.40E-06	2.93E-06
Nb-95	3.45E-08	1.94E-09	1.94E-11	3.06E-12	1.00E-06	1.00E-06	2.81E-06	3.85E-06
Ru-103	2.33E-08	4.72E-10	2.33E-10	2.06E-08	5.43E-07	5.64E-07	7.99E-07	1.39E-06
Ru-106	2.36E-08	1.08E-11	1.27E-10	1.21E-08	3.81E-07	3.93E-07	2.53E-07	6.70E-07
Sb-125	3.36E-09	1.53E-11	6.33E-11	5.48E-10	4.82E-08	4.88E-08	6.89E-07	7.41E-07
I-131	1.26E-04	8.26E-07	4.29E-03	9.52E-04	6.84E-03	1.21E-02	2.83E-04	1.25E-02
I-132	4.55E-06	1.46E-05	2.84E-12	1.92E-28	0.00E+00	2.84E-12	5.77E-05	7.69E-05
I-133	7.26E-05	3.85E-06	9.71E-05	6.08E-07	2.79E-08	9.77E-05	1.44E-04	3.18E-04
I-134	1.79E-06	1.40E-05	4.03E-23	0.00E+00	0.00E+00	4.03E-23	2.09E-05	3.66E-05
I-135	2.55E-05	1.74E-05	4.07E-07	4.78E-13	1.20E-19	4.07E-07	1.81E-04	2.25E-04
Xe-131m	0.00E+00	2.57E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.57E-04
Xe-133	0.00E+00	1.36E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-03
Xe-133m	0.00E+00	1.52E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-05
Xe-135	0.00E+00	5.23E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.23E-04
Xe-135m	0.00E+00	2.04E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E-06
Xe-138	0.00E+00	3.35E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.35E-06
Cs-134	1.45E-07	4.46E-09	1.06E-05	1.38E-05	6.59E-05	9.03E-05	1.41E-04	2.31E-04
Cs-136	1.81E-08	4.33E-09	6.11E-07	6.16E-07	1.75E-06	2.98E-06	2.30E-06	5.30E-06
Cs-137	1.90E-07	3.03E-09	1.57E-05	2.07E-05	9.47E-05	1.31E-04	9.69E-04	1.10E-03
Ba-140	1.11E-08	0.00E+00	2.30E-09	4.21E-10	1.86E-07	1.89E-07	0.00E+00	2.00E-07
Ce-141	2.26E-08	0.00E+00	3.52E-10	8.70E-10	3.64E-07	3.65E-07	8.07E-08	4.69E-07
Total Dose	1.18E-02	6.26E-03	3.26E-02	3.29E-02	4.75E-02	1.13E-01	9.29E-03	1.40E-01

Tables V–9, V–11 and V–13 provide the relative contributions of radionuclides to the dose from a given pathway in atmospheric cases A, B and C. Table V–14 summarize doses and relative contributions to the total dose from the different pathways in all atmospheric cases. Figures V–1 to V–18 help to compare contributions from different radionuclides and different pathways in atmospheric cases A, B and C.

TABLE V–9. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3(HTO)	97.49	-	25.62	8.35	34.34	24.25	-	29.68
C-14(CO2)	0.18	-	60.76	88.62	47.62	63.36	-	54.65
Ar-41	-	23.50	-	-	-	-	-	1.12
Cr-51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mn-54	0.00	0.00	0.00	0.00	0.01	0.00	0.40	0.00
Fe-59	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Co-57	0.32	-	0.01	0.01	2.47	1.04	64.25	0.93
Co-58	0.00	0.00	0.00	0.00	0.04	0.02	0.87	0.02
Co-60	0.01	0.00	0.00	0.00	0.06	0.03	13.59	0.03
Kr-85	-	24.30	-	-	-	-	-	1.16
Kr-85m	-	0.64	-	-	-	-	-	0.03
Kr-87	-	1.43	-	-	-	-	-	0.07
Kr-88	-	14.79	-	-	-	-	-	0.71
Sr-89	0.00	0.00	0.00	0.00	0.04	0.02	0.02	0.02
Sr-90	0.04	0.00	0.05	0.01	0.66	0.30	1.40	0.26
Zr-95	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Nb-95	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Ru-103	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Ru-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sb-125	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
I-131	1.07	0.01	13.16	2.89	14.41	10.69	3.04	9.32
I-132	0.04	0.23	0.00	0.00	-	0.00	0.62	0.01
I-133	0.62	0.06	0.30	0.00	0.00	0.09	1.55	0.13
I-134	0.02	0.22	0.00	-	-	0.00	0.22	0.01
I-135	0.22	0.28	0.00	0.00	0.00	0.00	1.95	0.03
Xe-131m	-	4.11	-	-	-	-	-	0.20
Xe-133	-	21.74	-	-	-	-	-	1.04
Xe-133m	-	0.24	-	-	-	-	-	0.01
Xe-135	-	8.36	-	-	-	-	-	0.40
Xe-135m	-	0.03	-	-	-	-	-	0.00
Xe-138	-	0.05	-	-	-	-	-	0.00
Cs-134	0.00	0.00	0.03	0.04	0.14	0.08	1.52	0.07
Cs-136	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Cs-137	0.00	0.00	0.05	0.06	0.20	0.12	10.42	0.10
Ba-140	0.00	-	0.00	0.00	0.00	0.00	-	0.00
Ce-141	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
Total dose	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE V–10. TOTAL ANNUAL DOSE, μSv/a. ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	1.03E-02	0.00E+00	5.05E-03	2.42E-03	1.33E-02	2.08E-02	0.00E+00	3.11E-02
C-14 CO2	1.85E-05	0.00E+00	9.02E-03	1.33E-02	1.03E-02	3.26E-02	0.00E+00	3.26E-02
Ar-41	0.00E+00	1.02E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-03
Cr-51	1.46E-09	1.63E-10	3.36E-09	1.75E-07	1.49E-07	3.27E-07	2.37E-07	5.66E-07
Mn-54	3.49E-08	2.61E-09	4.80E-09	2.69E-08	3.26E-06	3.29E-06	4.17E-05	4.50E-05
Fe-59	4.59E-08	1.88E-09	4.17E-09	4.96E-07	2.65E-06	3.15E-06	4.06E-06	7.26E-06
Co-57	3.31E-05	0.00E+00	5.24E-06	7.80E-06	1.33E-03	1.34E-03	6.76E-03	8.13E-03
Co-58	4.12E-07	2.54E-08	9.91E-08	1.29E-07	2.21E-05	2.23E-05	9.21E-05	1.15E-04
Co-60	1.39E-06	1.75E-08	1.30E-07	2.02E-07	3.37E-05	3.40E-05	1.43E-03	1.46E-03
Kr-85	0.00E+00	1.38E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-03
Kr-85m	0.00E+00	3.27E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.27E-05
Kr-87	0.00E+00	5.47E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.47E-05
Kr-88	0.00E+00	7.05E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.05E-04
Sr-89	5.16E-07	7.88E-11	1.32E-06	4.08E-07	2.33E-05	2.50E-05	1.60E-06	2.71E-05
Sr-90	4.11E-06	6.87E-12	2.01E-05	8.05E-06	3.53E-04	3.81E-04	1.47E-04	5.32E-04
Zr-95	2.41E-08	3.87E-10	8.51E-11	9.23E-12	5.71E-07	5.71E-07	2.71E-06	3.31E-06
Nb-95	3.07E-08	1.77E-09	2.24E-11	3.90E-12	1.13E-06	1.13E-06	3.19E-06	4.35E-06
Ru-103	2.08E-08	4.30E-10	2.69E-10	2.70E-08	6.15E-07	6.42E-07	9.04E-07	1.57E-06
Ru-106	2.10E-08	9.88E-12	1.44E-10	1.95E-08	4.32E-07	4.52E-07	2.86E-07	7.58E-07
Sb-125	2.99E-09	1.40E-11	7.17E-11	8.95E-10	5.47E-08	5.57E-08	7.80E-07	8.39E-07
I-131	1.13E-04	7.51E-07	5.30E-03	5.12E-04	7.73E-03	1.35E-02	3.20E-04	1.40E-02
I-132	3.29E-06	1.07E-05	4.52E-09	0.00E+00	0.00E+00	4.52E-09	5.24E-05	6.64E-05
I-133	6.38E-05	3.42E-06	2.45E-04	3.07E-11	3.08E-08	2.45E-04	1.60E-04	4.72E-04
I-134	9.03E-07	7.13E-06	8.38E-15	0.00E+00	0.00E+00	8.38E-15	1.32E-05	2.12E-05
I-135	2.13E-05	1.46E-05	5.74E-06	4.96E-27	1.26E-19	5.74E-06	1.91E-04	2.33E-04
Xe-131m	0.00E+00	2.34E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.34E-04
Xe-133	0.00E+00	1.24E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-03
Xe-133m	0.00E+00	1.37E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E-05
Xe-135	0.00E+00	4.50E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.50E-04
Xe-135m	0.00E+00	2.52E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.52E-07
Xe-138	0.00E+00	3.52E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.52E-07
Cs-134	1.30E-07	4.06E-09	1.20E-05	2.25E-05	7.46E-05	1.09E-04	1.60E-04	2.69E-04
Cs-136	1.61E-08	3.93E-09	7.30E-07	5.11E-07	1.98E-06	3.22E-06	2.60E-06	5.84E-06
Cs-137	1.69E-07	2.76E-09	1.78E-05	3.40E-05	1.07E-04	1.59E-04	1.10E-03	1.26E-03
Ba-140	9.87E-09	0.00E+00	2.75E-09	3.41E-10	2.10E-07	2.13E-07	0.00E+00	2.23E-07
Ce-141	2.01E-08	0.00E+00	4.08E-10	1.09E-09	4.13E-07	4.14E-07	9.14E-08	5.26E-07
Total dose	1.06E-02	5.17E-03	1.97E-02	1.63E-02	3.33E-02	6.93E-02	1.05E-02	9.55E-02

TABLE V–11. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	97.53	-	25.66	14.84	39.96	29.98	-	36.55
C-14 CO2	0.18	-	45.84	81.56	30.94	47.09	-	38.39
Ar-41	-	19.74	-	-	-	-	-	1.20
Cr-51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mn-54	0.00	0.00	0.00	0.00	0.01	0.00	0.40	0.00
Fe-59	0.00	0.00	0.00	0.00	0.01	0.00	0.04	0.00

TABLE V–11. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Co-57	0.31	-	0.03	0.05	4.00	1.94	64.49	1.63
Co-58	0.00	0.00	0.00	0.00	0.07	0.03	0.88	0.03
Co-60	0.01	0.00	0.00	0.00	0.10	0.05	13.63	0.04
Kr-85	-	26.71	-	-	-	-	-	1.62
Kr-85m	-	0.63	-	-	-	-	-	0.04
Kr-87	-	1.06	-	-	-	-	-	0.06
Kr-88	-	13.64	-	-	-	-	-	0.83
Sr-89	0.00	0.00	0.01	0.00	0.07	0.04	0.02	0.03
Sr-90	0.04	0.00	0.10	0.05	1.06	0.55	1.40	0.45
Zr-95	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Nb-95	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Ru-103	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Ru-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sb-125	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
I-131	1.07	0.01	26.93	3.14	23.22	19.55	3.05	16.06
I-132	0.03	0.21	0.00	-	-	0.00	0.50	0.02
I-133	0.60	0.07	1.25	0.00	0.00	0.35	1.53	0.37
I-134	0.01	0.14	0.00	-	-	0.00	0.13	0.01
I-135	0.20	0.28	0.03	0.00	0.00	0.01	1.83	0.05
Xe-131m	-	4.53	-	-	-	-	-	0.28
Xe-133	-	24.00	-	-	-	-	-	1.46
Xe-133m	-	0.27	-	-	-	-	-	0.02
Xe-135	-	8.71	-	-	-	-	-	0.53
Xe-135m	-	0.00	-	-	-	-	-	0.00
Xe-138	-	0.01	-	-	-	-	-	0.00
Cs-134	0.00	0.00	0.06	0.14	0.22	0.16	1.53	0.13
Cs-136	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00
Cs-137	0.00	0.00	0.09	0.21	0.32	0.23	10.47	0.19
Ba-140	0.00	-	0.00	0.00	0.00	0.00	-	0.00
Ce-141	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
Total dose	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE V–12. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	1.01E-02	0.00E+00	2.10E-03	5.99E-04	1.87E-02	2.14E-02	0.00E+00	3.15E-02
C-14 CO2	1.82E-05	0.00E+00	4.98E-03	1.50E-02	1.03E-01	1.23E-01	0.00E+00	1.23E-01
Ar-41	0.00E+00	1.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.47E-03
Cr-51	1.45E-09	1.79E-10	3.80E-09	3.82E-10	8.34E-08	8.76E-08	1.47E-07	2.36E-07
Mn-54	3.45E-08	2.86E-09	5.18E-09	4.26E-08	2.02E-06	2.07E-06	2.58E-05	2.79E-05
Fe-59	4.53E-08	2.06E-09	5.78E-09	1.28E-07	1.44E-06	1.57E-06	2.51E-06	4.13E-06
Co-57	3.27E-05	0.00E+00	2.24E-05	3.32E-06	7.03E-04	7.29E-04	4.18E-03	4.94E-03
Co-58	4.07E-07	2.79E-08	4.04E-07	5.72E-08	1.19E-05	1.24E-05	5.69E-05	6.97E-05
Co-60	1.38E-06	1.92E-08	5.17E-07	7.92E-08	1.77E-05	1.83E-05	8.22E-04	8.42E-04
Kr-85	0.00E+00	1.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-03
Kr-85m	0.00E+00	4.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.02E-05
Kr-87	0.00E+00	8.97E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.97E-05

TABLE V–12. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Kr-88	0.00E+00	9.25E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.25E-04
Sr-89	5.09E-07	8.65E-11	2.93E-07	2.80E-08	1.47E-05	1.50E-05	9.91E-07	1.65E-05
Sr-90	4.06E-06	7.54E-12	1.35E-05	1.24E-06	9.50E-04	9.65E-04	4.95E-05	1.02E-03
Zr-95	2.38E-08	4.25E-10	6.15E-09	6.96E-10	3.06E-07	3.13E-07	1.68E-06	2.02E-06
Nb-95	3.04E-08	1.94E-09	1.64E-07	1.45E-09	6.25E-07	7.90E-07	1.97E-06	2.79E-06
Ru-103	2.05E-08	4.72E-10	4.90E-12	1.65E-09	3.38E-07	3.40E-07	5.59E-07	9.20E-07
Ru-106	2.08E-08	1.08E-11	2.92E-12	1.10E-09	2.38E-07	2.39E-07	1.77E-07	4.37E-07
Sb-125	2.96E-09	1.53E-11	8.36E-10	5.16E-10	3.04E-08	3.18E-08	4.79E-07	5.14E-07
I-131	1.11E-04	8.26E-07	8.98E-04	3.10E-04	2.93E-03	4.14E-03	9.92E-05	4.35E-03
I-132	4.01E-06	1.46E-05	5.83E-13	5.94E-29	7.85E-10	7.86E-10	2.02E-05	3.88E-05
I-133	6.39E-05	3.85E-06	2.00E-05	1.88E-07	6.19E-05	8.21E-05	5.07E-05	2.01E-04
I-134	1.58E-06	1.40E-05	8.28E-24	0.00E+00	7.37E-16	7.37E-16	7.29E-06	2.29E-05
I-135	2.24E-05	1.74E-05	8.36E-08	1.48E-13	1.31E-06	1.39E-06	6.36E-05	1.05E-04
Xe-131m	0.00E+00	2.57E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.57E-04
Xe-133	0.00E+00	1.36E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-03
Xe-133m	0.00E+00	1.52E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-05
Xe-135	0.00E+00	5.23E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.23E-04
Xe-135m	0.00E+00	2.04E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E-06
Xe-138	0.00E+00	3.35E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.35E-06
Cs-134	1.28E-07	4.46E-09	6.33E-06	7.46E-06	4.38E-05	5.76E-05	9.85E-05	1.56E-04
Cs-136	1.59E-08	4.33E-09	2.91E-07	2.25E-07	1.25E-06	1.77E-06	1.61E-06	3.40E-06
Cs-137	1.67E-07	3.03E-09	9.82E-06	1.22E-05	8.48E-05	1.07E-04	3.66E-04	4.73E-04
Ba-140	9.77E-09	0.00E+00	1.36E-09	4.07E-10	1.33E-07	1.35E-07	0.00E+00	1.45E-07
Ce-141	1.99E-08	0.00E+00	1.51E-10	1.13E-09	2.28E-07	2.29E-07	5.65E-08	3.06E-07
Total dose	1.04E-02	6.26E-03	8.05E-03	1.59E-02	1.27E-01	1.51E-01	5.85E-03	1.73E-01

TABLE V–13. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
H-3 HTO	97.48	-	26.08	3.76	14.78	14.22	-	18.85
C-14 CO2	0.18	-	61.85	94.14	81.41	81.71	-	73.59
Ar-41	-	23.50	-	-	-	-	-	0.88
Cr-51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mn-54	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00
Fe-59	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Co-57	0.32	-	0.28	0.02	0.56	0.48	71.45	0.46
Co-58	0.00	0.00	0.01	0.00	0.01	0.01	0.97	0.01
Co-60	0.01	0.00	0.01	0.00	0.01	0.01	14.05	0.01
Kr-85	-	24.30	-	-	-	-	-	0.91
Kr-85m	-	0.64	-	-	-	-	-	0.02
Kr-87	-	1.43	-	-	-	-	-	0.05
Kr-88	-	14.79	-	-	-	-	-	0.55
Sr-89	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01
Sr-90	0.04	0.00	0.17	0.01	0.75	0.64	0.85	0.58
Zr-95	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Nb-95	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Ru-103	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

TABLE V–13. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	Deposition	Total dose
			Milk	Meat	Vegetables			
Ru-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sb-125	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
I-131	1.07	0.01	11.15	1.95	2.32	2.75	1.70	2.54
I-132	0.04	0.23	0.00	0.00	0.00	0.00	0.35	0.01
I-133	0.62	0.06	0.25	0.00	0.05	0.05	0.87	0.09
I-134	0.02	0.22	0.00	-	0.00	0.00	0.12	0.01
I-135	0.22	0.28	0.00	0.00	0.00	0.00	1.09	0.02
Xe-131m	-	4.11	-	-	-	-	-	0.15
Xe-133	-	21.74	-	-	-	-	-	0.81
Xe-133m	-	0.24	-	-	-	-	-	0.01
Xe-135	-	8.36	-	-	-	-	-	0.31
Xe-135m	-	0.03	-	-	-	-	-	0.00
Xe-138	-	0.05	-	-	-	-	-	0.00
Cs-134	0.00	0.00	0.08	0.05	0.03	0.04	1.68	0.03
Cs-136	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Cs-137	0.00	0.00	0.12	0.08	0.07	0.07	6.26	0.06
Ba-140	0.00	-	0.00	0.00	0.00	0.00	-	0.00
Ce-141	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00
Total dose	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE V–14. ANNUAL DOSE FROM VARIOUS PATHWAYS. ATMOSPHERIC CASES A, B AND C

Pathway	Atmospheric case A		Atmospheric case B		Atmospheric case C	
	Dose, µSv/a	Contrib., %	Dose, µSv/a	Contrib., %	Dose, µSv/a	Contrib., %
Inhalation	1.18E-02	8.41	1.06E-02	11.06	1.04E-02	5.99
Immersion	6.26E-03	4.46	5.17E-03	5.41	6.26E-03	3.62
Ingestion	1.13E-01	80.52	6.93E-02	72.55	1.51E-01	87.01
Ground deposition	9.29E-03	6.62	1.05E-02	10.97	5.85E-03	3.38
Total	1.40E-01		9.55E-02		1.73E-01	

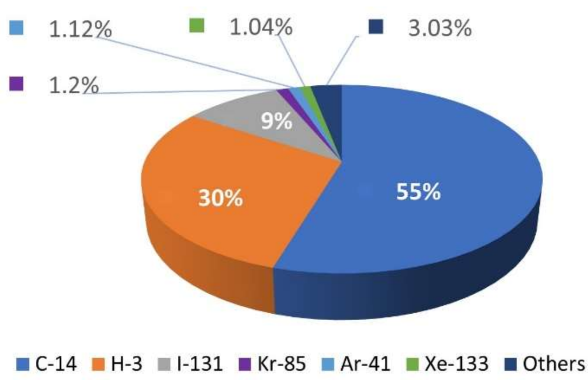

FIG. V–1. Total dose contribution per radionuclide, %. Atmospheric case A

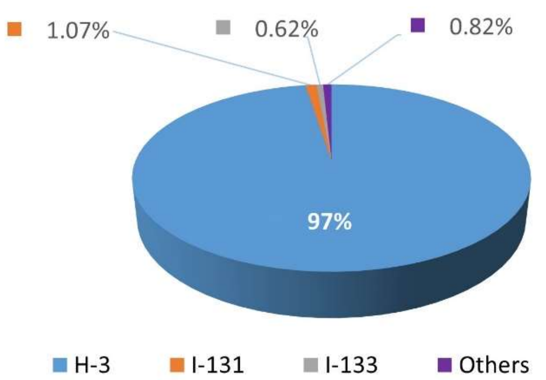

FIG. V–2. Inhalation dose contribution per radionuclide, %. Atmospheric case A

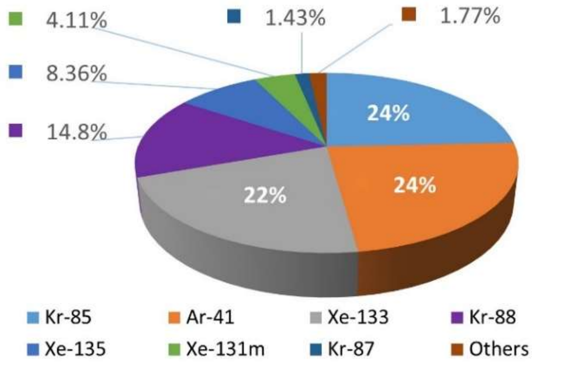

FIG. V–3. Immersion dose contribution per radionuclide, %, Atmospheric case A

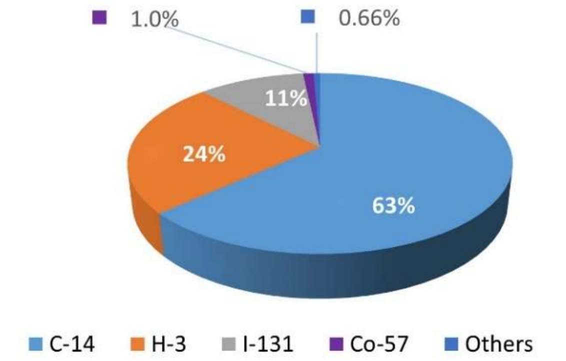

FIG. V–4. Ingestion dose contribution per radionuclide, %, Atmospheric case A

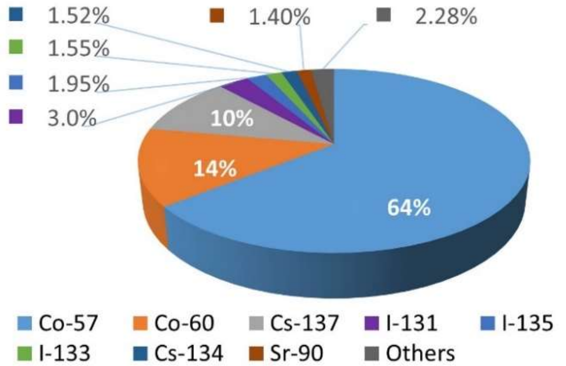

FIG. V–5. Ground deposition contribution per radionuclide, %, Atmospheric case A

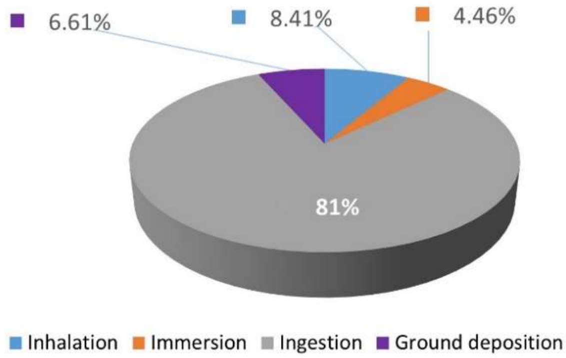

FIG. V–6. Total dose contribution per pathway, %, Atmospheric case A

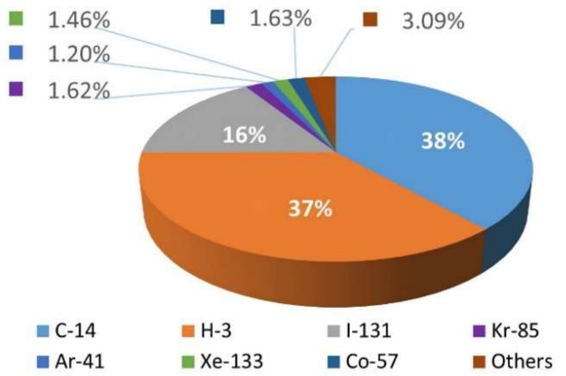

FIG. V–7. Total dose contribution per radionuclide, %. Atmospheric case B

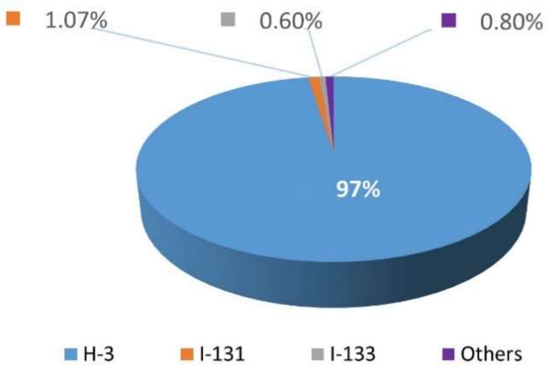

FIG. V–8. Inhalation dose contribution per radionuclide, %. Atmospheric case B

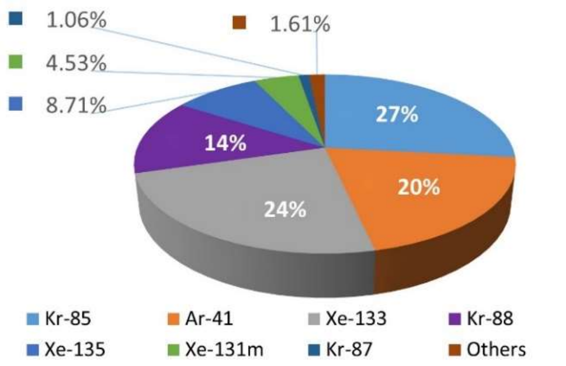

FIG. V–9. Immersion dose contribution per radionuclide, %, Atmospheric case B

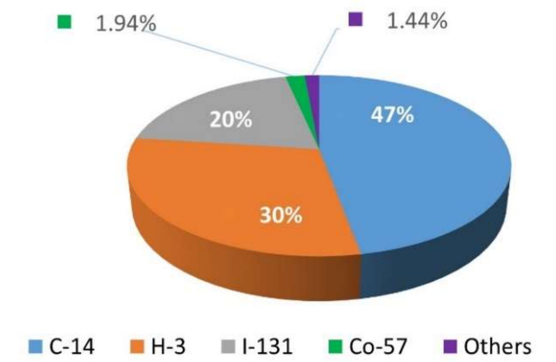

FIG. V–10. Ingestion dose contribution per radionuclide, %, Atmospheric case B

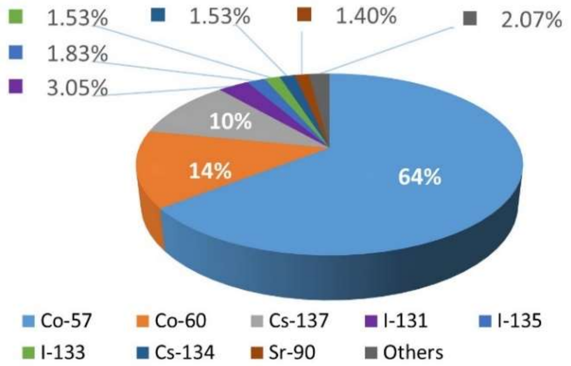

FIG. V–11. Ground deposition contribution per radionuclide, %, Atmospheric case B

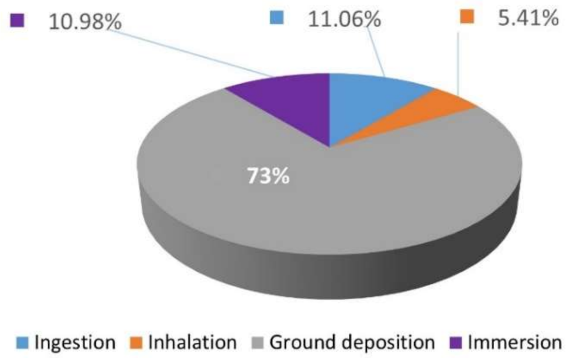

FIG. V–12. Total dose contribution per pathway, %, Atmospheric case B

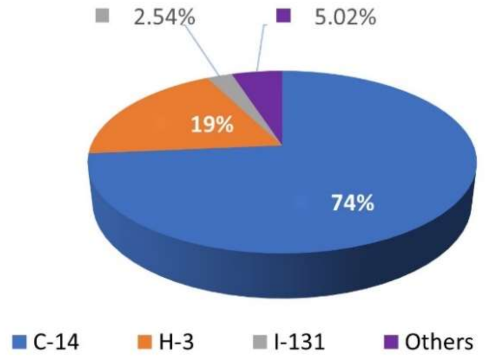

FIG. V–13. Total dose contribution per radionuclide, %. Atmospheric case C

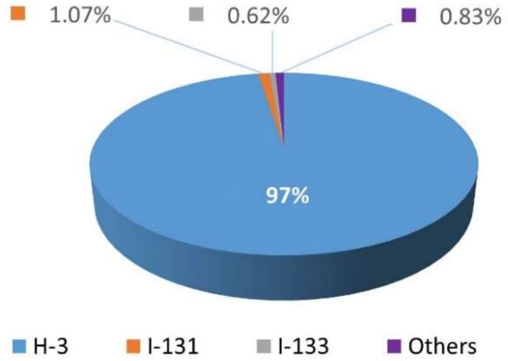

FIG. V–14. Inhalation dose contribution per radionuclide, %. Atmospheric case C

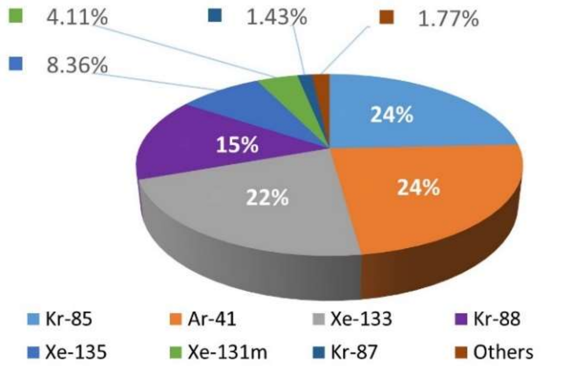

FIG. V–15. Immersion dose contribution per radionuclide, %, Atmospheric case C

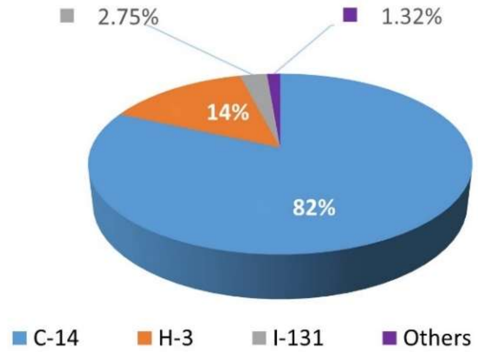

FIG. V–16. Ingestion dose contribution per radionuclide, %, Atmospheric case C

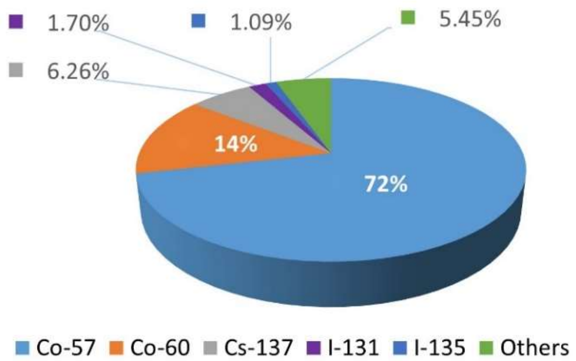

FIG. V-17. Ground deposition contribution per radionuclide, %, Atmospheric case C

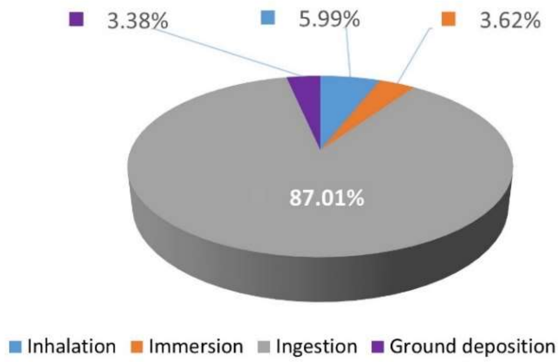

FIG. V-18. Total dose contribution per pathway, %, Atmospheric case C

TABLE V–15. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM ALL PATHWAYS COMBINED (CUT-OFF LEVEL 0.5%). ATMOSPHERIC CASE A

Radionuclide	Pathway	Dose, µSv/a	Contribution, %	Rank	Rank category
C-14 (CO2)	Ingestion	7.16E-02	51.02	1	B_{75}
H-3 (HTO)	Ingestion	2.74E-02	19.52	2	E_{25}
I-131	Ingestion	1.21E-02	8.61	3	F_{10}
H-3 (HTO)	Inhalation	1.15E-02	8.19	4	F_{10}
Co-57	Ground	5.97E-03	4.25	5	G_5
Kr-85	Immersion	1.52E-03	1.08	6	G_5
Ar-41	Immersion	1.47E-03	1.05	7	G_5
Xe-133	Immersion	1.36E-03	0.97	8	G_5
Co-60	Ground	1.26E-03	0.90	9	G_5
Co-57	Ingestion	1.18E-03	0.84	10	G_5
Cs-137	Ground	9.69E-04	0.69	11	G_5
Kr-88	Immersion	9.25E-04	0.66	12	G_5

TABLE V–16. RANKING BASED ON CONTRIBUTION TO DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE A

Rank	Inhalation		Immersion		Ingestion		Ground deposition	
	Isotope	Contrib., %	Isotope	Contrib., %	Isotope	Contrib., %	Isotope	Contrib., %
1	H-3(HTO)	97.5	Kr-85	24.3	C-14(CO2)	63.4	Co-57	64.3
2	I-131	1.1	Ar-41	23.5	H-3(HTO)	24.2	Co-60	13.6
3	I-133	0.6	Xe-133	21.7	I-131	10.7	Cs-137	10.4
4	Co-57	0.3	Kr-88	14.8	Co-57	1.0	I-131	3.0
5	I-135	0.2	Xe-135	8.4	Sr-90	0.3	I-135	2.0
6	C-14(CO2)	0.2	Xe-131m	4.1	Cs-137	0.1	I-133	1.6
7	Sr-90	0.0	Kr-87	1.4	I-133	0.1	Cs-134	1.5
8	I-132	0.0	Kr-85m	0.6	Cs-134	0.1	Sr-90	1.4
9	I-134	0.0	I-135	0.3	Co-60	0.0	Co-58	0.9
10	Co-60	0.0	Xe-133m	0.2	Sr-89	0.0	I-132	0.6
11	Sr-89	0.0	I-132	0.2	Co-58	0.0	Mn-54	0.4
12	Co-58	0.0	I-134	0.2	Cs-136	0.0	I-134	0.2
13	Cs-137	0.0	I-133	0.1	Mn-54	0.0	Fe-59	0.0
14	Cs-134	0.0	Xe-138	0.1	Fe-59	0.0	Nb-95	0.0
15	Fe-59	0.0	Xe-135m	0.0	Nb-95	0.0	Zr-95	0.0
16	Mn-54	0.0	I-131	0.0	Ru-103	0.0	Cs-136	0.0
17	Nb-95	0.0	Co-58	0.0	Zr-95	0.0	Sr-89	0.0
18	Zr-95	0.0	Co-60	0.0	I-135	0.0	Ru-103	0.0
19	Ru-106	0.0	Cs-134	0.0	Ru-106	0.0	Sb-125	0.0
20	Ru-103	0.0	Cs-136	0.0	Ce-141	0.0	Ru-106	0.0
21	Ce-141	0.0	Cs-137	0.0	Cr-51	0.0	Cr-51	0.0
22	Cs-136	0.0	Mn-54	0.0	Ba-140	0.0	Ce-141	0.0
23	Ba-140	0.0	Fe-59	0.0	Sb-125	0.0		
24	Sb-125	0.0	Nb-95	0.0	I-132	0.0		
25	Cr-51	0.0	Ru-103	0.0	I-134	0.0		
26			Zr-95	0.0				
27			Cr-51	0.0				
28			Sr-89	0.0				
29			Sb-125	0.0				
30			Ru-106	0.0				
31			Sr-90	0.0				

TABLE V–17. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM ALL PATHWAYS COMBINED (CUT-OFF LEVEL 0.5%). ATMOSPHERIC CASE B

Radionuclide	Pathway	Dose, μSv/a	Contribution, %	Rank	Rank category
C-14 (CO2)	Ingestion	3.26E-02	34.17	1	C_{50}
H-3 (HTO)	Ingestion	2.08E-02	21.75	2	E_{25}
I-131	Ingestion	1.35E-02	14.18	3	E_{25}
H-3 (HTO)	Inhalation	1.03E-02	10.79	4	E_{25}
Co-57	Ground	6.76E-03	7.08	5	F_{10}
Co-60	Ground	1.43E-03	1.50	6	G_5
Kr-85	Immersion	1.38E-03	1.45	7	G_5
Co-57	Ingestion	1.34E-03	1.41	8	G_5
Xe-133	Immersion	1.24E-03	1.30	9	G_5
Cs-137	Ground	1.10E-03	1.15	10	G_5
Ar-41	Immersion	1.02E-03	1.07	11	G_5
Kr-88	Immersion	7.05E-04	0.74	12	G_5

TABLE V–18. RANKING BASED ON CONTRIBUTION TO DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE B

Rank	Inhalation		Immersion		Ingestion		Ground deposition	
	Isotope	Contrib., %	Isotope	Contrib., %	Isotope	Contrib., %	Isotope	Contrib., %
1	H-3(HTO)	97.5	Kr-85	26.7	C-14(CO2)	47.1	Co-57	64.5
2	I-131	1.1	Xe-133	24.0	H-3(HTO)	30.0	Co-60	13.6
3	I-133	0.6	Ar-41	19.7	I-131	19.5	Cs-137	10.5
4	Co-57	0.3	Kr-88	13.6	Co-57	1.9	I-131	3.1
5	I-135	0.2	Xe-135	8.7	Sr-90	0.6	I-135	1.8
6	C-14(CO2)	0.2	Xe-131m	4.5	I-133	0.4	I-133	1.5
7	Sr-90	0.0	Kr-87	1.1	Cs-137	0.2	Cs-134	1.5
8	I-132	0.0	Kr-85m	0.6	Cs-134	0.2	Sr-90	1.4
9	Co-60	0.0	I-135	0.3	Co-60	0.0	Co-58	0.9
10	I-134	0.0	Xe-133m	0.3	Sr-89	0.0	I-132	0.5
11	Sr-89	0.0	I-132	0.2	Co-58	0.0	Mn-54	0.4
12	Co-58	0.0	I-134	0.1	I-135	0.0	I-134	0.1
13	Cs-137	0.0	I-133	0.1	Mn-54	0.0	Fe-59	0.0
14	Cs-134	0.0	I-131	0.0	Cs-136	0.0	Nb-95	0.0
15	Fe-59	0.0	Xe-138	0.0	Fe-59	0.0	Zr-95	0.0
16	Mn-54	0.0	Xe-135m	0.0	Nb-95	0.0	Cs-136	0.0
17	Nb-95	0.0	Co-58	0.0	Ru-103	0.0	Sr-89	0.0
18	Zr-95	0.0	Co-60	0.0	Zr-95	0.0	Ru-103	0.0
19	Ru-106	0.0	Cs-134	0.0	Ru-106	0.0	Sb-125	0.0
20	Ru-103	0.0	Cs-136	0.0	Ce-141	0.0	Ru-106	0.0
21	Ce-141	0.0	Cs-137	0.0	Cr-51	0.0	Cr-51	0.0
22	Cs-136	0.0	Mn-54	0.0	Ba-140	0.0	Ce-141	0.0
23	Ba-140	0.0	Fe-59	0.0	Sb-125	0.0		
24	Sb-125	0.0	Nb-95	0.0	I-132	0.0		
25	Cr-51	0.0	Ru-103	0.0	I-134	0.0		
26			Zr-95	0.0				
27			Cr-51	0.0				
28			Sr-89	0.0				
29			Sb-125	0.0				
30			Ru-106	0.0				
31			Sr-90	0.0				

TABLE V–19. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM ALL PATHWAYS COMBINED (CUT-OFF LEVEL 0.5%). ATMOSPHERIC CASE C

Radionuclide	Pathway	Dose, µSv/a	Contribution, %	Rank	Rank category
C-14 (CO2)	Ingestion	1.23E-01	71.10	1	B_{75}
H-3 (HTO)	Ingestion	2.14E-02	12.37	2	E_{25}
H-3 (HTO)	Inhalation	1.01E-02	5.84	3	F_{10}
Co-57	Ground	4.18E-03	2.42	4	G_5
I-131	Ingestion	4.14E-03	2.39	5	G_5
Kr-85	Immersion	1.52E-03	0.88	6	G_5
Ar-41	Immersion	1.47E-03	0.85	7	G_5
Xe-133	Immersion	1.36E-03	0.79	8	G_5
Sr-90	Ingestion	9.65E-04	0.56	9	G_5
Kr-88	Immersion	9.25E-04	0.53	10	G_5
Co-60	Ground	8.22E-04	0.48		
Co-57	Ingestion	7.29E-04	0.42		

TABLE V–20. RANKING BASED ON CONTRIBUTION TO DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C

Rank	Inhalation		Immersion		Ingestion		Ground deposition	
	Isotope	Contrib., %	Isotope	Contrib., %	Isotope	Contrib., %	Isotope	Contrib., %
1	H-3(HTO)	9.75E+01	Kr-85	2.43E+01	C-14(CO2)	8.17E+01	Co-57	7.15E+01
2	I-131	1.07E+00	Ar-41	2.35E+01	H-3(HTO)	1.42E+01	Co-60	1.41E+01
3	I-133	6.17E-01	Xe-133	2.17E+01	I-131	2.75E+00	Cs-137	6.26E+00
4	Co-57	3.16E-01	Kr-88	1.48E+01	Sr-90	6.41E-01	I-131	1.70E+00
5	I-135	2.16E-01	Xe-135	8.36E+00	Co-57	4.84E-01	Cs-134	1.68E+00
6	C-14(CO2)	1.76E-01	Xe-131m	4.11E+00	Cs-137	7.10E-02	I-135	1.09E+00
7	Sr-90	3.92E-02	Kr-87	1.43E+00	I-133	5.45E-02	Co-58	9.73E-01
8	I-132	3.87E-02	Kr-85m	6.43E-01	Cs-134	3.83E-02	I-133	8.67E-01
9	I-134	1.52E-02	I-135	2.78E-01	Co-60	1.22E-02	Sr-90	8.46E-01
10	Co-60	1.33E-02	Xe-133m	2.43E-01	Sr-89	9.98E-03	Mn-54	4.41E-01
11	Sr-89	4.91E-03	I-132	2.33E-01	Co-58	8.21E-03	I-132	3.45E-01
12	Co-58	3.93E-03	I-134	2.24E-01	Mn-54	1.37E-03	I-134	1.25E-01
13	Cs-137	1.61E-03	I-133	6.15E-02	Cs-136	1.17E-03	Fe-59	4.29E-02
14	Cs-134	1.24E-03	Xe-138	5.35E-02	Fe-59	1.05E-03	Nb-95	3.37E-02
15	Fe-59	4.37E-04	Xe-135m	3.26E-02	I-135	9.26E-04	Zr-95	2.87E-02
16	Mn-54	3.33E-04	I-131	1.32E-02	Nb-95	5.25E-04	Cs-136	2.75E-02
17	Nb-95	2.93E-04	Co-58	4.46E-04	Ru-103	2.26E-04	Sr-89	1.69E-02
18	Zr-95	2.30E-04	Co-60	3.07E-04	Zr-95	2.08E-04	Ru-103	9.56E-03
19	Ru-106	2.01E-04	Cs-134	7.13E-05	Ru-106	1.59E-04	Sb-125	8.19E-03
20	Ru-103	1.98E-04	Cs-136	6.92E-05	Ce-141	1.52E-04	Ru-106	3.03E-03
21	Ce-141	1.92E-04	Cs-137	4.84E-05	Ba-140	8.95E-05	Cr-51	2.51E-03
22	Cs-136	1.53E-04	Mn-54	4.57E-05	Cr-51	5.82E-05	Ce-141	9.66E-04
23	Ba-140	9.43E-05	Fe-59	3.29E-05	Sb-125	2.11E-05		
24	Sb-125	2.86E-05	Nb-95	3.10E-05	I-132	5.22E-07		
25	Cr-51	1.40E-05	Ru-103	7.54E-06	I-134	4.90E-13		
26			Zr-95	6.79E-06				
27			Cr-51	2.86E-06				
28			Sr-89	1.38E-06				
29			Sb-125	2.45E-07				
30			Ru-106	1.73E-07				
31			Sr-90	1.21E-07				

Tables V–15 and V–16 provide the rankings of radionuclides based on their contribution to the total dose and to the doses from every pathway in atmospheric case A. Tables V–17 and V–18 provide the same types of rankings for the atmospheric case B, and Tables V–19 and V–20 – for the atmospheric case C.

The rankings based on total adult dose contribution of the major radionuclides (e.g. C-14 and H-3 from the ingestion pathway) don't change between cases even though the total adult dose estimates show essential differences as shown in Table V–14. The same can be said for the relative contributions of the individual pathways (plume immersion, ingestion etc). However, for less prominent radionuclide pathway combinations, some variability was observed. For example, I-131 from ingestion pathway was ranked 5 in case C instead of rank 3 in case A and case B and the adult dose from I-131 ingestion in case C is about 30% of that in case A. The lower rate of milk consumption in Korea, 63 l/a, compared with the European value, 250 l/a, applied in case A, results in a lower exposure adult dose from I-131 ingestion pathway in Korea. We may conclude that the food chain dose, including consumption rate, is an important factor to consider when evaluating radiological exposure of the public.

Table V–21 gives the results of dose calculations (absolute values and relative contributions) for the marine case A. Absolute values of doses for marine case B are provided in Table V–22, and relative contributions – in Table V–23. Figures V–19 to V–26 help to compare contributions from different radionuclides in the marine cases A and B.

TABLE V–21. TOTAL ANNUAL DOSE (FROM INGESTION) AND CONTRIBUTION TO TOTAL ANNUAL DOSE, MARINE CASE A

Nuclide	Dose from ingestion of		Total dose, µSv/a	Contribution to dose from		Contribution to total dose, %
	Fish, µSv/a	Shellfish, µSv/a		Fish, %	Shellfish, %	
H-3(HTO)	7.81E-04	2.34E-04	1.02E-03	3.94	0.25	0.90
Na-24	2.53E-09	2.28E-09	4.81E-09	0.00	0.00	0.00
P-32	7.84E-04	1.57E-04	9.41E-04	3.96	0.17	0.83
Cr-51	5.78E-06	6.94E-06	1.27E-05	0.03	0.01	0.01
Mn-54	1.45E-04	5.44E-04	6.89E-04	0.73	0.58	0.61
Fe-55	6.59E-04	2.17E-03	2.83E-03	3.33	2.33	2.50
Fe-59	1.01E-03	3.33E-03	4.34E-03	5.10	3.57	3.84
Co-58	9.19E-04	1.38E-03	2.30E-03	4.64	1.48	2.03
Co-60	3.40E-03	5.10E-03	8.50E-03	17.17	5.47	7.52
Ni-63	1.70E-05	1.02E-05	2.72E-05	0.09	0.01	0.02
Zn-65	3.10E-04	4.65E-03	4.96E-03	1.57	4.99	4.39
Br-84	3.50E-37	3.50E-37	7.00E-37	0.00	0.00	0.00
Rb-88	0	0	0	-	-	-
Sr-89	1.39E-07	4.16E-08	1.81E-07	0.00	0.00	0.00
Sr-90	1.56E-07	4.69E-08	2.03E-07	0.00	0.00	0.00
Sr-91	2.43E-10	7.29E-11	3.16E-10	0.00	0.00	0.00
Y-90	3.64E-08	5.46E-07	5.82E-07	0.00	0.00	0.00
Y-91	3.12E-07	4.69E-06	5.00E-06	0.00	0.01	0.00
Y-91m	2.89E-27	4.34E-26	4.63E-26	0.00	0.00	0.00
Y-93	2.49E-08	3.73E-07	3.98E-07	0.00	0.00	0.00
Zr-95	2.48E-06	1.86E-04	1.88E-04	0.01	0.20	0.17
Nb-95	2.90E-06	2.90E-05	3.19E-05	0.01	0.03	0.03
Mo-99	1.45E-06	4.35E-06	5.80E-06	0.01	0.00	0.01
Tc-99m	9.47E-10	9.47E-09	1.04E-08	0.00	0.00	0.00
Ru-103	1.60E-06	4.79E-04	4.81E-04	0.01	0.51	0.43
Ru-106	2.14E-04	6.41E-02	6.43E-02	1.08	68.77	56.91
Rh-103m	4.28E-07	1.28E-06	1.71E-06	0.00	0.00	0.00

TABLE V–21. TOTAL ANNUAL DOSE (FROM INGESTION) AND CONTRIBUTION TO TOTAL ANNUAL DOSE, MARINE CASE A (cont.)

Nuclide	Dose from ingestion of		Total dose, μSv/a	Contribution to dose from		Contribution to total dose, %
	Fish, μSv/a	Shellfish, μSv/a		Fish, %	Shellfish, %	
Ag-110	0	0	0	-	-	-
Ag-110m	3.99E-04	2.39E-03	2.79E-03	2.02	2.56	2.47
Sb-124	2.80E-05	8.40E-06	3.64E-05	0.14	0.01	0.03
Te-129	1.51E-20	1.51E-19	1.66E-19	0.00	0.00	0.00
Te-129m	2.47E-06	2.47E-05	2.72E-05	0.01	0.03	0.02
Te-131	0	0	0	-	-	-
Te-131m	7.76E-07	7.76E-06	8.54E-06	0.00	0.01	0.01
Te-132	8.94E-06	8.94E-05	9.83E-05	0.05	0.10	0.09
I-131	2.35E-03	7.04E-04	3.05E-03	11.87	0.76	2.70
I-132	8.62E-13	2.58E-13	1.12E-12	0.00	0.00	0.00
I-133	5.79E-05	1.74E-05	7.53E-05	0.29	0.02	0.07
I-134	4.52E-24	1.35E-24	5.87E-24	0.00	0.00	0.00
I-135	1.78E-07	5.35E-08	2.32E-07	0.00	0.00	0.00
Cs-134	4.30E-03	3.87E-04	4.69E-03	21.72	0.42	4.15
Cs-136	3.78E-05	3.40E-06	4.12E-05	0.19	0.00	0.04
Cs-137	4.07E-03	3.67E-04	4.44E-03	20.56	0.39	3.93
Ba-135m	2.61E-06	7.84E-08	2.69E-06	0.01	0.00	0.00
Ba-140	4.04E-05	1.21E-06	4.16E-05	0.20	0.00	0.04
La-140	1.93E-05	5.78E-07	1.99E-05	0.10	0.00	0.02
Ce-141	1.27E-06	3.81E-05	3.94E-05	0.01	0.04	0.03
Ce-143	1.75E-06	5.24E-05	5.42E-05	0.01	0.06	0.05
Ce-144	2.24E-04	6.73E-03	6.95E-03	1.13	7.22	6.15
Pr-143	2.54E-08	7.61E-09	3.30E-08	0.00	0.00	0.00
Pr-144	0	0	0	-	-	-
W-187	8.24E-09	2.47E-09	1.07E-08	0.00	0.00	0.00
Np-239	5.34E-07	6.40E-06	6.93E-06	0.00	0.01	0.01
TOTAL	1.98E-02	9.32E-02	1.13E-01	100.00	100.00	100.00

TABLE V–22. TOTAL ANNUAL DOSE (FROM INGESTION), μSv/a. MARINE CASE B

Nuclide	Dose from ingestion of			Total dose including algae	Total dose excluding algae
	Fish	Shellfish	Seaweed (algae)		
H-3(HTO)	4.62E-04	1.06E-04	9.51E-05	6.63E-04	5.68E-04
Na-24	3.16E-09	1.99E-09	8.93E-09	1.41E-08	5.15E-09
P-32	5.21E-04	1.20E-04	1.07E-05	6.52E-04	6.41E-04
Cr-51	7.77E-06	8.63E-06	7.75E-06	2.42E-05	1.64E-05
Mn-54	1.43E-04	5.30E-04	9.52E-04	1.63E-03	6.73E-04
Fe-55	4.33E-04	6.41E-04	1.44E-03	2.51E-03	1.07E-03
Fe-59	6.72E-04	9.95E-04	2.23E-03	3.90E-03	1.67E-03
Co-58	6.09E-05	2.70E-04	1.21E-04	4.52E-04	3.31E-04
Co-60	2.23E-04	9.90E-04	4.45E-04	1.66E-03	1.21E-03
Ni-63	1.12E-06	6.19E-07	5.56E-07	2.30E-06	1.74E-06
Zn-65	4.08E-04	4.53E-03	4.07E-05	4.98E-03	4.94E-03
Br-84	7.83E-27	3.59E-25	1.56E-25	5.23E-25	3.67E-25
Rb-88	3.57E-37	1.63E-37	1.46E-37	6.66E-37	5.20E-37
Sr-89	2.30E-08	6.44E-08	1.19E-07	2.06E-07	8.74E-08
Sr-90	2.57E-08	7.18E-08	1.33E-07	2.31E-07	9.75E-08
Sr-91	2.07E-10	5.80E-10	1.07E-09	1.86E-09	7.87E-10
Y-90	3.82E-08	3.39E-07	1.52E-06	1.90E-06	3.77E-07

TABLE V–22. TOTAL ANNUAL DOSE (FROM INGESTION), µSv/a. MARINE CASE B (cont.)

Nuclide	Dose from ingestion of			Total dose including algae	Total dose excluding algae
	Fish	Shellfish	Seaweed (algae)		
Y-91	2.59E-07	2.30E-06	1.03E-05	1.29E-05	2.56E-06
Y-91m	3.89E-19	3.45E-18	1.55E-17	1.93E-17	3.84E-18
Y-93	9.63E-08	8.55E-07	3.84E-06	4.79E-06	9.51E-07
Zr-95	1.64E-05	3.65E-07	3.28E-05	4.96E-05	1.68E-05
Nb-95	1.94E-03	1.43E-06	6.44E-06	1.95E-03	1.94E-03
Mo-99	1.21E-06	2.68E-07	2.40E-07	1.72E-06	1.48E-06
Tc-99m	2.80E-09	3.10E-09	2.23E-07	2.29E-07	5.90E-09
Ru-103	5.33E-06	2.37E-04	2.12E-04	4.54E-04	2.42E-04
Ru-106	7.03E-04	3.12E-02	2.80E-02	5.99E-02	3.19E-02
Rh-103m	2.82E-08	1.25E-06	1.12E-06	2.40E-06	1.28E-06
Ag-110	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag-110m	1.73E-03	3.85E-04	2.09E-05	2.14E-03	2.12E-03
Sb-124	1.86E-06	5.15E-08	1.39E-05	1.58E-05	1.91E-06
Te-129	2.41E-15	5.36E-12	4.81E-14	5.41E-12	5.36E-12
Te-129m	5.52E-07	1.23E-03	1.10E-05	1.24E-03	1.23E-03
Te-131	1.94E-27	4.30E-24	3.86E-26	4.34E-24	4.30E-24
Te-131m	2.86E-07	6.35E-04	5.70E-06	6.41E-04	6.35E-04
Te-132	2.39E-06	5.31E-03	4.76E-05	5.36E-03	5.31E-03
I-131	1.67E-03	1.85E-03	1.33E-01	1.37E-01	3.52E-03
I-132	5.13E-10	5.69E-10	4.09E-08	4.20E-08	1.08E-09
I-133	8.07E-05	8.96E-05	6.43E-03	6.60E-03	1.70E-04
I-134	1.72E-16	1.91E-16	1.37E-14	1.41E-14	3.63E-16
I-135	1.25E-06	1.39E-06	9.97E-05	1.02E-04	2.64E-06
Cs-134	8.49E-04	1.26E-04	1.13E-04	1.09E-03	9.75E-04
Cs-136	7.82E-06	1.16E-06	1.04E-06	1.00E-05	8.98E-06
Cs-137	8.03E-04	1.19E-04	1.07E-04	1.03E-03	9.22E-04
Ba-135m	2.95E-06	6.56E-06	2.94E-05	3.89E-05	9.51E-06
Ba-140	2.79E-05	6.20E-05	2.78E-04	3.68E-04	8.99E-05
La-140	1.87E-05	4.14E-05	1.86E-04	2.46E-04	6.01E-05
Ce-141	4.25E-07	3.77E-06	1.69E-05	2.11E-05	4.20E-06
Ce-143	9.19E-07	8.16E-06	3.66E-05	4.57E-05	9.08E-06
Ce-144	7.38E-05	6.55E-04	2.94E-03	3.67E-03	7.29E-04
Pr-143	4.37E-07	3.88E-06	1.74E-05	2.17E-05	4.32E-06
Pr-144	1.51E-33	1.34E-32	6.00E-32	7.49E-32	1.49E-32
W-187	3.13E-07	6.94E-08	6.23E-08	4.45E-07	3.82E-07
Np-239	4.62E-07	1.03E-07	5.52E-08	6.20E-07	5.65E-07
TOTAL	1.09E-02	5.02E-02	1.77E-01	2.38E-01	6.10E-02

TABLE V–23. CONTRIBUTION TO TOTAL ANNUAL DOSE (FROM INGESTION), %. MARINE CASE B

Nuclide	Contribution to dose from			Contrib. to total dose incl. algae	Contrib. to total dose excl. algae
	Fish	Shellfish	Seaweed (algae)		
H-3	4.25	0.21	0.05	0.28	0.93
Na-24	0.00	0.00	0.00	0.00	0.00
P-32	4.79	0.24	0.01	0.27	1.05
Cr-51	0.07	0.02	0.00	0.01	0.03
Mn-54	1.32	1.06	0.54	0.68	1.10
Fe-55	3.98	1.28	0.81	1.06	1.76

TABLE V–23. CONTRIBUTION TO TOTAL ANNUAL DOSE (FROM INGESTION), %. MARINE CASE B (cont.)

Nuclide	Contribution to dose from			Contrib. to total dose incl. algae	Contrib. to total dose excl. algae
	Fish	Shellfish	Seaweed (algae)		
Fe-59	6.18	1.98	1.26	1.64	2.73
Co-58	0.56	0.54	0.07	0.19	0.54
Co-60	2.05	1.97	0.25	0.70	1.99
Ni-63	0.01	0.00	0.00	0.00	0.00
Zn-65	3.75	9.03	0.02	2.09	8.09
Br-84	0.00	0.00	0.00	0.00	0.00
Rb-88	0.00	0.00	0.00	0.00	0.00
Sr-89	0.00	0.00	0.00	0.00	0.00
Sr-90	0.00	0.00	0.00	0.00	0.00
Sr-91	0.00	0.00	0.00	0.00	0.00
Y-90	0.00	0.00	0.00	0.00	0.00
Y-91	0.00	0.00	0.01	0.01	0.00
Y-91m	0.00	0.00	0.00	0.00	0.00
Y-93	0.00	0.00	0.00	0.00	0.00
Zr-95	0.15	0.00	0.02	0.02	0.03
Nb-95	17.85	0.00	0.00	0.82	3.18
Mo-99	0.01	0.00	0.00	0.00	0.00
Tc-99m	0.00	0.00	0.00	0.00	0.00
Ru-103	0.05	0.47	0.12	0.19	0.40
Ru-106	6.47	62.20	15.82	25.17	52.27
Rh-103m	0.00	0.00	0.00	0.00	0.00
Ag-110	-	-	-	-	-
Ag-110m	15.91	0.77	0.01	0.90	3.47
Sb-124	0.02	0.00	0.01	0.01	0.00
Te-129	0.00	0.00	0.00	0.00	0.00
Te-129m	0.01	2.45	0.01	0.52	2.02
Te-131	0.00	0.00	0.00	0.00	0.00
Te-131m	0.00	1.27	0.00	0.27	1.04
Te-132	0.02	10.59	0.03	2.25	8.70
I-131	15.36	3.69	75.16	57.36	5.77
I-132	0.00	0.00	0.00	0.00	0.00
I-133	0.74	0.18	3.63	2.77	0.28
I-134	0.00	0.00	0.00	0.00	0.00
I-135	0.01	0.00	0.06	0.04	0.00
Cs-134	7.81	0.25	0.06	0.46	1.60
Cs-136	0.07	0.00	0.00	0.00	0.01
Cs-137	7.39	0.24	0.06	0.43	1.51
Ba-135m	0.03	0.01	0.02	0.02	0.02
Ba-140	0.26	0.12	0.16	0.15	0.15
La-140	0.17	0.08	0.11	0.10	0.10
Ce-141	0.00	0.01	0.01	0.01	0.01
Ce-143	0.01	0.02	0.02	0.02	0.01
Ce-144	0.68	1.31	1.66	1.54	1.19
Pr-143	0.00	0.01	0.01	0.01	0.01
Pr-144	0.00	0.00	0.00	0.00	0.00
W-187	0.00	0.00	0.00	0.00	0.00
Np-239	0.00	0.00	0.00	0.00	0.00
TOTAL	100.00	100.00	100.00	100.00	100.00

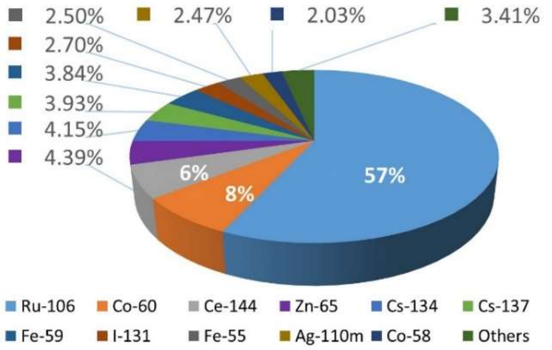

FIG. V–19. Contribution of radionuclides to the total dose from ingestion. Marine case A

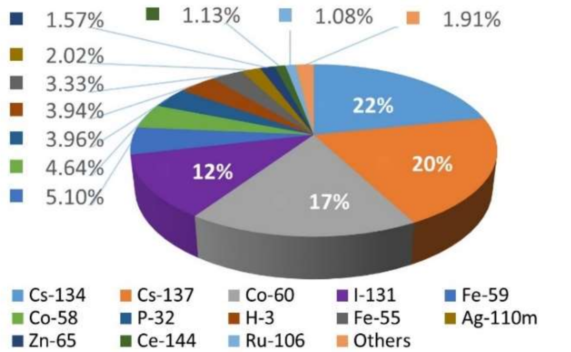

FIG. V–20. Contribution of radionuclides to the dose from fish ingestion. Marine case A

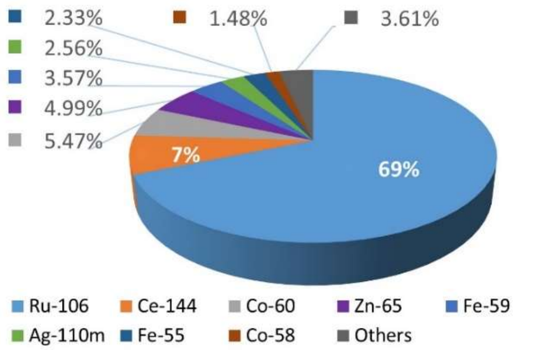

FIG. V–21. Contribution of radionuclides to dose from shellfish ingestion. Marine case A

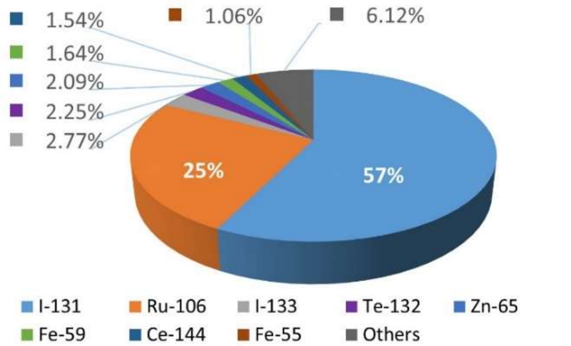

FIG. V–22. Contribution of radionuclides to the total dose from ingestion. Marine case B

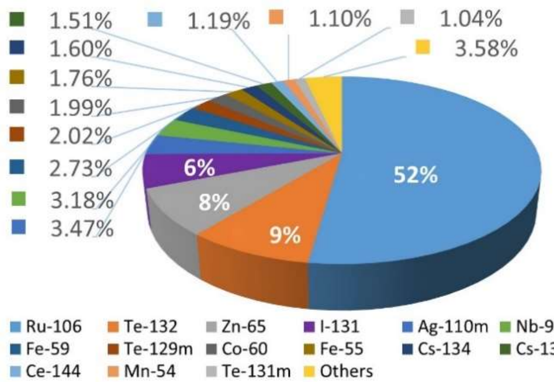

FIG. V–23. Contribution of radionuclides to the total dose from ingestion excluding algae. Marine case B

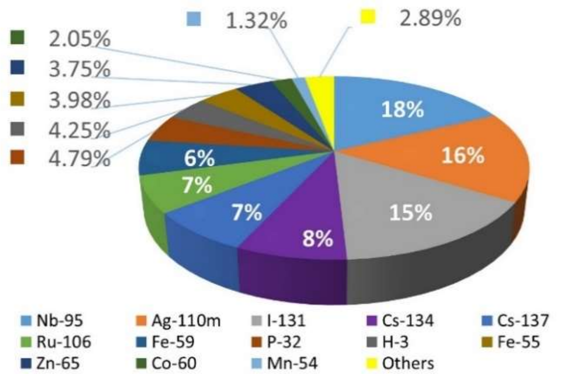

FIG. V–24. Contribution of radionuclides to the dose from ingestion of fish. Marine case B

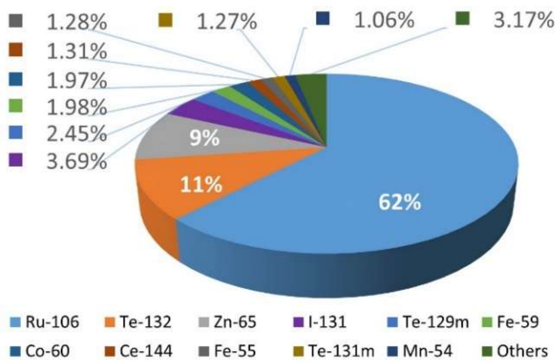

FIG. V–25. Contribution of radionuclides to dose from shellfish ingestion. Marine case B

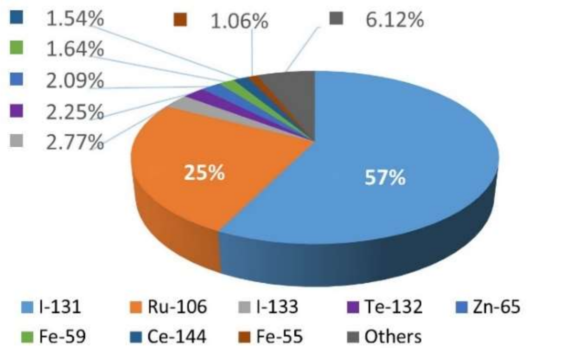

FIG. V–26. Contribution of radionuclides to the dose from algae ingestion. Marine case B

Tables V–24 to V–27 provide the rankings of radionuclides based on their contribution to the total dose and to the doses from every pathway in marine cases A and B. The ranking based on total adult dose contribution under case B when the consumption of seaweed (algae) was excluded differ from that of case A. This effect is caused by the different bioaccumulation factors for radionuclides used in cases A and B.

When the consumption of seaweed (algae) was included, the difference in ranking between case A and B is greater and there also a large difference in the estimates of total adult dose. I-131 is ranked 1 in case B instead of rank 8 in case A. The dose from I-131 in case B is higher than that in case A by two orders of magnitude. Because of that change, Ru-106 is ranked 2 in case B (ranked 1 in case A). Similarly, I-133 is ranked 3 in case B (18 in case A) and Te-132 is ranked 4 in case B (17 in case A).

It can be inferred that the large amount of seaweed consumption of Korea, which is an endemic food chain, provides such an impact on the result. The unique food chain in a country can be one of the important factors to impact the evaluation of public dose.

TABLE V–24. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, MARINE CASE A

Rank	Ingestion of fish		Ingestion of shellfish		Total ingestion	
	Nuclide	Contribution, %	Nuclide	Contribution, %	Nuclide	Contribution, %
1	Cs-134	2.17E+01	Ru-106	6.88E+01	Ru-106	5.69E+01
2	Cs-137	2.06E+01	Ce-144	7.22E+00	Co-60	7.52E+00
3	Co-60	1.72E+01	Co-60	5.47E+00	Ce-144	6.15E+00
4	I-131	1.19E+01	Zn-65	4.99E+00	Zn-65	4.39E+00
5	Fe-59	5.10E+00	Fe-59	3.57E+00	Cs-134	4.15E+00
6	Co-58	4.64E+00	Ag-110m	2.56E+00	Cs-137	3.93E+00
7	P-32	3.96E+00	Fe-55	2.33E+00	Fe-59	3.84E+00
8	H-3(HTO)	3.94E+00	Co-58	1.48E+00	I-131	2.70E+00
9	Fe-55	3.33E+00	I-131	7.55E-01	Fe-55	2.50E+00
10	Ag-110m	2.02E+00	Mn-54	5.84E-01	Ag-110m	2.47E+00
11	Zn-65	1.57E+00	Ru-103	5.14E-01	Co-58	2.03E+00
12	Ce-144	1.13E+00	Cs-134	4.15E-01	H-3(HTO)	8.98E-01
13	Ru-106	1.08E+00	Cs-137	3.94E-01	P-32	8.33E-01
14	Mn-54	7.32E-01	H-3(HTO)	2.51E-01	Mn-54	6.10E-01
15	I-133	2.92E-01	Zr-95	2.00E-01	Ru-103	4.25E-01
16	Ba-140	2.04E-01	P-32	1.68E-01	Zr-95	1.67E-01
17	Cs-136	1.91E-01	Te-132	9.59E-02	Te-132	8.70E-02
18	Sb-124	1.41E-01	Ce-143	5.62E-02	I-133	6.66E-02
19	La-140	9.75E-02	Ce-141	4.09E-02	Ce-143	4.79E-02
20	Ni-63	8.59E-02	Nb-95	3.11E-02	Ba-140	3.68E-02
21	Te-132	4.52E-02	Te-129m	2.65E-02	Cs-136	3.65E-02
22	Cr-51	2.92E-02	I-133	1.87E-02	Ce-141	3.48E-02
23	Nb-95	1.46E-02	Ni-63	1.09E-02	Sb-124	3.22E-02
24	Ba-135m	1.32E-02	Sb-124	9.01E-03	Nb-95	2.82E-02
25	Zr-95	1.25E-02	Te-131m	8.32E-03	Ni-63	2.41E-02
26	Te-129m	1.25E-02	Cr-51	7.45E-03	Te-129m	2.40E-02
27	Ce-143	8.84E-03	Np-239	6.87E-03	La-140	1.76E-02
28	Ru-103	8.08E-03	Y-91	5.03E-03	Cr-51	1.13E-02
29	Mo-99	7.32E-03	Mo-99	4.67E-03	Te-131m	7.55E-03
30	Ce-141	6.41E-03	Cs-136	3.65E-03	Np-239	6.14E-03
31	Te-131m	3.92E-03	Rh-103m	1.37E-03	Mo-99	5.13E-03

TABLE V–24. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, MARINE CASE A (cont.)

Rank	Ingestion of fish		Ingestion of shellfish		Total ingestion	
	Nuclide	Contribution, %	Nuclide	Contribution, %	Nuclide	Contribution, %
32	Np-239	2.70E-03	Ba-140	1.30E-03	Y-91	4.43E-03
33	Rh-103m	2.16E-03	La-140	6.20E-04	Ba-135m	2.38E-03
34	Y-91	1.58E-03	Y-90	5.86E-04	Rh-103m	1.51E-03
35	I-135	8.99E-04	Y-93	4.00E-04	Y-90	5.15E-04
36	Sr-90	7.88E-04	Ba-135m	8.41E-05	Y-93	3.52E-04
37	Sr-89	7.02E-04	I-135	5.74E-05	I-135	2.05E-04
38	Y-90	1.84E-04	Sr-90	5.03E-05	Sr-90	1.80E-04
39	Pr-143	1.28E-04	Sr-89	4.46E-05	Sr-89	1.60E-04
40	Y-93	1.26E-04	Tc-99m	1.02E-05	Pr-143	2.92E-05
41	W-187	4.16E-05	Pr-143	8.16E-06	W-187	9.48E-06
42	Na-24	1.28E-05	W-187	2.65E-06	Tc-99m	9.22E-06
43	Tc-99m	4.78E-06	Na-24	2.45E-06	Sr-91	2.80E-07
44	Sr-91	1.23E-06	Sr-91	7.82E-08	I-132	9.91E-10
45	I-132	4.35E-09	I-132	2.77E-10	Te-129	1.47E-16
46	Te-129	7.63E-17	Te-129	1.62E-16	I-134	5.19E-21
47	I-134	2.28E-20	I-134	1.45E-21	Y-91m	4.10E-23
48	Y-91m	1.46E-23	Y-91m	4.66E-23	Br-84	6.19E-34
49	Br-84	1.77E-33	Br-84	3.75E-34	Na-24	0.00E+00
50	Rb-88	0.00E+00	Rb-88	0.00E+00	Rb-88	0.00E+00
51	Ag-110	0.00E+00	Ag-110	0.00E+00	Ag-110	0.00E+00
52	Te-131	0.00E+00	Te-131	0.00E+00	Te-131	0.00E+00
53	Pr-144	0.00E+00	Pr-144	0.00E+00	Pr-144	0.00E+00

TABLE V–25. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE, MARINE CASE B

Rank	Total ingestion excl. algae		Total ingestion incl. algae	
	Nuclide	Contribution, %	Nuclide	Contribution, %
1	Ru-106	5.23E+01	I-131	5.74E+01
2	Te-132	8.70E+00	Ru-106	2.52E+01
3	Zn-65	8.09E+00	I-133	2.77E+00
4	I-131	5.77E+00	Te-132	2.25E+00
5	Ag-110m	3.47E+00	Zn-65	2.09E+00
6	Nb-95	3.18E+00	Fe-59	1.64E+00
7	Fe-59	2.73E+00	Ce-144	1.54E+00
8	Te-129m	2.02E+00	Fe-55	1.06E+00
9	Co-60	1.99E+00	Ag-110m	8.97E-01
10	Fe-55	1.76E+00	Nb-95	8.18E-01
11	Cs-134	1.60E+00	Co-60	6.97E-01
12	Cs-137	1.51E+00	Mn-54	6.83E-01
13	Ce-144	1.19E+00	Te-129m	5.22E-01
14	Mn-54	1.10E+00	Cs-134	4.57E-01
15	P-32	1.05E+00	Cs-137	4.32E-01
16	Te-131m	1.04E+00	H-3(HTO)	2.79E-01
17	H-3(HTO)	9.31E-01	P-32	2.74E-01
18	Co-58	5.42E-01	Te-131m	2.69E-01
19	Ru-103	3.97E-01	Co-58	1.90E-01
20	I-133	2.79E-01	Ba-140	1.55E-01

TABLE V–25. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE, MARINE CASE B (cont.)

Rank	Total ingestion excl. algae		Total ingestion incl. algae	
	Nuclide	Contribution, %	Nuclide	Contribution, %
21	Ba-140	1.47E-01	La-140	1.03E-01
22	La-140	9.85E-02	Ru-103	1.91E-01
23	Zr-95	2.75E-02	I-135	4.30E-02
24	Cr-51	2.69E-02	Zr-95	2.08E-02
25	Ba-135m	1.56E-02	Ce-143	1.92E-02
26	Ce-143	1.49E-02	Ba-135m	1.63E-02
27	Cs-136	1.47E-02	Cr-51	1.01E-02
28	Pr-143	7.07E-03	Pr-143	9.12E-03
29	Ce-141	6.87E-03	Ce-141	8.86E-03
30	I-135	4.33E-03	Sb-124	6.64E-03
31	Y-91	4.19E-03	Y-91	5.40E-03
32	Sb-124	3.13E-03	Cs-136	4.21E-03
33	Ni-63	2.85E-03	Y-93	2.01E-03
34	Mo-99	2.42E-03	Rh-103m	1.01E-03
35	Rh-103m	2.09E-03	Ni-63	9.64E-04
36	Y-93	1.56E-03	Y-90	7.97E-04
37	Np-239	9.26E-04	Mo-99	7.22E-04
38	W-187	6.27E-04	Np-239	2.61E-04
39	Y-90	6.18E-04	W-187	1.87E-04
40	Sr-90	1.60E-04	Sr-90	9.68E-05
41	Sr-89	1.43E-04	Tc-99m	9.62E-05
42	Tc-99m	9.67E-06	Sr-89	8.67E-05
43	Na-24	8.44E-06	I-132	1.76E-05
44	I-132	1.77E-06	Na-24	5.92E-06
45	Sr-91	1.29E-06	Sr-91	7.80E-07
46	Te-129	8.79E-09	Te-129	2.27E-09
47	I-134	5.95E-13	I-134	5.91E-12
48	Y-91m	6.29E-15	Y-91m	8.13E-15
49	Te-131	7.05E-21	Te-131	1.82E-21
50	Br-84	6.01E-22	Br-84	2.20E-22
51	Pr-144	2.44E-29	Pr-144	3.15E-29
52	Rb-88	8.52E-34	Rb-88	2.80E-34
53	Ag-110	0.00E+00	Ag-110	0.00E+00

TABLE V–26. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, MARINE CASE B

Rank	Ingestion of fish		Ingestion of shellfish		Ingestion of algae	
	Nuclide	Contribution, %	Nuclide	Contribution, %	Nuclide	Contribution, %
1	Nb-95	1.78E+01	Ru-106	6.22E+01	I-131	7.52E+01
2	Ag-110m	1.59E+01	Te-132	1.06E+01	Ru-106	1.58E+01
3	I-131	1.54E+01	Zn-65	9.03E+00	I-133	3.63E+00
4	Cs-134	7.81E+00	I-131	3.69E+00	Ce-144	1.66E+00
5	Cs-137	7.39E+00	Te-129m	2.45E+00	Fe-59	1.26E+00
6	Ru-106	6.47E+00	Fe-59	1.98E+00	Fe-55	8.14E-01
7	Fe-59	6.18E+00	Co-60	1.97E+00	Mn-54	5.38E-01
8	P-32	4.79E+00	Ce-144	1.31E+00	Co-60	2.51E-01
9	H-3(HTO)	4.25E+00	Fe-55	1.28E+00	Ba-140	1.57E-01

TABLE V–26. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, MARINE CASE B (cont.)

Rank	Ingestion of fish		Ingestion of shellfish		Ingestion of algae	
	Nuclide	Contribution, %	Nuclide	Contribution, %	Nuclide	Contribution, %
10	Fe-55	3.98E+00	Te-131m	1.27E+00	Ru-103	1.20E-01
11	Zn-65	3.75E+00	Mn-54	1.06E+00	La-140	1.05E-01
12	Co-60	2.05E+00	Ag-110m	7.67E-01	Co-58	6.84E-02
13	Mn-54	1.32E+00	Co-58	5.38E-01	Cs-134	6.39E-02
14	I-133	7.42E-01	Ru-103	4.72E-01	Cs-137	6.05E-02
15	Ce-144	6.79E-01	Cs-134	2.51E-01	I-135	5.63E-02
16	Co-58	5.60E-01	P-32	2.39E-01	H-3(HTO)	5.37E-02
17	Ba-140	2.57E-01	Cs-137	2.37E-01	Te-132	2.69E-02
18	La-140	1.72E-01	H-3(HTO)	2.11E-01	Zn-65	2.30E-02
19	Zr-95	1.51E-01	I-133	1.79E-01	Ce-143	2.07E-02
20	Cs-136	7.19E-02	Ba-140	1.24E-01	Zr-95	1.85E-02
21	Cr-51	7.15E-02	La-140	8.25E-02	Ba-135m	1.66E-02
22	Ru-103	4.90E-02	Cr-51	1.72E-02	Ag-110m	1.18E-02
23	Ba-135m	2.71E-02	Ce-143	1.63E-02	Pr-143	9.83E-03
24	Te-132	2.20E-02	Ba-135m	1.31E-02	Ce-141	9.55E-03
25	Sb-124	1.71E-02	Pr-143	7.73E-03	Sb-124	7.85E-03
26	I-135	1.15E-02	Ce-141	7.52E-03	Te-129m	6.22E-03
27	Mo-99	1.11E-02	Y-91	4.59E-03	P-32	6.05E-03
28	Ni-63	1.03E-02	Nb-95	2.85E-03	Y-91	5.82E-03
29	Ce-143	8.45E-03	I-135	2.77E-03	Cr-51	4.38E-03
30	Te-129m	5.08E-03	Rh-103m	2.49E-03	Nb-95	3.64E-03
31	Np-239	4.25E-03	Cs-136	2.31E-03	Te-131m	3.22E-03
32	Pr-143	4.02E-03	Y-93	1.70E-03	Y-93	2.17E-03
33	Ce-141	3.91E-03	Ni-63	1.23E-03	Y-90	8.59E-04
34	W-187	2.88E-03	Zr-95	7.28E-04	Rh-103m	6.33E-04
35	Te-131m	2.63E-03	Y-90	6.76E-04	Cs-136	5.88E-04
36	Y-91	2.38E-03	Mo-99	5.34E-04	Ni-63	3.14E-04
37	Y-93	8.86E-04	Np-239	2.05E-04	Mo-99	1.36E-04
38	Y-90	3.51E-04	Sr-90	1.43E-04	Tc-99m	1.26E-04
39	Rh-103m	2.59E-04	W-187	1.38E-04	Sr-90	7.52E-05
40	Sr-90	2.36E-04	Sr-89	1.28E-04	Sr-89	6.72E-05
41	Sr-89	2.12E-04	Sb-124	1.03E-04	W-187	3.52E-05
42	Na-24	2.91E-05	Tc-99m	6.18E-06	Np-239	3.12E-05
43	Tc-99m	2.58E-05	Na-24	3.97E-06	I-132	2.31E-05
44	I-132	4.72E-06	Sr-91	1.16E-06	Na-24	5.05E-06
45	Sr-91	1.90E-06	I-132	1.13E-06	Sr-91	6.05E-07
46	Te-129	2.22E-11	Te-129	1.07E-08	Te-129	2.72E-11
47	I-134	1.58E-12	I-134	3.81E-13	I-134	7.74E-12
48	Y-91m	3.58E-15	Y-91m	6.88E-15	Y-91m	8.76E-15
49	Br-84	7.20E-23	Te-131	8.57E-21	Br-84	8.82E-23
50	Te-131	1.78E-23	Br-84	7.16E-22	Te-131	2.18E-23
51	Pr-144	1.39E-29	Pr-144	2.67E-29	Pr-144	3.39E-29
52	Rb-88	3.28E-33	Rb-88	3.25E-34	Rb-88	8.25E-35
53	Ag-110	0.00E+00	Ag-110	0.00E+00	Ag-110	0.00E+00

TABLE V–27. SUMMARY OF RANKING BASED ON CONTRIBUTION OF EACH RADIONUCLIDE TO THE TOTAL DOSE

Rank	Marine case A			Marine case B excl. algae			Marine case B incl. algae		
	Nuclide	Dose, μSv/a	Conrib., %	Nuclide	Dose, μSv/a	Conrib., %	Nuclide	Dose, μSv/a	Conrib., %
1	Ru-106	6.43E-02	56.91	Ru-106	3.19E-02	52.27	I-131	1.37E-01	57.36
2	Co-60	8.50E-03	7.52	Te-132	5.31E-03	8.70	Ru-106	5.99E-02	25.17
3	Ce-144	6.95E-03	6.15	Zn-65	4.94E-03	8.09	I-133	6.60E-03	2.77
4	Zn-65	4.96E-03	4.39	I-131	3.52E-03	5.77	Te-132	5.36E-03	2.25
5	Cs-134	4.69E-03	4.15	Ag-110m	2.12E-03	3.47	Zn-65	4.98E-03	2.09
6	Cs-137	4.44E-03	3.93	Nb-95	1.94E-03	3.18	Fe-59	3.90E-03	1.64
7	Fe-59	4.34E-03	3.84	Fe-59	1.67E-03	2.73	Ce-144	3.67E-03	1.54
8	I-131	3.05E-03	2.70	Te-129m	1.23E-03	2.02	Fe-55	2.51E-03	1.06
9	Fe-55	2.83E-03	2.50	Co-60	1.21E-03	1.99	Ag-110m	2.14E-03	0.90
10	Ag-110m	2.79E-03	2.47	Fe-55	1.07E-03	1.76	Nb-95	1.95E-03	0.82

REFERENCES TO ANNEX V

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[V–12] SAGENDORF, J., GOLL, J., SANDUSKY, W., XOQDOQ Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations, NUREG/CR-2919 (PNL-4380), US Nuclear Regulatory Commission, Washington (1982).

ANNEX VI. RUSSIAN FEDERATION

VI–1. DESCRIPTION OF MODELS AND METHODOLOGIES APPLIED

The generic model from SRS-19 [VI–1] was used for dose estimation. This model suits for the task defined by the participants of exercise because of its optimal level of complexity and well-developed parameterization.

VI–2. STRUCTURE OF CONSIDERATION OF PUBLIC EXPOSURES FROM NORMAL OPERATION

Within the atmospheric dispersion cases, a spot located 10 km from the source of releases in the "north" direction was chosen for radiological dose estimation. The radionuclide source and dispersion data were identical for atmospheric cases A and C. The source term was based on data provided by Korea and the meteorological data were provided by Brazil. This was to allow easy comparison of dose estimates and radionuclide rankings among the participants.

TABLE VI–1. FOOD CONSUMPTION RATES FOR ADULTS [VI–3]

Diet components	Ingestion rates, kg/a	Diet components	Ingestion rates, kg/a
Cereals	192	Root vegetables	188
Milk	146	Green vegetables	184
Meat	58	Fruits and berries	30
Freshwater fish	12	Sea fish	12

TABLE VI–2. SOIL-TO-PLANT [VI–4] AND ANIMAL TRANSFER COEFFICIENTS FOR ATMOSPHERIC CASE C OF RUSSIA

Nuclide	Transfer coefficient				Milk	Meat
	Cereals	Leafy veg.	Non-leafy veg.	Root veg.		
Cr-51	2.00E-04	1.00E-03	1.00E-03	1.00E-03	4.30E-04	9.00E-02
Mn-54	2.20E-01	1.70E-01	3.10E-01	4.20E-01	4.10E-05	6.00E-04
Fe-59	2.00E-04	1.00E-03	1.00E-03	1.00E-03	3.50E-05	1.40E-02
Co-57	5.40E-03	9.70E-02	1.60E-01	1.00E-01	1.10E-04	4.30E-04
Co-58	5.40E-03	9.70E-02	1.60E-01	1.00E-01	1.10E-04	4.30E-04
Co-60	5.40E-03	9.70E-02	1.60E-01	1.00E-01	1.10E-04	4.30E-04
Sr-89	7.80E-02	1.50E-01	1.30E-01	4.10E-01	1.30E-03	1.30E-03
Sr-90	7.80E-02	1.50E-01	1.30E-01	4.10E-01	1.56E-03	1.30E-03
Zr-95	1.00E-03	4.00E-03	4.00E-03	4.00E-03	3.60E-06	1.20E-06
Nb-95	1.40E-02	1.70E-02	8.00E-03	1.70E-02	4.10E-07	2.60E-07
Ru-103	1.30E-03	9.00E-02	2.00E-02	1.00E-02	9.40E-06	3.30E-03
Ru-106	1.30E-03	9.00E-02	2.00E-02	1.00E-02	9.40E-06	3.30E-03
Sb-125	1.80E-03	9.40E-05	1.30E-04	6.20E-04	3.80E-05	1.20E-03
I-131	5.70E-04	4.60E-03	1.00E-01	4.50E-03	5.40E-03	6.70E-03
I-132(e)	5.70E-04	4.60E-03	1.00E-01	4.50E-03	5.40E-03	6.70E-03
I-133(e)	5.70E-04	4.60E-03	1.00E-01	4.50E-03	5.40E-03	6.70E-03
I-134(e)	5.70E-04	4.60E-03	1.00E-01	4.50E-03	5.40E-03	6.70E-03
I-135(e)	5.70E-04	4.60E-03	1.00E-01	4.50E-03	5.40E-03	6.70E-03
Cs-134	1.10E-02	1.80E-02	9.10E-03	2.40E-02	4.60E-03	2.20E-02
Cs-136	1.10E-02	1.80E-02	9.10E-03	2.40E-02	4.60E-03	2.20E-02
Cs-137	1.10E-02	1.80E-02	9.10E-03	2.40E-02	8.0E-03	2.20E-02
Ba-140	1.00E-03	5.00E-03	5.00E-03	5.00E-03	1.60E-04	1.40E-04
Ce-141	1.60E-03	6.00E-03	-	6.00E-03	2.00E-05	2.00E-04

For atmospheric case B, the same source term was applied as in cases A and B, however the indigenous meteorological data were used to estimate downwind activity concentrations. Atmospheric case B considered the meteorological conditions in the Rostov NPP region. The meteorological factor (χ/Q) was 1.2E-08 s/m^3 (direction – "north", distance – 10 km) which is essentially different to the value of 4.7E-08 s/m^3 for case A; the average wind speed was 3.4 m/s.

In the atmospheric case C, the source terms and dispersion characteristics are the same as applied in case A, however the values of food and water consumption rates, breathing rates and transfer coefficients are derived from national information sources. This was to assess the effect of local data on dose estimates. The following parameters were changed from the default SRS-19 [VI–1] values applied in case A:

- Breathing rate of 8200 m^3/a (from the Methodological Guides [VI–2]);
- Food consumption rates from Ref. [VI–3] as provided in Table VI–1;
- Environmental transfer factors for cereals /vegetables [VI–4] and milk /meat as provided in Table VI–2.

The Rostov NPP region is dominated by clay soils. Dose estimations for atmospheric case C used the transfer coefficients for this soil group [VI–4] as presented in Table VI–2.

In the marine discharge scenarios pre-calculated concentrations of radionuclides in the water at 1 km from discharge location were used as input data. In marine case A the dose from ingestion of contaminated fish and shellfish was considered.

TABLE VI–3. RUSSIAN MARINE BIOACCUMULATION FACTORS [VI–5]

Radionuclide	Bioaccumulation factor for fish, (Bq/kg)/(Bq/l)	Radionuclide	Bioaccumulation factor for fish, (Bq/kg)/(Bq/l)
H-3(HTO)	1	Ru-106	5
Na-24	0.07	Rh-103m	100
P-32	1200	Rh-106m	100
Cr-51	70	Ag-110	100
Mn-54	300	Ag-110m	100
Fe-55	1000	Sb-124	90
Fe-59	1000	Te-129m	30
Co-58	30	Te-129	30
Co-60	30	Te-131	30
Ni-63	1000	Te-131m	30
Zn-65	900	Te-132	30
Br-84	3	I-131	10
Rb-88	100	I-132	10
Sr-89	2	I-133	10
Sr-90	2	I-134	10
Sr-91	2	I-135	10
Y-90	20	Cs-134	150
Y-91m	20	Cs-136	150
Y-91	20	Cs-137	150
Y-93	20	Ba-135m	10
Zr-95	20	Ba-140	10
Nb-95	100	Ce-141	10
Mo-99	10	Ce-143	10
Tc-99m	30	Ce-144	10
Ru-103	5	Np-239	10

In marine case B only the dose from ingestion of fish was estimated. The estimations used values of bioaccumulation factors for sea fish published in the Russian methodological guides [VI–5] (Table VI–3). The ingestion rate for fish, according to the data on foodstuffs consumption in Russia [VI–6], is assumed to be 12 kg/a. Since data on the consumption of marine shellfish are not included in the diet, this type of product was neglected in the calculations.

In the riverine discharge scenarios only the dose from ingestion of contaminated fish was evaluated. Pre-calculated concentrations of radionuclides in the water at 1 km from discharge were used in both riverine cases A and B. In riverine case A the transfer coefficients and consumption rates were used as agreed among the project participants.

In riverine case B the estimations used values of bioaccumulation factors for freshwater fish published in the Russian methodological guides [VI–5] and presented in Table VI–4. The ingestion rate for fish, according to the data on foodstuffs consumption in Russia [VI–6], is assumed to be 12 kg/a.

TABLE VI–4. BIOACCUMULATION VALUES FOR RUSSIAN FRESHWATER FISH [VI–5]

Radionuclide	Bioaccumulation factor for fish, wet weight, (Bq/kg)/(Bq/l)	Radionuclide	Bioaccumulation factor for fish, wet weight, (Bq/kg)/(Bq/l)
H-3	1	Zr-95	300
Cr-51	200	Nb-95	300
Mn-54	400	Ru-106	10
Fe-59	200	Ag-110m	200
Co-58	300	I-131	40
Co-60	300	Cs-134	2000
Zn-65	1000	Cs-137	2000
Sr-90	60	Ce-144	30

VI–3. RESULTS OF ASSESSMENT

Calculations were performed for all three atmospheric cases. Tables VI–5, VI-7 and VI-9 provide the annual adult doses in μSv/a from individual radionuclides for each of the pathways for atmospheric cases A, B and C. The total adult doses from all the pathways are 1.76E-02 μSv/a for case A, 6.44E-03 μSv/a for case B and 1.88E-02 μSv/a for case C.

Tables VI–6, VI–8 and VI–10 give the percentage contribution of each radionuclide within each pathway for atmospheric cases A, B and C. Figures VI–1 to VI–18 help to compare contributions from different radionuclides and different pathways in atmospheric cases A, B and C.

Tables VI–11, VI–12 and VI–13 provide the rankings of radionuclides based on the total dose contributed through all pathways in atmospheric cases A, B and C. Tables VI–14, VI–15 and VI–16 provide the rankings of radionuclides based on their contribution to the total dose from a given pathway.

Several important factors influencing the estimation of dose and subsequent ranking were identified. In regard to the standardized approaches agreed between the participants prior to undertaking the dose estimation exercises reported here, there were important outcomes. For example, variation in the initial data on the composition of releases may be due to both objective reasons (different composition of releases for different NPPs) and subjective reasons (which radionuclides are measured in the release compositions and which are presented in the reports). Similarly, variations in the values of dose coefficients for the main dose-forming radionuclides can substantially alter the final outcomes. For example, the decision not to apply the special considerations in SRS-19 [VI–1] radically changed the radionuclide rating and the relative contribution of the exposure pathways to the total adult dose. The assumptions adopted in the modeling to facilitate comparisons between participants also had effects. For example, neglecting the delay times between harvest and consumption of the food, as well as between collection and human consumption of milk and meat (t_h, t_m and t_f in SRS-19 [VI–1]) has caused changes in the ranking results for the radionuclides whose contribution to the total adult dose exceeds 1%.

TABLE VI–5. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	1.35E-03	-	-	-	-	-	-	1.35E-03
C-14	3.65E-06	-	-	-	-	-	-	3.65E-06
Ar-41	-	6.22E-04	-	-	-	-	-	6.22E-04
Cr-51	2.90E-10	4.48E-11	2.18E-09	1.37E-07	5.75E-08	1.97E-07	3.66E-08	2.34E-07
Mn-54	6.91E-09	7.13E-10	5.14E-09	2.26E-08	9.04E-07	9.32E-07	6.48E-06	7.42E-06
Fe-59	9.08E-09	5.14E-10	2.68E-09	3.22E-07	8.95E-07	1.22E-06	6.24E-07	1.85E-06
Co-57	6.62E-10	-	3.75E-10	4.39E-10	3.74E-08	3.82E-08	-	3.89E-08
Co-58	8.16E-08	6.94E-09	6.54E-08	7.67E-08	6.87E-06	7.01E-06	1.42E-05	2.13E-05
Co-60	2.75E-07	4.76E-09	1.40E-07	1.64E-07	8.84E-06	9.15E-06	2.16E-04	2.26E-04
Kr-85	-	3.78E-04	-	-	-	-	-	3.78E-04
Kr-85m	-	1.24E-05	-	-	-	-	-	1.24E-05
Kr-87	-	4.77E-05	-	-	-	-	-	4.77E-05
Kr-88	-	3.24E-04	-	-	-	-	-	3.24E-04
Sr-89	1.02E-07	2.15E-11	9.50E-07	2.85E-07	7.63E-06	8.86E-06	2.47E-07	9.21E-06
Sr-90	8.14E-07	1.88E-12	3.37E-05	1.01E-05	5.73E-05	1.01E-04	1.66E-05	1.19E-04
Zr-95	4.77E-09	1.06E-10	5.45E-11	5.45E-12	1.80E-07	1.80E-07	4.19E-07	6.03E-07
Nb-95	6.09E-09	4.83E-10	1.45E-11	2.76E-12	4.06E-07	4.06E-07	4.91E-07	9.04E-07
Ru-103	4.12E-09	1.18E-10	1.73E-10	1.83E-08	2.13E-07	2.32E-07	1.39E-07	3.75E-07
Ru-106	4.16E-09	2.70E-12	9.18E-11	9.67E-09	1.19E-07	1.29E-07	4.40E-08	1.77E-07
Sb-125	5.92E-10	3.82E-12	4.65E-11	4.41E-10	1.49E-08	1.54E-08	1.20E-07	1.36E-07
Xe-131m	-	6.42E-05	-	-	-	-	-	6.42E-05
Xe-133	-	3.42E-04	-	-	-	-	-	3.42E-04
Xe-133m	-	3.87E-06	-	-	-	-	-	3.87E-06
Xe-135	-	1.45E-04	-	-	-	-	-	1.45E-04
Xe-135m	-	2.25E-05	-	-	-	-	-	2.25E-05
Xe-138	-	4.96E-05	-	-	-	-	-	4.96E-05
I-131	2.21E-05	2.07E-07	3.67E-03	1.36E-03	7.07E-03	1.21E-02	4.96E-05	1.22E-02
I-132(e)	1.22E-06	5.54E-06	3.97E-06	1.48E-06	7.54E-06	1.30E-05	1.53E-05	3.51E-05
I-133(e)	1.33E-05	1.01E-06	3.47E-04	1.29E-04	6.58E-04	1.13E-03	2.64E-05	1.18E-03
I-134(e)	9.45E-07	1.05E-05	9.36E-07	3.48E-07	1.78E-06	3.06E-06	1.09E-05	2.54E-05
I-135(e)	5.17E-06	5.00E-06	4.51E-05	1.68E-05	8.56E-05	1.48E-04	3.66E-05	1.94E-04
Cs-134	2.57E-08	1.11E-09	8.63E-06	1.24E-05	2.04E-05	4.14E-05	2.46E-05	6.60E-05
Cs-136	3.20E-09	1.08E-09	4.90E-07	7.02E-07	1.14E-06	2.33E-06	4.02E-07	2.73E-06
Cs-137	3.34E-08	7.53E-10	1.66E-05	2.39E-05	2.70E-05	6.75E-05	1.23E-04	1.91E-04
Ba-140	1.73E-09	-	1.85E-09	4.85E-10	1.24E-07	1.26E-07	-	1.28E-07
Ce-141	3.99E-09	-	2.64E-10	7.92E-10	1.51E-07	1.52E-07	1.41E-08	1.70E-07
Total	1.40E-03	2.03E-03	4.12E-03	1.56E-03	7.96E-03	1.36E-02	5.43E-04	1.76E-02

TABLE VI–6. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total
			Milk	Meat	Vegetables			
H-3	9.66E+01	-	-	-	-	-	-	7.67E+00
C-14	2.61E-01	-	-	-	-	-	-	2.07E-02
Ar-41	-	3.06E+01	-	-	-	-	-	3.53E+00
Cr-51	2.07E-05	2.20E-06	5.30E-05	8.79E-03	7.22E-04	1.44E-03	6.74E-03	1.33E-03
Mn-54	4.94E-04	3.51E-05	1.25E-04	1.45E-03	1.14E-02	6.83E-03	1.19E+00	4.21E-02
Fe-59	6.49E-04	2.53E-05	6.51E-05	2.06E-02	1.12E-02	8.94E-03	1.15E-01	1.05E-02
Co-57	4.73E-05	-	9.08E-06	2.81E-05	4.70E-04	2.80E-04	-	2.21E-04
Co-58	5.83E-03	3.41E-04	1.59E-03	4.91E-03	8.63E-02	5.14E-02	2.61E+00	1.21E-01
Co-60	1.97E-02	2.34E-04	3.39E-03	1.05E-02	1.11E-01	6.71E-02	3.98E+01	1.28E+00
Kr-85	-	1.86E+01	-	-	-	-	-	2.14E+00
Kr-85m	-	6.10E-01	-	-	-	-	-	7.04E-02
Kr-87	-	2.35E+00	-	-	-	-	-	2.71E-01
Kr-88	-	1.59E+01	-	-	-	-	-	1.84E+00
Sr-89	7.29E-03	1.06E-06	2.30E-02	1.83E-02	9.58E-02	6.49E-02	4.55E-02	5.23E-02
Sr-90	5.81E-02	9.24E-08	8.17E-01	6.48E-01	7.20E-01	7.41E-01	3.06E+00	6.73E-01
Zr-95	3.41E-04	5.21E-06	1.32E-06	3.49E-07	2.26E-03	1.32E-03	7.71E-02	3.43E-03
Nb-95	4.35E-04	2.38E-05	3.51E-07	1.77E-07	5.10E-03	2.98E-03	9.04E-02	5.13E-03
Ru-103	2.94E-04	5.79E-06	4.20E-06	1.17E-03	2.68E-03	1.70E-03	2.57E-02	2.13E-03
Ru-106	2.98E-04	1.33E-07	2.23E-06	6.20E-04	1.50E-03	9.47E-04	8.09E-03	1.01E-03
Sb-125	4.23E-05	1.88E-07	1.13E-06	2.82E-05	1.88E-04	1.13E-04	2.21E-02	7.71E-04
Xe-131m	-	3.16E+00	-	-	-	-	-	3.64E-01
Xe-133	-	1.68E+01	-	-	-	-	-	1.94E+00
Xe-133m	-	1.90E-01	-	-	-	-	-	2.19E-02
Xe-135	-	7.12E+00	-	-	-	-	-	8.21E-01
Xe-135m	-	1.11E+00	-	-	-	-	-	1.28E-01
Xe-138	-	2.44E+00	-	-	-	-	-	2.82E-01
I-131	1.58E+00	1.02E-02	8.89E+01	8.74E+01	8.89E+01	8.87E+01	9.13E+00	6.91E+01
I-132(e)	8.68E-02	2.73E-01	9.63E-02	9.48E-02	9.47E-02	9.52E-02	2.82E+00	1.99E-01
I-133(e)	9.52E-01	4.94E-02	8.41E+00	8.27E+00	8.27E+00	8.31E+00	4.87E+00	6.67E+00
I-134(e)	6.75E-02	5.17E-01	2.27E-02	2.23E-02	2.23E-02	2.24E-02	2.01E+00	1.44E-01
I-135(e)	3.69E-01	2.46E-01	1.09E+00	1.08E+00	1.08E+00	1.08E+00	6.75E+00	1.10E+00
Cs-134	1.83E-03	5.46E-05	2.09E-01	7.94E-01	2.56E-01	3.03E-01	4.53E+00	3.75E-01
Cs-136	2.28E-04	5.30E-05	1.19E-02	4.50E-02	1.43E-02	1.71E-02	7.40E-02	1.55E-02
Cs-137	2.39E-03	3.71E-05	4.04E-01	1.53E+00	3.39E-01	4.95E-01	2.27E+01	1.08E+00
Ba-140	1.23E-04	-	4.48E-05	3.11E-05	1.55E-03	9.23E-04	-	7.25E-04
Ce-141	2.85E-04	-	6.40E-06	5.07E-05	1.90E-03	1.11E-03	2.59E-03	9.66E-04
Total	100	100	100	100	100	100	100	100

TABLE VI–7. TOTAL ANNUAL DOSE, µSv/a. ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	4.95E-04	-	-	-	-	-	0.00E+00	4.95E-04
C-14	1.34E-06	-	-	-	-	-	0.00E+00	1.34E-06
Ar-41	-	2.28E-04	-	-	-	-	0.00E+00	2.28E-04
Cr-51	1.06E-10	1.64E-11	7.99E-10	5.02E-08	2.10E-08	7.20E-08	1.34E-08	8.56E-08
Mn-54	2.53E-09	2.61E-10	1.88E-09	8.25E-09	3.31E-07	3.41E-07	2.37E-06	2.72E-06
Fe-59	3.32E-09	1.88E-10	9.82E-10	1.18E-07	3.27E-07	4.46E-07	2.28E-07	6.78E-07

TABLE VI–7. TOTAL ANNUAL DOSE, μSv/a. ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Co-57	2.42E-10	-	1.37E-10	1.61E-10	1.37E-08	1.40E-08	0.00E+00	1.42E-08
Co-58	2.99E-08	2.54E-09	2.39E-08	2.81E-08	2.51E-06	2.56E-06	5.19E-06	7.79E-06
Co-60	1.01E-07	1.74E-09	5.12E-08	6.00E-08	3.24E-06	3.35E-06	7.91E-05	8.26E-05
Kr-85	-	1.38E-04	-	-	-	-	0.00E+00	1.38E-04
Kr-85m	-	4.54E-06	-	-	-	-	0.00E+00	4.54E-06
Kr-87	-	1.75E-05	-	-	-	-	0.00E+00	1.75E-05
Kr-88	-	1.18E-04	-	-	-	-	0.00E+00	1.18E-04
Sr-89	3.74E-08	7.88E-12	3.48E-07	1.04E-07	2.79E-06	3.24E-06	9.04E-08	3.37E-06
Sr-90	2.98E-07	6.87E-13	1.23E-05	3.70E-06	2.10E-05	3.70E-05	6.09E-06	4.34E-05
Zr-95	1.74E-09	3.87E-11	2.00E-11	2.00E-12	6.59E-08	6.59E-08	1.53E-07	2.21E-07
Nb-95	2.23E-09	1.77E-10	5.30E-12	1.01E-12	1.49E-07	1.49E-07	1.80E-07	3.31E-07
Ru-103	1.51E-09	4.31E-11	6.34E-11	6.68E-09	7.81E-08	8.49E-08	5.10E-08	1.37E-07
Ru-106	1.52E-09	9.90E-13	3.36E-11	3.54E-09	4.37E-08	4.73E-08	1.61E-08	6.49E-08
Sb-125	2.17E-10	1.40E-12	1.70E-11	1.61E-10	5.47E-09	5.64E-09	4.39E-08	4.97E-08
Xe-131m	-	2.35E-05	-	-	-	-	0.00E+00	2.35E-05
Xe-133	-	1.25E-04	-	-	-	-	0.00E+00	1.25E-04
Xe-133m	-	1.41E-06	-	-	-	-	0.00E+00	1.41E-06
Xe-135	-	5.29E-05	-	-	-	-	0.00E+00	5.29E-05
Xe-135m	-	8.22E-06	-	-	-	-	0.00E+00	8.22E-06
Xe-138	-	1.82E-05	-	-	-	-	0.00E+00	1.82E-05
I-131	8.10E-06	7.56E-08	1.34E-03	4.99E-04	2.59E-03	4.43E-03	1.81E-05	4.46E-03
I-132(e)	3.69E-07	1.68E-06	1.21E-06	4.49E-07	2.29E-06	3.95E-06	4.65E-06	1.07E-05
I-133(e)	4.88E-06	3.68E-07	1.27E-04	4.73E-05	2.41E-04	4.15E-04	9.68E-06	4.30E-04
I-134(e)	2.11E-07	2.34E-06	2.09E-07	7.78E-08	3.97E-07	6.83E-07	2.44E-06	5.68E-06
I-135(e)	1.89E-06	1.83E-06	1.65E-05	6.15E-06	3.13E-05	5.40E-05	1.34E-05	7.11E-05
Cs-134	9.39E-09	4.06E-10	3.16E-06	4.53E-06	7.45E-06	1.51E-05	9.00E-06	2.42E-05
Cs-136	1.17E-09	3.95E-10	1.79E-07	2.57E-07	4.15E-07	8.52E-07	1.47E-07	1.00E-06
Cs-137	1.22E-08	2.76E-10	6.09E-06	8.74E-06	9.89E-06	2.47E-05	4.52E-05	6.99E-05
Ba-140	6.32E-10	-	6.77E-10	1.78E-10	4.53E-08	4.61E-08	0.00E+00	4.67E-08
Ce-141	1.46E-09	-	9.66E-11	2.90E-10	5.53E-08	5.57E-08	5.16E-09	6.23E-08
Total	5.12E-04	7.42E-04	1.51E-03	5.71E-04	2.91E-03	4.99E-03	1.96E-04	6.44E-03

TABLE VI–8. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	9.66E+01							7.68E+00
C-14	2.61E-01							2.08E-02
Ar-41		3.07E+01						3.53E+00
Cr-51	2.07E-05	2.21E-06	5.30E-05	8.79E-03	7.23E-04	1.44E-03	6.82E-03	1.33E-03
Mn-54	4.94E-04	3.52E-05	1.25E-04	1.45E-03	1.14E-02	6.83E-03	1.21E+00	4.22E-02
Fe-59	6.49E-04	2.53E-05	6.51E-05	2.06E-02	1.12E-02	8.94E-03	1.16E-01	1.05E-02
Co-57	4.73E-05		9.09E-06	2.82E-05	4.70E-04	2.80E-04		2.21E-04
Co-58	5.83E-03	3.42E-04	1.59E-03	4.91E-03	8.63E-02	5.14E-02	2.64E+00	1.21E-01
Co-60	1.97E-02	2.35E-04	3.39E-03	1.05E-02	1.11E-01	6.71E-02	4.03E+01	1.28E+00
Kr-85		1.86E+01						2.15E+00
Kr-85m		6.12E-01						7.05E-02
Kr-87		2.35E+00						2.71E-01

TABLE VI–8. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Kr-88		1.60E+01						1.84E+00
Sr-89	7.30E-03	1.06E-06	2.31E-02	1.83E-02	9.58E-02	6.50E-02	4.61E-02	5.23E-02
Sr-90	5.82E-02	9.26E-08	8.17E-01	6.48E-01	7.20E-01	7.41E-01	3.10E+00	6.74E-01
Zr-95	3.41E-04	5.22E-06	1.32E-06	3.50E-07	2.26E-03	1.32E-03	7.81E-02	3.43E-03
Nb-95	4.35E-04	2.38E-05	3.51E-07	1.77E-07	5.10E-03	2.98E-03	9.16E-02	5.13E-03
Ru-103	2.94E-04	5.81E-06	4.20E-06	1.17E-03	2.68E-03	1.70E-03	2.60E-02	2.13E-03
Ru-106	2.98E-04	1.33E-07	2.23E-06	6.20E-04	1.50E-03	9.47E-04	8.20E-03	1.01E-03
Sb-125	4.23E-05	1.88E-07	1.13E-06	2.83E-05	1.88E-04	1.13E-04	2.24E-02	7.72E-04
Xe-131m		3.17E+00						3.65E-01
Xe-133		1.68E+01						1.94E+00
Xe-133m		1.91E-01						2.20E-02
Xe-135		7.13E+00						8.22E-01
Xe-135m		1.11E+00						1.28E-01
Xe-138		2.45E+00						2.82E-01
I-131	1.58E+00	1.02E-02	8.89E+01	8.75E+01	8.89E+01	8.87E+01	9.25E+00	6.92E+01
I-132(e)	7.21E-02	2.27E-01	8.00E-02	7.87E-02	7.86E-02	7.91E-02	2.37E+00	1.65E-01
I-133(e)	9.53E-01	4.96E-02	8.41E+00	8.28E+00	8.27E+00	8.32E+00	4.93E+00	6.68E+00
I-134(e)	4.12E-02	3.16E-01	1.38E-02	1.36E-02	1.36E-02	1.37E-02	1.24E+00	8.81E-02
I-135(e)	3.70E-01	2.47E-01	1.09E+00	1.08E+00	1.08E+00	1.08E+00	6.83E+00	1.10E+00
Cs-134	1.83E-03	5.48E-05	2.09E-01	7.94E-01	2.56E-01	3.03E-01	4.59E+00	3.75E-01
Cs-136	2.28E-04	5.32E-05	1.19E-02	4.50E-02	1.43E-02	1.71E-02	7.49E-02	1.55E-02
Cs-137	2.39E-03	3.71E-05	4.04E-01	1.53E+00	3.40E-01	4.95E-01	2.30E+01	1.09E+00
Ba-140	1.23E-04		4.49E-05	3.11E-05	1.55E-03	9.24E-04		7.26E-04
Ce-141	2.85E-04		6.40E-06	5.07E-05	1.90E-03	1.11E-03	2.63E-03	9.67E-04
Total	100	100	100	100	100	100	100	100

TABLE VI–9. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	1.32E-03	-	-	-	-	-	-	1.32E-03
C-14	3.57E-06	-	-	-	-	-	-	3.57E-06
Ar-41	-	6.22E-04	-	-	-	-	-	6.22E-04
Cr-51	2.83E-10	4.48E-11	1.28E-09	7.96E-08	8.33E-08	1.64E-07	3.66E-08	2.01E-07
Mn-54	6.75E-09	7.13E-10	3.00E-09	1.31E-08	1.31E-06	1.33E-06	6.48E-06	7.82E-06
Fe-59	8.87E-09	5.14E-10	1.57E-09	1.87E-07	1.30E-06	1.48E-06	6.24E-07	2.12E-06
Co-57	6.46E-10	-	2.19E-10	2.55E-10	5.41E-08	5.46E-08	-	5.52E-08
Co-58	7.97E-08	6.94E-09	3.82E-08	4.45E-08	9.94E-06	1.00E-05	1.42E-05	2.43E-05
Co-60	2.69E-07	4.76E-09	8.16E-08	9.51E-08	1.27E-05	1.29E-05	2.16E-04	2.29E-04
Kr-85	-	3.78E-04	-	-	-	-	-	3.78E-04
Kr-85m	-	1.24E-05	-	-	-	-	-	1.24E-05
Kr-87	-	4.77E-05	-	-	-	-	-	4.77E-05
Kr-88	-	3.24E-04	-	-	-	-	-	3.24E-04
Sr-89	9.97E-08	2.15E-11	5.55E-07	1.65E-07	1.10E-05	1.17E-05	2.47E-07	1.21E-05
Sr-90	7.95E-07	1.88E-12	1.97E-05	5.86E-06	6.78E-05	9.34E-05	1.66E-05	1.11E-04
Zr-95	4.65E-09	1.06E-10	3.18E-11	3.16E-12	2.61E-07	2.61E-07	4.19E-07	6.84E-07
Nb-95	5.95E-09	4.83E-10	8.46E-12	1.60E-12	5.88E-07	5.88E-07	4.91E-07	1.09E-06
Ru-103	4.02E-09	1.18E-10	1.01E-10	1.06E-08	3.09E-07	3.20E-07	1.39E-07	4.63E-07

TABLE VI–9. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Ru-106	4.07E-09	2.70E-12	5.36E-11	5.61E-09	1.73E-07	1.78E-07	4.40E-08	2.26E-07
Sb-125	5.78E-10	3.82E-12	2.72E-11	2.56E-10	2.16E-08	2.19E-08	1.20E-07	1.42E-07
Xe-131m	-	6.42E-05	-	-	-	-	-	6.42E-05
Xe-133	-	3.42E-04	-	-	-	-	-	3.42E-04
Xe-133m	-	3.87E-06	-	-	-	-	-	3.87E-06
Xe-135	-	1.45E-04	-	-	-	-	-	1.45E-04
Xe-135m	-	2.25E-05	-	-	-	-	-	2.25E-05
Xe-138	-	4.96E-05	-	-	-	-	-	4.96E-05
I-131	2.16E-05	2.07E-07	2.14E-03	7.91E-04	1.02E-02	1.32E-02	4.96E-05	1.33E-02
I-132(e)	1.19E-06	5.54E-06	2.32E-06	8.58E-07	1.09E-05	1.41E-05	1.53E-05	3.62E-05
I-133(e)	1.30E-05	1.01E-06	2.03E-04	7.49E-05	9.54E-04	1.23E-03	2.64E-05	1.27E-03
I-134(e)	9.23E-07	1.05E-05	5.47E-07	2.02E-07	2.57E-06	3.32E-06	1.09E-05	2.57E-05
I-135(e)	5.05E-06	5.00E-06	2.63E-05	9.74E-06	1.24E-04	1.60E-04	3.66E-05	2.07E-04
Cs-134	2.50E-08	1.11E-09	5.04E-06	7.18E-06	2.94E-05	4.16E-05	2.46E-05	6.62E-05
Cs-136	3.12E-09	1.08E-09	2.86E-07	4.07E-07	1.64E-06	2.34E-06	4.02E-07	2.74E-06
Cs-137	3.26E-08	7.53E-10	9.72E-06	1.38E-05	3.86E-05	6.22E-05	1.23E-04	1.86E-04
Ba-140	1.68E-09	-	1.08E-09	2.82E-10	1.79E-07	1.81E-07	-	1.82E-07
Ce-141	3.90E-09	-	1.54E-10	4.59E-10	2.19E-07	2.19E-07	1.41E-08	2.37E-07
Total	1.37E-03	2.03E-03	2.41E-03	9.05E-04	1.15E-02	1.48E-02	5.43E-04	1.88E-02

TABLE VI–10. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
H-3	9.66E+01	-	-	-	-	-	-	7.03E+00
C-14	2.61E-01	-	-	-	-	-	-	1.90E-02
Ar-41	-	3.06E+01	-	-	-	-	-	3.31E+00
Cr-51	2.07E-05	2.20E-06	5.30E-05	8.79E-03	7.23E-04	1.11E-03	6.74E-03	1.07E-03
Mn-54	4.94E-04	3.51E-05	1.25E-04	1.45E-03	1.14E-02	8.96E-03	1.19E+00	4.16E-02
Fe-59	6.49E-04	2.53E-05	6.51E-05	2.06E-02	1.13E-02	1.00E-02	1.15E-01	1.13E-02
Co-57	4.73E-05	-	9.08E-06	2.81E-05	4.70E-04	3.68E-04	-	2.94E-04
Co-58	5.83E-03	3.41E-04	1.59E-03	4.91E-03	8.63E-02	6.76E-02	2.61E+00	1.29E-01
Co-60	1.97E-02	2.34E-04	3.39E-03	1.05E-02	1.10E-01	8.67E-02	3.98E+01	1.22E+00
Kr-85	-	1.86E+01	-	-	-	-	-	2.01E+00
Kr-85m	-	6.10E-01	-	-	-	-	-	6.61E-02
Kr-87	-	2.35E+00	-	-	-	-	-	2.54E-01
Kr-88	-	1.59E+01	-	-	-	-	-	1.72E+00
Sr-89	7.29E-03	1.06E-06	2.30E-02	1.83E-02	9.54E-02	7.90E-02	4.55E-02	6.42E-02
Sr-90	5.81E-02	9.24E-08	8.17E-01	6.48E-01	5.89E-01	6.30E-01	3.06E+00	5.90E-01
Zr-95	3.41E-04	5.21E-06	1.32E-06	3.49E-07	2.26E-03	1.76E-03	7.71E-02	3.64E-03
Nb-95	4.35E-04	2.38E-05	3.51E-07	1.77E-07	5.11E-03	3.97E-03	9.04E-02	5.78E-03
Ru-103	2.94E-04	5.79E-06	4.20E-06	1.17E-03	2.69E-03	2.16E-03	2.57E-02	2.47E-03
Ru-106	2.98E-04	1.33E-07	2.23E-06	6.20E-04	1.50E-03	1.20E-03	8.09E-03	1.21E-03
Sb-125	4.23E-05	1.88E-07	1.13E-06	2.82E-05	1.88E-04	1.48E-04	2.21E-02	7.58E-04
Xe-131m	-	3.16E+00	-	-	-	-	-	3.42E-01
Xe-133	-	1.68E+01	-	-	-	-	-	1.82E+00
Xe-133m	-	1.90E-01	-	-	-	-	-	2.06E-02
Xe-135	-	7.12E+00	-	-	-	-	-	7.71E-01

TABLE VI–10. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Immersion	Ingestion			Total ingestion	External	Total dose
			Milk	Meat	Vegetables			
Xe-135m	-	1.11E+00	-	-	-	-	-	1.20E-01
Xe-138	-	2.44E+00	-	-	-	-	-	2.64E-01
I-131	1.58E+00	1.02E-02	8.89E+01	8.74E+01	8.90E+01	8.89E+01	9.13E+00	7.06E+01
I-132(e)	8.68E-02	2.73E-01	9.63E-02	9.48E-02	9.49E-02	9.51E-02	2.82E+00	1.93E-01
I-133(e)	9.52E-01	4.94E-02	8.41E+00	8.27E+00	8.28E+00	8.30E+00	4.87E+00	6.77E+00
I-134(e)	6.75E-02	5.17E-01	2.27E-02	2.23E-02	2.23E-02	2.24E-02	2.01E+00	1.37E-01
I-135(e)	3.69E-01	2.46E-01	1.09E+00	1.08E+00	1.08E+00	1.08E+00	6.75E+00	1.10E+00
Cs-134	1.83E-03	5.46E-05	2.09E-01	7.94E-01	2.55E-01	2.81E-01	4.53E+00	3.53E-01
Cs-136	2.28E-04	5.30E-05	1.19E-02	4.50E-02	1.43E-02	1.58E-02	7.40E-02	1.46E-02
Cs-137	2.39E-03	3.71E-05	4.04E-01	1.53E+00	3.35E-01	4.19E-01	2.27E+01	9.89E-01
Ba-140	1.23E-04	-	4.48E-05	3.11E-05	1.56E-03	1.22E-03	-	9.71E-04
Ce-141	2.85E-04	-	6.40E-06	5.07E-05	1.90E-03	1.48E-03	2.59E-03	1.26E-03
Total	100	100	100	100	100	100	100	100

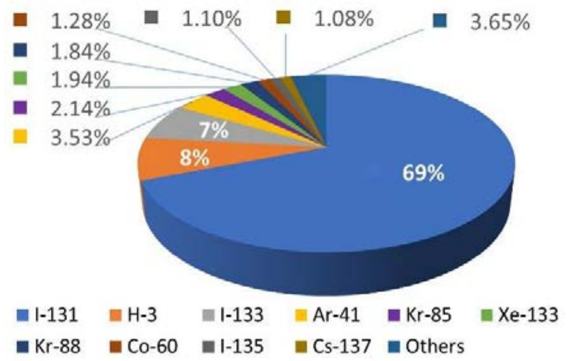

FIG. VI–1. Total dose contribution per radionuclide, %. Atmospheric case A

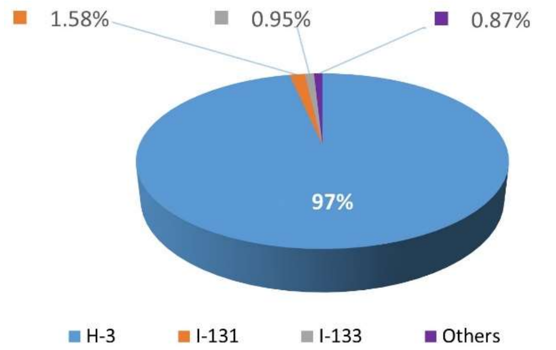

FIG. VI–2. Inhalation dose contribution per radionuclide, %. Atmospheric case A

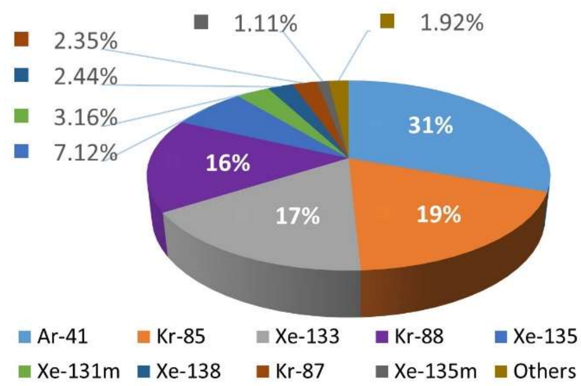

FIG. VI–3. Immersion dose contribution per radionuclide, %. Atmospheric case A

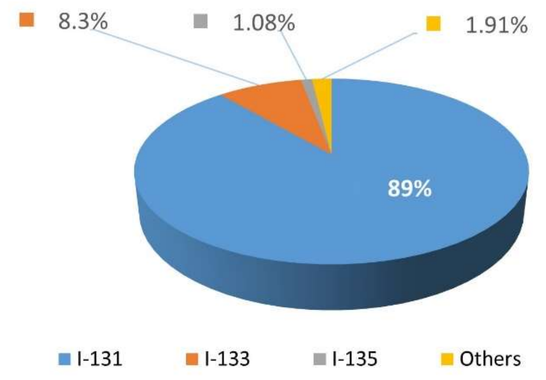

FIG. VI–4. Ingestion dose contribution per radionuclide, %. Atmospheric case A

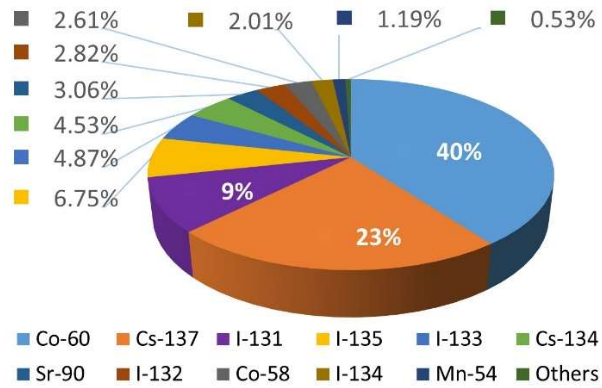

FIG. VI–5. Ground deposition contribution per radionuclide, %. Atmospheric case A

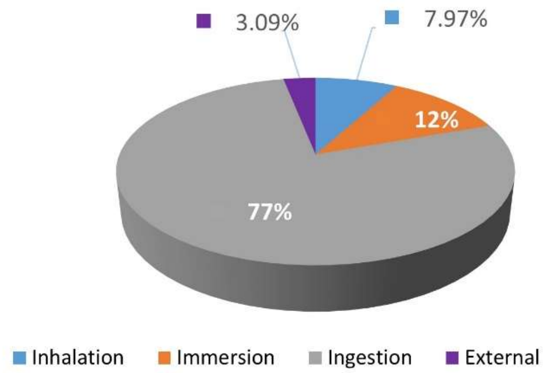

FIG. VI–6. Total dose contribution per pathway, %. Atmospheric case A

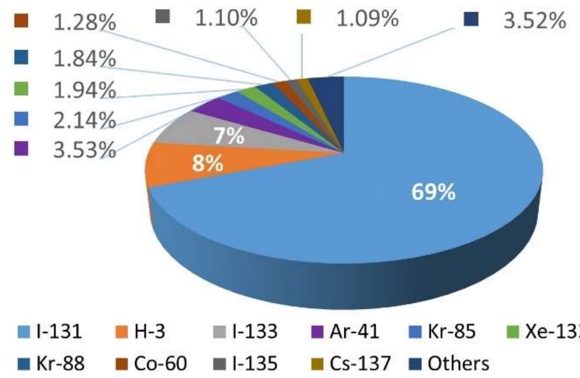

FIG. VI–7. Total dose contribution per radionuclide, %. Atmospheric case B

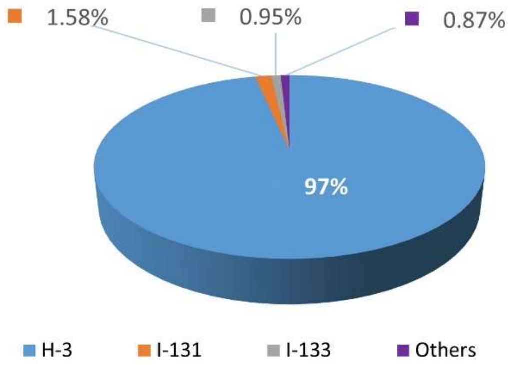

FIG. VI–8. Inhalation dose contribution per radionuclide, %. Atmospheric case B

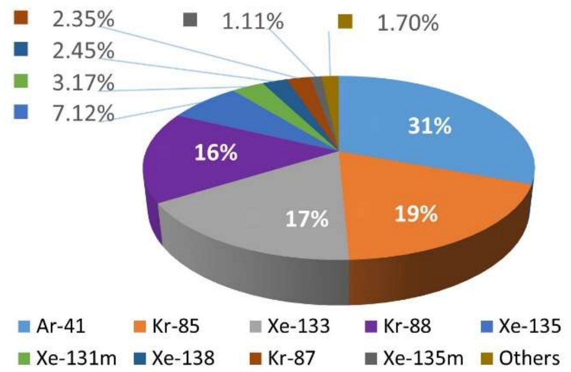

FIG. VI–9. Immersion dose contribution per radionuclide, %. Atmospheric case B

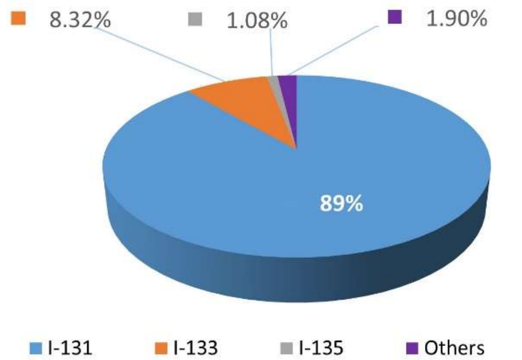

FIG. VI–10. Ingestion dose contribution per radionuclide, %. Atmospheric case B

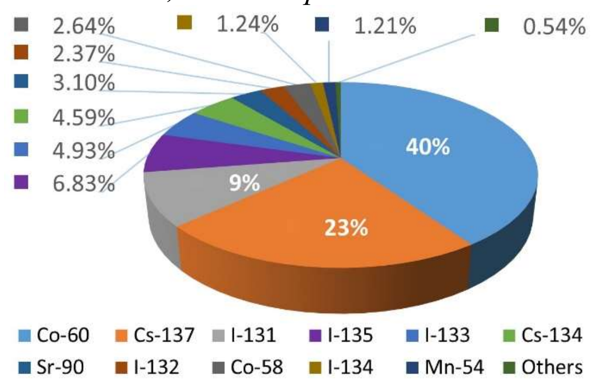

FIG. VI–11. Ground deposition contribution per radionuclide, %. Atmospheric case B

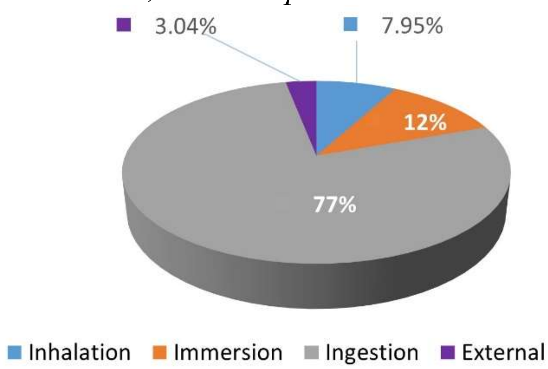

FIG. VI–12. Total dose contribution per pathway, %. Atmospheric case B

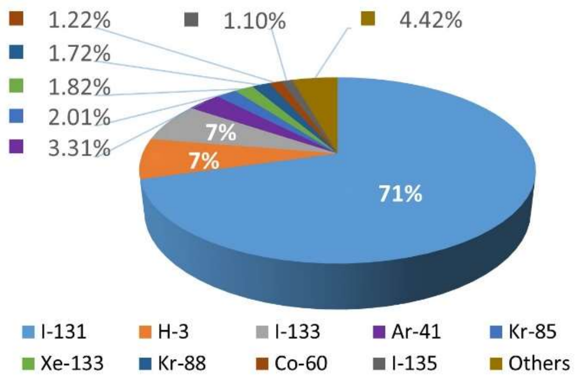

FIG. VI–13. Total dose contribution per radionuclide, %. Atmospheric case C

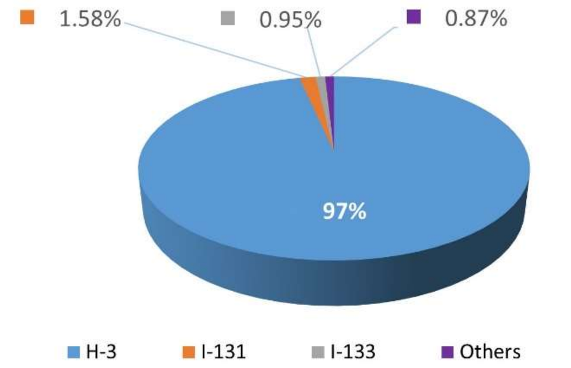

FIG. VI–14. Inhalation dose contribution per radionuclide, %. Atmospheric case C

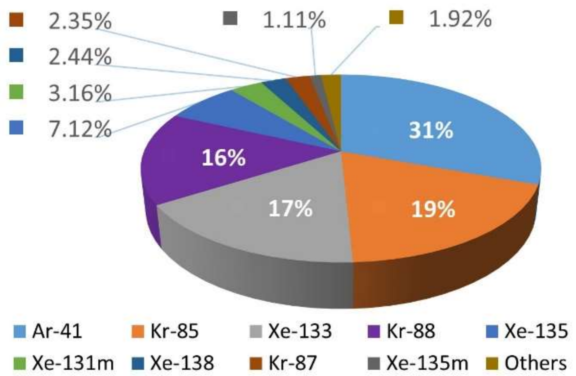

FIG. VI–15. Immersion dose contribution per radionuclide, %. Atmospheric case C

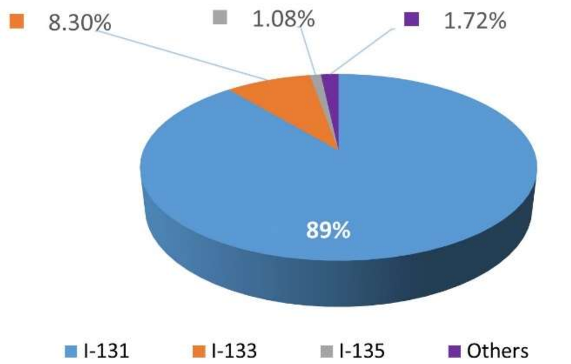

FIG. VI–16. Ingestion dose contribution per radionuclide, %. Atmospheric case C

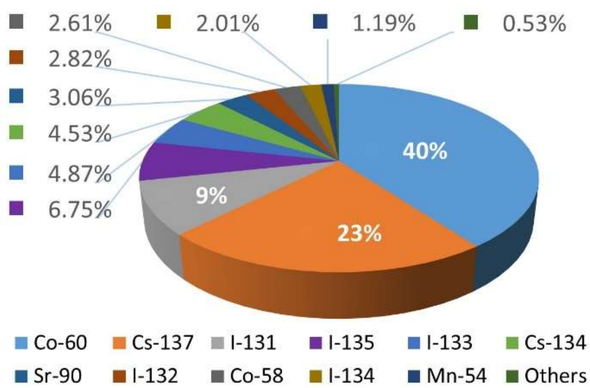

FIG. VI–17. Ground deposition contribution per radionuclide, %. Atmospheric case C

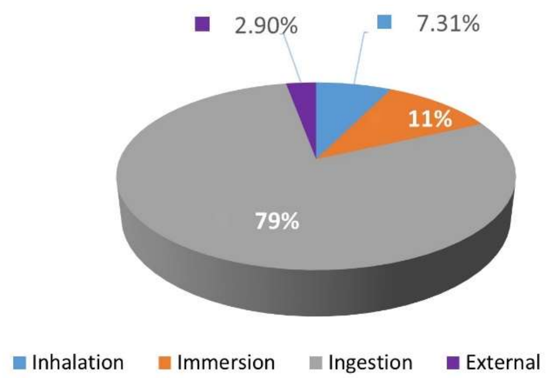

FIG. VI–18. Total dose contribution per pathway, %. Atmospheric case C

TABLE VI–11. RANKING BASED ON CONTRIBUTION OF EACH RADIONUCLIDE TO THE TOTAL DOSE FOR ALL PATHWAYS. ATMOSPHERIC CASE A

Rank	Rank category	Radionuclide	Dose, µSv/a	Contribution, %
1	B	I-131	1.22E-02	69.1
2	F	H-3	1.35E-03	7.7
3	F	I-133	1.18E-03	6.7
4	G	Ar-41	6.22E-04	3.5
5	G	Kr-85	3.78E-04	2.1
6	G	Xe-133	3.42E-04	1.9
7	G	Kr-88	3.24E-04	1.8
8	G	Co-60	2.26E-04	1.3
9	G	I-135	1.94E-04	1.1
10	G	Cs-137	1.91E-04	1.1
11	G	Xe-135	1.45E-04	0.8
12	G	Sr-90	1.19E-04	0.7

TABLE VI–12. RANKING BASED ON CONTRIBUTION OF EACH RADIONUCLIDE TO THE TOTAL DOSE FOR ALL PATHWAYS. ATMOSPHERIC CASE B

Rank	Rank category	Radionuclide	Dose, µSv/a	Contribution, %
1	B	I-131	4.46E-03	69.2
2	F	H-3	4.95E-04	7.7
3	F	I-133	4.30E-04	6.7
4	G	Ar-41	2.28E-04	3.5
5	G	Kr-85	1.38E-04	2.1
6	G	Xe-133	1.25E-04	1.9
7	G	Kr-88	1.18E-04	1.8
8	G	Co-60	8.26E-05	1.3
9	G	I-135	7.11E-05	1.1
10	G	Cs-137	6.99E-05	1.1
11	G	Xe-135	5.29E-05	0.8
12	G	Sr-90	4.34E-05	0.7

TABLE VI–13. RANKING BASED ON CONTRIBUTION OF EACH RADIONUCLIDE TO THE TOTAL DOSE FOR ALL PATHWAYS. ATMOSPHERIC CASE C

Rank	Rank category	Radionuclide	Dose, µSv/a	Contribution, %
1	B	I-131	1.33E-02	70.6
2	F	H-3	1.32E-03	7.0
3	F	I-133	1.27E-03	6.8
4	G	Ar-41	6.22E-04	3.3
5	G	Kr-85	3.78E-04	2.0
6	G	Xe-133	3.42E-04	1.8
7	G	Kr-88	3.24E-04	1.7
8	G	Co-60	2.29E-04	1.2
9	G	I-135	2.07E-04	1.1
10	G	Cs-137	1.86E-04	1.0
11	G	Xe-135	1.45E-04	0.8
12	G	Sr-90	1.11E-04	0.6

TABLE VI–14. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE A

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.66E+01	Ar-41	3.06E+01	I-131	8.87E+01	Co-60	3.98E+01
2	I-131	1.58E+00	Kr-85	1.86E+01	I-133	8.31E+00	Cs-137	2.27E+01
3	I-133	9.52E-01	Xe-133	1.68E+01	I-135	1.08E+00	I-131	9.13E+00
4	I-135	3.69E-01	Kr-88	1.59E+01	Sr-90	7.41E-01	I-135(e)	6.75E+00
5	C-14	2.61E-01	Xe-135	7.12E+00	Cs-137	4.95E-01	I-133(e)	4.87E+00
6	I-132	8.68E-02	Xe-131m	3.16E+00	Cs-134	3.03E-01	Cs-134	4.53E+00
7	I-134	6.75E-02	Xe-138	2.44E+00	I-132	9.52E-02	Sr-90	3.06E+00
8	Sr-90	5.81E-02	Kr-87	2.35E+00	Co-60	6.71E-02	I-132(e)	2.82E+00
9	Co-60	1.97E-02	Xe-135m	1.11E+00	Sr-89	6.49E-02	Co-58	2.61E+00
10	Sr-89	7.29E-03	Kr-85m	6.10E-01	Co-58	5.14E-02	I-134(e)	2.01E+00
11	Co-58	5.83E-03	I-134	5.17E-01	I-134	2.24E-02	Mn-54	1.19E+00
12	Cs-137	2.39E-03	I-132	2.73E-01	Cs-136	1.71E-02	Fe-59	1.15E-01
13	Cs-134	1.83E-03	I-135	2.46E-01	Fe-59	8.94E-03	Nb-95	9.04E-02
14	Fe-59	6.49E-04	Xe-133m	1.90E-01	Mn-54	6.83E-03	Zr-95	7.71E-02
15	Mn-54	4.94E-04	I-133	4.94E-02	Nb-95	2.98E-03	Cs-136	7.40E-02
16	Nb-95	4.35E-04	I-131	1.02E-02	Ru-103	1.70E-03	Sr-89	4.55E-02
17	Zr-95	3.41E-04	Co-58	3.41E-04	Cr-51	1.44E-03	Ru-103	2.57E-02
18	Ru-106	2.98E-04	Co-60	2.34E-04	Zr-95	1.32E-03	Sb-125	2.21E-02
19	Ru-103	2.94E-04	Cs-134	5.46E-05	Ce-141	1.11E-03	Ru-106	8.09E-03
20	Ce-141	2.85E-04	Cs-136	5.30E-05	Ru-106	9.47E-04	Cr-51	6.74E-03
21	Cs-136	2.28E-04	Cs-137	3.71E-05	Ba-140	9.23E-04	Ce-141	2.59E-03
22	Ba-140	1.23E-04	Mn-54	3.51E-05	Co-57	2.80E-04		
23	Co-57	4.73E-05	Fe-59	2.53E-05	Sb-125	1.13E-04		
24	Sb-125	4.23E-05	Nb-95	2.38E-05				
25	Cr-51	2.07E-05	Ru-103	5.79E-06				
26			Zr-95	5.21E-06				
27			Cr-51	2.20E-06				
28			Sr-89	1.06E-06				
29			Sb-125	1.88E-07				
30			Ru-106	1.33E-07				
31			Sr-90	9.24E-08				

TABLE VI–15. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE B

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.66E+01	Ar-41	3.07E+01	I-131	8.87E+01	Co-60	4.03E+01
2	I-131	1.58E+00	Kr-85	1.86E+01	I-133	8.31E+00	Cs-137	2.30E+01
3	I-133	9.53E-01	Xe-133	1.68E+01	I-135	1.08E+00	I-131	9.25E+00
4	I-135	3.70E-01	Kr-88	1.60E+01	Sr-90	7.41E-01	I-135	6.83E+00
5	C-14	2.61E-01	Xe-135	7.13E+00	Cs-137	4.95E-01	I-133	4.93E+00
6	I-132	7.21E-02	Xe-131m	3.17E+00	Cs-134	3.03E-01	Cs-134	4.59E+00
7	I-134	5.82E-02	Xe-138	2.45E+00	I-132	9.52E-02	Sr-90	3.10E+00
8	Sr-90	4.12E-02	Kr-87	2.35E+00	Co-60	6.71E-02	I-132	2.64E+00
9	Co-60	1.97E-02	Xe-135m	1.11E+00	Sr-89	6.49E-02	Co-58	2.37E+00
10	Sr-89	7.30E-03	Kr-85m	6.12E-01	Co-58	5.14E-02	I-134	1.24E+00
11	Co-58	5.83E-03	I-134	3.16E-01	I-134	2.24E-02	Mn-54	1.21E+00

TABLE VI–15. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE B (cont.)

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
12	Cs-137	2.39E-03	I-132	2.47E-01	Cs-136	1.71E-02	Fe-59	1.16E-01
13	Cs-134	1.83E-03	I-135	2.27E-01	Fe-59	8.94E-03	Nb-95	9.16E-02
14	Fe-59	6.49E-04	Xe-133m	1.91E-01	Mn-54	6.83E-03	Zr-95	7.81E-02
15	Mn-54	4.94E-04	I-133	4.96E-02	Nb-95	2.98E-03	Cs-136	7.49E-02
16	Nb-95	4.35E-04	I-131	1.02E-02	Ru-103	1.70E-03	Sr-89	4.61E-02
17	Zr-95	3.41E-04	Co-58	3.42E-04	Cr-51	1.44E-03	Ru-103	2.60E-02
18	Ru-106	2.98E-04	Co-60	2.35E-04	Zr-95	1.32E-03	Sb-125	2.24E-02
19	Ru-103	2.94E-04	Cs-134	5.48E-05	Ce-141	1.11E-03	Ru-106	8.20E-03
20	Ce-141	2.85E-04	Cs-136	5.32E-05	Ru-106	9.47E-04	Cr-51	6.82E-03
21	Cs-136	2.28E-04	Cs-137	3.71E-05	Ba-140	9.23E-04	Ce-141	2.63E-03
22	Ba-140	1.23E-04	Mn-54	3.52E-05	Co-57	2.80E-04		
23	Co-57	4.73E-05	Fe-59	2.53E-05	Sb-125	1.13E-04		
24	Sb-125	4.23E-05	Nb-95	2.38E-05				
25	Cr-51	2.07E-05	Ru-103	5.81E-06				
26			Zr-95	5.22E-06				
27			Cr-51	2.21E-06				
28			Sr-89	1.06E-06				
29			Sb-125	1.88E-07				
30			Ru-106	1.33E-07				
31			Sr-90	9.26E-08				

TABLE VI–16. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.66E+01	Ar-41	3.06E+01	I-131	8.89E+01	Co-60	3.98E+01
2	I-131	1.58E+00	Kr-85	1.86E+01	I-133	8.30E+00	Cs-137	2.27E+01
3	I-133	9.52E-01	Xe-133	1.68E+01	I-135	1.08E+00	I-131	9.13E+00
4	I-135	3.69E-01	Kr-88	1.59E+01	Sr-90	6.30E-01	I-135	6.75E+00
5	C-14	2.61E-01	Xe-135	7.12E+00	Cs-137	4.19E-01	I-133	4.87E+00
6	I-132	8.68E-02	Xe-131m	3.16E+00	Cs-134	2.81E-01	Cs-134	4.53E+00
7	I-134	6.75E-02	Xe-138	2.44E+00	I-132	9.51E-02	Sr-90	3.06E+00
8	Sr-90	5.81E-02	Kr-87	2.35E+00	Co-60	8.67E-02	I-132	2.82E+00
9	Co-60	1.97E-02	Xe-135m	1.11E+00	Sr-89	7.90E-02	Co-58	2.61E+00
10	Sr-89	7.29E-03	Kr-85m	6.10E-01	Co-58	6.76E-02	I-134	2.01E+00
11	Co-58	5.83E-03	I-134(e)	5.17E-01	I-134	2.24E-02	Mn-54	1.19E+00
12	Cs-137	2.39E-03	I-132(e)	2.73E-01	Cs-136	1.58E-02	Fe-59	1.15E-01
13	Cs-134	1.83E-03	I-135(e)	2.46E-01	Fe-59	1.00E-02	Nb-95	9.04E-02
14	Fe-59	6.49E-04	Xe-133m	1.90E-01	Mn-54	8.96E-03	Zr-95	7.71E-02
15	Mn-54	4.94E-04	I-133(e)	4.94E-02	Nb-95	3.97E-03	Cs-136	7.40E-02
16	Nb-95	4.35E-04	I-131	1.02E-02	Ru-103	2.16E-03	Sr-89	4.55E-02
17	Zr-95	3.41E-04	Co-58	3.41E-04	Zr-95	1.76E-03	Ru-103	2.57E-02
18	Ru-106	2.98E-04	Co-60	2.34E-04	Ce-141	1.48E-03	Sb-125	2.21E-02
19	Ru-103	2.94E-04	Cs-134	5.46E-05	Ba-140	1.22E-03	Ru-106	8.09E-03
20	Ce-141	2.85E-04	Cs-136	5.30E-05	Ru-106	1.20E-03	Cr-51	6.74E-03
21	Cs-136	2.28E-04	Cs-137	3.71E-05	Cr-51	1.11E-03	Ce-141	2.59E-03
22	Ba-140	1.23E-04	Mn-54	3.51E-05	Co-57	3.68E-04		

TABLE VI–16. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C (cont.)

Rank	Inhalation		Immersion		Ingestion		External exposure	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
23	Co-57	4.73E-05	Fe-59	2.53E-05	Sb-125	1.48E-04		
24	Sb-125	4.23E-05	Nb-95	2.38E-05				
25	Cr-51	2.07E-05	Ru-103	5.79E-06				
26			Zr-95	5.21E-06				
27			Cr-51	2.20E-06				
28			Sr-89	1.06E-06				
29			Sb-125	1.88E-07				
30			Ru-106	1.33E-07				
31			Sr-90	9.24E-08				

Within the exercise, comparing the results of atmospheric cases A, B and C shows that using the point sampling approach, radionuclide ranks in case B do not differ from case A, but the absolute dose values do differ. Using Russian data on human diets, breathing rate and transfer coefficients (within case C) had little influence on the ranking results. Ranks of the main dose-forming radionuclides remained unchanged.

Table VI–17 gives the results of dose calculations (from ingestion of marine fish and shellfish) and percentage contribution of each radionuclide for the marine case A. Table VI–18 gives the results of dose calculations only from ingestion of marine fish and percentage contribution of each radionuclide for the marine case B. Figures VI–19 to VI-22 illustrate results provided in Tables VI–17 and VI–18. Table VI–19 provides the ranking of radionuclides based on their contribution to the total dose in the marine cases A and B.

The radionuclide ranking in marine case B significantly differs from that of marine case A. This is caused by the two reasons. The values of radionuclide bioaccumulation factors in fish reported in the Russian methodological guides differ from data used in the marine case A. The estimations in marine case B did not include the consumption of shellfish, since this product was not presented in the human diet (neither the Russian average, nor regional data).

TABLE VI–17. DOSE AND CONTRIBUTION FROM EACH RADIONUCLIDE, MARINE CASE A

Nuclide	Dose from ingestion of		Total dose, µSv/a	Contribution to dose from		Contribution to total dose, %
	Fish, µSv/a	Shellfish, µSv/a		Fish, %	Shellfish, %	
Na-24	9.02E-09	8.12E-09	1.71E-08	1.09E-04	2.07E-05	3.61E-05
P-32	3.57E-04	7.13E-05	4.28E-04	4.29E+00	1.82E-01	9.02E-01
Cr-51	2.51E-06	3.02E-06	5.53E-06	3.03E-02	7.70E-03	1.17E-02
Mn-54	6.04E-05	2.26E-04	2.87E-04	7.27E-01	5.78E-01	6.04E-01
Fe-55	2.73E-04	9.02E-04	1.17E-03	3.29E+00	2.30E+00	2.48E+00
Fe-59	4.31E-04	1.42E-03	1.85E-03	5.18E+00	3.63E+00	3.90E+00
Co-58	3.88E-04	5.82E-04	9.69E-04	4.67E+00	1.49E+00	2.04E+00
Co-60	1.41E-03	2.11E-03	3.52E-03	1.69E+01	5.39E+00	7.41E+00
Ni-63	7.04E-06	4.22E-06	1.13E-05	8.47E-02	1.08E-02	2.37E-02
Zn-65	1.29E-04	1.94E-03	2.07E-03	1.56E+00	4.95E+00	4.35E+00
Br-84	4.20E-11	4.20E-11	8.40E-11	5.06E-07	1.07E-07	1.77E-07
Rb-88	2.15E-10	1.29E-11	2.28E-10	2.59E-06	3.30E-08	4.81E-07
Sr-89	5.89E-08	1.77E-08	7.66E-08	7.09E-04	4.51E-05	1.61E-04
Sr-90	6.47E-08	1.94E-08	8.42E-08	7.80E-04	4.96E-05	1.77E-04
Sr-91	3.01E-09	9.03E-10	3.92E-09	3.63E-05	2.31E-06	8.25E-06

TABLE VI–17. DOSE AND CONTRIBUTION FROM EACH RADIONUCLIDE, MARINE CASE A (cont.)

Nuclide	Dose from ingestion of		Total	Contribution to dose from		Contribution
	Fish, μSv/a	Shellfish, μSv/a	dose, μSv/a	Fish, %	Shellfish, %	to total dose, %
Y-90	2.50E-08	3.74E-07	3.99E-07	3.00E-04	9.56E-04	8.41E-04
Y-91m	1.04E-10	1.56E-09	1.66E-09	1.25E-06	3.97E-06	3.50E-06
Y-91	1.32E-07	1.99E-06	2.12E-06	1.59E-03	5.07E-03	4.46E-03
Y-93	2.52E-07	3.78E-06	4.03E-06	3.04E-03	9.66E-03	8.50E-03
Zr-95	1.05E-06	7.86E-05	7.96E-05	1.26E-02	2.01E-01	1.68E-01
Nb-95	1.25E-06	1.25E-05	1.37E-05	1.50E-02	3.19E-02	2.89E-02
Mo-99	9.79E-07	2.94E-06	3.92E-06	1.18E-02	7.50E-03	8.25E-03
Tc-99m	8.38E-08	8.38E-07	9.22E-07	1.01E-03	2.14E-03	1.94E-03
Ru-103	6.84E-07	2.05E-04	2.06E-04	8.24E-03	5.24E-01	4.34E-01
Ru-106	8.88E-05	2.67E-02	2.67E-02	1.07E+00	6.81E+01	5.64E+01
Rh-103m	1.78E-07	5.35E-07	7.13E-07	2.15E-03	1.37E-03	1.50E-03
Rh-106m	9.45E-05	2.84E-04	3.78E-04	1.14E+00	7.24E-01	7.97E-01
Ag-110m	1.66E-04	9.96E-04	1.16E-03	2.00E+00	2.54E+00	2.45E+00
Sb-124	1.19E-05	3.56E-06	1.54E-05	1.43E-01	9.08E-03	3.25E-02
Te-129m	1.07E-06	1.07E-05	1.17E-05	1.28E-02	2.72E-02	2.47E-02
Te-129	7.70E-09	7.70E-08	8.47E-08	9.27E-05	1.97E-04	1.78E-04
Te-131	7.73E-10	7.73E-09	8.51E-09	9.31E-06	1.98E-05	1.79E-05
Te-131m	9.43E-07	9.43E-06	1.04E-05	1.14E-02	2.41E-02	2.18E-02
Te-132	5.59E-06	5.59E-05	6.15E-05	6.74E-02	1.43E-01	1.30E-01
I-131	1.15E-03	3.44E-04	1.49E-03	1.38E+01	8.79E-01	3.14E+00
I-132	4.47E-07	1.34E-07	5.81E-07	5.38E-03	3.42E-04	1.22E-03
I-133	1.13E-04	3.40E-05	1.47E-04	1.36E+00	8.68E-02	3.10E-01
I-134	1.91E-08	5.72E-09	2.48E-08	2.29E-04	1.46E-05	5.22E-05
I-135	9.76E-06	2.93E-06	1.27E-05	1.18E-01	7.48E-03	2.67E-02
Cs-134	1.79E-03	1.61E-04	1.95E-03	2.15E+01	4.10E-01	4.10E+00
Cs-136	1.73E-05	1.56E-06	1.89E-05	2.09E-01	3.98E-03	3.98E-02
Cs-137	1.69E-03	1.52E-04	1.84E-03	2.03E+01	3.88E-01	3.88E+00
Ba-135m	4.24E-16	1.27E-17	4.37E-16	5.11E-12	3.25E-14	9.21E-13
Ba-140	1.86E-05	5.58E-07	1.92E-05	2.24E-01	1.42E-03	4.04E-02
Ce-141	5.47E-07	1.64E-05	1.70E-05	6.59E-03	4.19E-02	3.58E-02
Ce-143	1.92E-06	5.75E-05	5.94E-05	2.31E-02	1.47E-01	1.25E-01
Ce-144	9.33E-05	2.80E-03	2.89E-03	1.12E+00	7.15E+00	6.09E+00
Np-239	3.91E-07	4.69E-06	5.08E-06	4.70E-03	1.20E-02	1.07E-02
TOTAL	8.30E-03	3.91E-02	4.75E-02	100	100	100

TABLE VI–18. DOSE FROM INGESTION OF FISH AND CONTRIBUTION FROM EACH RADIONUCLIDE, MARINE CASE B

Radionuclide	Dose, μSv/a	Contribution, %	Radionuclide	Dose, μSv/a	Contribution, %
H-3(HTO)	7.75E-11	4.19E+00	Ru-106	5.33E-11	2.88E+00
Na-24	1.52E-15	8.19E-05	Rh-103m	4.28E-14	2.31E-03
P-32	3.42E-12	1.85E-01	Rh-106m	2.27E-11	1.23E+00
Cr-51	2.11E-13	1.14E-02	Ag-110m	7.97E-12	4.31E-01
Mn-54	1.09E-11	5.87E-01	Sb-124	6.40E-13	3.46E-02
Fe-55	2.19E-11	1.18E+00	Te-129m	2.56E-13	1.38E-02
Fe-59	3.44E-11	1.86E+00	Te-129	1.85E-15	9.98E-05
Co-58	2.79E-12	1.51E-01	Te-131	1.86E-16	1.00E-05
Co-60	1.01E-11	5.48E-01	Te-131m	2.26E-13	1.22E-02

TABLE VI–18. DOSE FROM INGESTION OF FISH AND CONTRIBUTION FROM EACH RADIONUCLIDE, MARINE CASE B (cont.)

Radionuclide	Dose, μSv/a	Contribution, %	Radionuclide	Dose, μSv/a	Contribution, %
Ni-63	1.69E-12	9.13E-02	Te-132	1.34E-12	7.26E-02
Zn-65	2.79E-11	1.51E+00	I-131	2.75E-10	1.49E+01
Br-84	1.01E-17	5.45E-07	I-132	1.07E-13	5.80E-03
Rb-88	5.17E-17	2.79E-06	I-133	2.72E-11	1.47E+00
Sr-89	1.41E-14	7.64E-04	I-134	4.57E-15	2.47E-04
Sr-90	1.55E-14	8.40E-04	I-135	2.34E-12	1.27E-01
Sr-91	7.23E-16	3.91E-05	Cs-134	6.43E-10	3.47E+01
Y-90	5.99E-15	3.24E-04	Cs-136	6.24E-12	3.37E-01
Y-91m	2.49E-17	1.35E-06	Cs-137	6.07E-10	3.28E+01
Y-91	3.18E-14	1.72E-03	Ba-135m	1.02E-22	5.51E-12
Y-93	6.05E-14	3.27E-03	Ba-140	4.46E-12	2.41E-01
Zr-95	2.52E-13	1.36E-02	Ce-141	2.63E-14	1.42E-03
Nb-95	9.98E-13	5.39E-02	Ce-143	9.20E-14	4.97E-03
Mo-99	2.35E-13	1.27E-02	Ce-144	4.48E-12	2.42E-01
Tc-99m	2.01E-14	1.09E-03	Np-239	9.38E-14	5.07E-03
Ru-103	4.11E-13	2.22E-02	Total	1.85E-09	1.00E+02

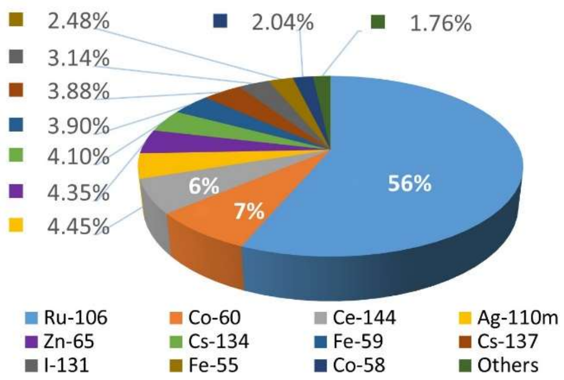

FIG. VI–19. Contribution of radionuclides to the dose from ingestion. Marine case A

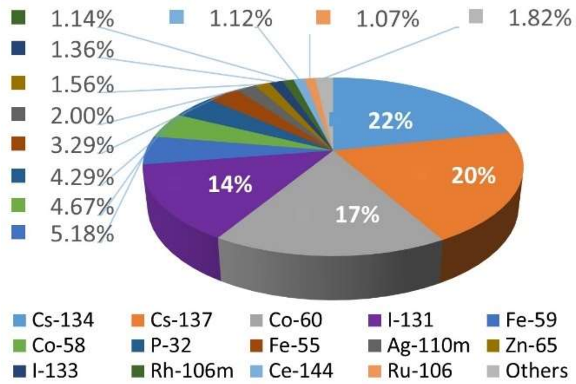

FIG. VI–20. Contribution of radionuclides to the dose from ingestion of fish. Marine case A

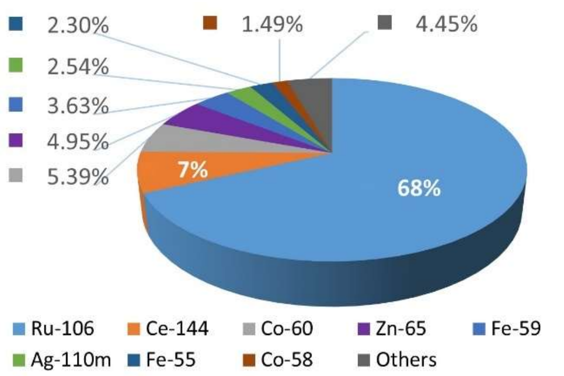

FIG. VI–21. Contribution of radionuclides to the dose from shellfish ingestion. Marine case A

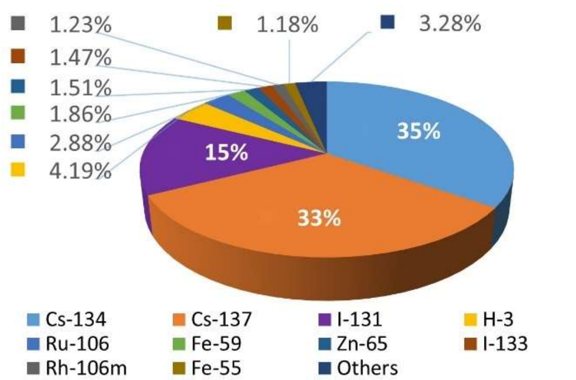

FIG. VI–22. Contribution of radionuclides to the total dose. Marine case B

TABLE VI–19. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM INGESTION, MARINE CASES A AND B

Rank	Marine case A		Marine case B	
	Radionculide	Contribution, %	Radionculide	Contribution, %
1	Ru-106	5.64E+01	Cs-134	3.47E+01
2	Co-60	7.41E+00	Cs-137	3.28E+01
3	Ce-144	6.09E+00	I-131	1.49E+01
4	Zn-65	4.35E+00	H-3(HTO)	4.19E+00
5	Cs-134	4.10E+00	Ru-106	2.88E+00
6	Fe-59	3.90E+00	Fe-59	1.86E+00
7	Cs-137	3.88E+00	Zn-65	1.51E+00
8	I-131	3.14E+00	I-133	1.47E+00
9	Fe-55	2.48E+00	Rh-106m	1.23E+00
10	Ag-110m	2.45E+00	Fe-55	1.18E+00
11	Co-58	2.04E+00	Mn-54	5.87E-01
12	P-32	9.02E-01	Co-60	5.48E-01
13	Rh-106m	7.97E-01	Ag-110m	4.31E-01
14	Mn-54	6.04E-01	Cs-136	3.37E-01
15	Ru-103	4.34E-01	Ce-144	2.42E-01
16	I-133	3.10E-01	Ba-140	2.41E-01
17	Zr-95	1.68E-01	P-32	1.85E-01
18	Te-132	1.30E-01	Co-58	1.51E-01
19	Ce-143	1.25E-01	I-135	1.27E-01
20	Ba-140	4.04E-02	Ni-63	9.13E-02
21	Cs-136	3.98E-02	Te-132	7.26E-02
22	Ce-141	3.58E-02	Nb-95	5.39E-02
23	Sb-124	3.25E-02	Sb-124	3.46E-02
24	Nb-95	2.89E-02	Ru-103	2.22E-02
25	I-135	2.67E-02	Te-129m	1.38E-02
26	Te-129m	2.47E-02	Zr-95	1.36E-02
27	Ni-63	2.37E-02	Mo-99	1.27E-02
28	Te-131m	2.18E-02	Te-131m	1.22E-02
29	Cr-51	1.17E-02	Cr-51	1.14E-02
30	Np-239	1.07E-02	I-132	5.80E-03
31	Y-93	8.50E-03	Np-239	5.07E-03
32	Mo-99	8.25E-03	Ce-143	4.97E-03
33	Y-91	4.46E-03	Y-93	3.27E-03
34	Tc-99m	1.94E-03	Rh-103m	2.31E-03
35	Rh-103m	1.50E-03	Y-91	1.72E-03
36	I-132	1.22E-03	Ce-141	1.42E-03
37	Y-90	8.41E-04	Tc-99m	1.09E-03
38	Te-129	1.78E-04	Sr-90	8.40E-04
39	Sr-90	1.77E-04	Sr-89	7.64E-04
40	Sr-89	1.61E-04	Y-90	3.24E-04
41	I-134	5.22E-05	I-134	2.47E-04
42	Na-24	3.61E-05	Te-129	9.98E-05
43	Te-131	1.79E-05	Na-24	8.19E-05
44	Sr-91	8.25E-06	Sr-91	3.91E-05
45	Y-91m	3.50E-06	Te-131	1.00E-05
46	Rb-88	4.81E-07	Rb-88	2.79E-06
47	Br-84	1.77E-07	Y-91m	1.35E-06
48	Ba-135m	9.21E-13	Br-84	5.45E-07
49	-	-	Ba-135m	5.51E-12

Table VI–20 presents the results of dose calculations (absolute values) and percentage contribution of radionuclides in the riverine cases A and B. Table VI–21 provides the ranking of radionuclides based on contribution to the total dose in the riverine cases A and B. Figures VI–23 and VI–24 illustrate results provided in Table VI–20. The radionuclide ranking within riverine case B differs from that within riverine case A, since values of bioaccumulation factors in fish reported in the Russian methodological guides differ from that used in the riverine case A.

TABLE VI–20. ANNUAL DOSES AND CONTRIBUTIONS TO THE TOTAL DOSE FROM RADIONUCLIDES. RIVERINE CASES A AND B

	Riverine case A			Riverine case B	
Radionuclide	Dose, µSv/a	Contribution, %	Radionuclide	Dose, µSv/a	Contribution, %
-	-	-	H-3	6.00E-10	3.87E+00
Cr-51	6.33E-06	6.50E-03	Cr-51	2.53E-12	1.63E-02
Mn-54	5.25E-05	5.40E-02	Mn-54	1.87E-11	1.21E-01
Fe-59	6.12E-05	6.29E-02	Fe-59	3.50E-11	2.26E-01
Co-58	3.95E-05	4.05E-02	Co-58	1.18E-11	7.64E-02
Co-60	3.95E-04	4.06E-01	Co-60	1.19E-10	7.65E-01
Zn-65	1.04E-02	1.07E+01	Zn-65	8.88E-10	5.73E+00
Sr-90	3.32E-03	3.41E+00	Sr-90	4.19E-10	2.71E+00
Zr-95	4.24E-05	4.36E-02	Zr-95	5.36E-11	3.46E-01
Ru-106	1.50E-04	1.55E-01	Ru-106	6.02E-11	3.88E-01
I-131	3.65E-02	3.75E+01	I-131	8.98E-10	5.80E+00
Cs-134	2.20E-02	2.26E+01	Cs-134	5.86E-09	3.78E+01
Cs-137	2.43E-02	2.50E+01	Cs-137	6.48E-09	4.19E+01
Ce-144	3.71E-05	3.82E-02	Ce-144	3.71E-11	2.40E-01
Total	9.73E-02	1.00E+02	Total	1.55E-08	1.00E+02

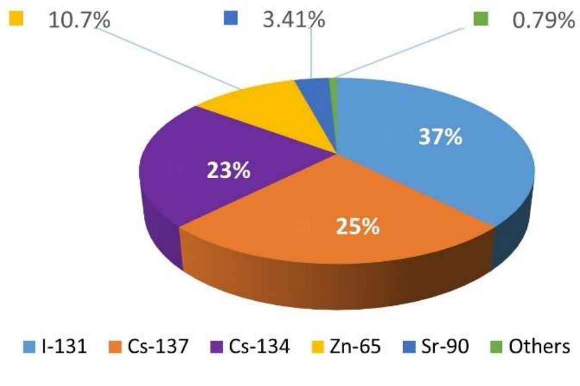

FIG. VI–23. Contribution of radionuclides to the total dose. Riverine case A

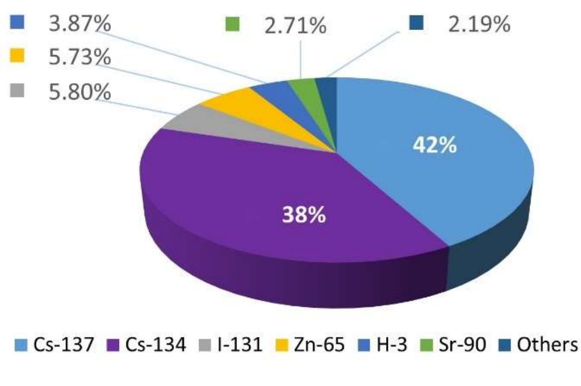

FIG. VI–24. Contribution of radionuclides to the total dose. Riverine case B

TABLE VI–21. RANKING OF RADIONUCLIDES BASED ON TOTAL DOSE CONTRIBUTION. RIVERINE CASES A AND B

Rank	Riverine case A		Riverine case B	
	Radionculide	Contribution, %	Radionculide	Contribution, %
1	I-131	3.75E+01	Cs-137	4.19E+01
2	Cs-137	2.50E+01	Cs-134	3.78E+01
3	Cs-134	2.26E+01	I-131	5.80E+00
4	Zn-65	1.07E+01	Zn-65	5.73E+00
5	Sr-90	3.41E+00	H-3	3.87E+00
6	Co-60	4.06E-01	Sr-90	2.71E+00
7	Ru-106	1.55E-01	Co-60	7.65E-01
8	Fe-59	6.29E-02	Ru-106	3.88E-01
9	Mn-54	5.40E-02	Zr-95	3.46E-01
10	Zr-95	4.36E-02	Ce-144	2.40E-01
11	Co-58	4.05E-02	Fe-59	2.26E-01
12	Ce-144	3.82E-02	Mn-54	1.21E-01
13	Cr-51	6.50E-03	Co-58	7.64E-02
14	-	-	Cr-51	1.63E-02

REFERENCES TO ANNEX VI

[VI–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment, IAEA Safety Reports Series No.19, IAEA, Vienna (2001).

[VI–2] RUSSIAN FEDERATION FEDERAL AGENCY OF MEDICAL-BIOLOGICAL PROBLEMS, RUSSIAN FEDERATION FEDERAL HYDROMETEOROLOGICAL AND ENVIRONMENTAL MONITORING SERVICE, Estimation of Permissible Radioactive Releases from Nuclear Power Plant to the Atmosphere. Methodological guide. “Rosenergoatom” concern, Moscow (2004).

[VI–3] RUSSIAN STATE ATOMIC ENERGY CORPORATION ROSATOM, NIAEP, Rostov NPP. Power Units 3, 4. Design. Part 10, Controlled access area. Vol. 1, Explanatory note (2008).

[VI–4] INTERNATIONAL ATOMIC ENERGY AGENCY, Handbook of Parameter Values for Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments, Technical Reports Series, No 472, IAEA, Vienna (2010).

[VI–5] NOSOV A.V., et al., The Methodological Guide for Establishing Permissible Radionuclide Discharges to Surface Water Bodies. Moscow (2003).

[VI–6] ALEXAKHIN R.M., SPIRIN YE.V., SAVKIN M.N., Radiation Safety of the Population and Agroindustrial Production (on Regulating Radionuclide Contents in Agricultural Products). Radiation Biology. Radioecology, **39**, 4, Moscow (1999).

ANNEX VII. UKRAINE

VII–1. DESCRIPTION OF MODELS AND METHODOLOGIES APPLIED

The models described in the IAEA SRS-19 [VII–1] were used for the calculations by Ukraine. It was agreed between the participants that the special considerations for H-3 and C-14 (as described in Ref. [VII–1]) would not be used for the calculations. This simplification resulted in 'zero' doses from H-3 and C-14 through some pathways, e.g. ingestion, and underestimation of total dose from H-3 and C-14 in this exercise. Evaluation of effects of the special considerations for H-3 and C-14 was performed in this national study and presented below.

As explained in the main report, several model parameters were changed using updated data from the IAEA TRS-422 [VII–2] and TRS-472 [VII–3]. Ref. [VII–1] provides only total consumption rate of vegetables. The consumption distribution among different types of vegetables was performed as suggested in Refs [VII–4, VII–5]. Other modifications of model parameters for cases B and C are described in section VII–2. Most of the results in this Annex are presented using two significant digits.

VII–2. STRUCTURE OF CONSIDERATION OF PUBLIC EXPOSURES FROM NORMAL OPERATION

All calculations were performed assuming 50 years of routine discharge of radionuclides. Annual committed effective doses (hereinafter – doses) were calculated for adults only. The following pathways were considered as contributing to the dose from atmospheric dispersal:

- Internal exposure due to inhalation;
- External exposure due to plume immersion;
- Internal exposure due to ingestion of contaminated food (meat, milk and vegetables);
- External exposure derived from ground deposition of radionuclides.

To minimize the potential for additional variability of results among participants, a pre-calculated χ/Q value (giving the dilution of the plume at the site located 10 km from the source; 4.705E-08 s/m^3) was applied by all participants for atmospheric cases A and C. Site-specific breathing rates, consumption and radionuclide transfer data were considered for atmospheric case C whilst applying the same source data and dispersion value as used for case A. Site-specific meteorological data (and respective χ/Q values) were used in atmospheric case B. Unlike the atmospheric cases A and C, in atmospheric case B the dose evaluations were performed at 2.5 km from the release. This distance is normally used in the national assessments of environmental impact from normal operation of Ukrainian NPPs.

In the atmospheric case A, the model parameters were taken from Ref. [VII–1] with modifications described in section VII–1. The ENV exercise task set up implies that the meteorological data will introduce the only difference between the atmospheric scenarios A and B. Dozes calculated for these two cases will differ due to the difference in the average wind speed assumed and consequently due to the different time of radionuclides transport. The latter is essential mostly for the dose from short lived radionuclides which provide relatively low contribution to the total dose. Due to this effect the doses from most important radionuclides (except Ar-41 and Kr-88) in atmospheric scenario B will be approx. proportional to the doses evaluated in the atmospheric scenario A. Scaling of the doses from Ar-41 and Kr-88 will be different however their contribution will not change essentially the whole picture. Total doses evaluated in atmospheric scenario B will be different from A, however relative contributions from different radionuclides will remain similar in both cases and ranking of radionuclides will remain essentially the same.

Unlike the atmospheric case A calculations at 10 km from the source, the evaluation of doses in the atmospheric case B using Ukrainian meteorological data was performed at 2.5 km from the source. Due to significant change of the radionuclides transport time Ar-41 and Kr-88 isotopes provide larger contribution to the total dose and rise in the ranking list. The distance selected for dose evaluation in the atmospheric case B (2.5 km) corresponds approximately to the radius of sanitary protective zones around NPPs in Ukraine and in several other countries.

Site-specific meteorological data for Rivne NPP (Ukraine) were used for atmospheric case B (see Table VII–1). The release height (stack height) was 100 m, consistent with the Brazilian meteorological data used for atmospheric case A.

TABLE VII–1. SITE-SPECIFIC JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION BY PASQUILL–GIFFORD STABILITY CLASS, %

Wind speed range, m/s	N	NE	E	SE	S	SW	W	NW	Total
				Stability class A					
1 – 3	0.4	0.5	0.4	0.4	0.2	0.3	0.4	0.4	3.0
				Stability class B					
0 – 1	1.3	1.0	1.8	2.2	1.2	1.8	2.8	1.7	13.8
1 – 3	0.9	0.6	0.8	1.2	0.5	0.5	0.8	0.7	6.0
3 – 5	0.3	0.2	0.1	0.2	0.1	0.1	0.3	0.2	1.5
				Stability class C					
1 – 3	1.9	1.5	2.1	2.3	1.4	2.0	2.8	1.9	15.9
3 – 5	0.2	0.1	0.3	0.4	0.2	0.2	0.3	0.1	1.8
5 – 7	0.1	–	0.1	0.2	0.1	0.1	0.3	0.2	1.1
				Stability class D					
1 – 3	1.2	0.8	1.0	1.0	0.7	1.2	1.6	1.3	8.8
3 – 5	0.8	0.5	1.4	1.7	0.7	1.8	3.1	1.5	11.5
5 – 7	0.3	0.1	0.7	1.0	0.2	1.0	2.0	0.7	6.0
7 – 10	0.2	–	0.3	0.2	0.1	0.4	0.7	0.4	2.3
10 – 14	0.1	–	0.1	0.1	–	0.2	0.6	0.1	1.2
14 – 18	–	–	–	–	–	–	–	–	–
20 – 24	–	–	–	–	–	–	0.2	–	0.2
				Stability class E					
1 – 3	0.4	0.5	1.1	1.9	0.8	1.3	1.4	0.7	8.1
3 – 5	–	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.9
5 – 7	–	–	–	0.1	–	–	0.1	–	0.2
				Stability class F					
1 – 3	1.6	1.4	2.7	2.9	2.2	1.9	2.8	2.0	17.5
3 – 5	–	–	0.1	–	–	–	0.1	–	0.2

The maximal χ/Q values for the site-specific meteorological data were in the west. The average wind speed from this direction was 3.36 m/s. This was 1.68 times higher than the wind speed in the atmospheric case A (2 m/s). The shorter transport time resulted in higher air concentrations and the values of relative increase (in comparison to atmospheric case A, at 10 km) are presented in Table VII–2 for distances 2.5 km and 10 km.

In comparison to atmospheric case A, in case B the doses from short-lived radionuclides in relative values notably increased. However, only the contributions of Ar-41 and Kr-88 to the total dose were non-negligible. The change of these two radionuclides concentrations is higher at closer distance (2.5 km) and theoretically, substantial changes in ranking could be expected. The χ/Q value for 2.5 km (1.78E-07 s/m^3) is 3.78 times higher than the one used in atmospheric case A at 10 km (4.705E-08 s/m^3). However, this multiplier is the same for all radionuclides. It influences the dose values; however, it cannot influence rankings.

TABLE VII–2. INCREASE OF RADIONUCLIDE CONCENTRATION IN THE AIR DUE TO THE REDUCED TRANSPORT TIME, %

Radionuclide	Increase (compared to case A), %		Radionuclide	Increase (compared to case A), %	
	2.5 km	10 km		2.5 km	10 km
Xe-138	3113	421	Ce-141	0.11	0.050
Xe-135m	2392	361	Nb-95	0.097	0.046
I-134	155	56	Ru-103	0.087	0.041
Kr-87	90	36	Fe-59	0.077	0.036
Ar-41	57	24	Sr-89	0.068	0.032
I-132	43	18	Zr-95	0.053	0.025
Kr-88	33	15	Co-58	0.048	0.023
Kr-85m	20	9.1	Co-57	0.013	0.006
I-135	13	6.1	Mn-54	0.011	0.006
Xe-135	9.4	4.4	Ru-106	0.009	0.005
I-133	4.0	1.9	Cs-134	0.005	0.004
Xe-133m	1.6	0.74	Sb-125	0.003	0.002
Xe-133	0.65	0.31	Co-60	0.002	0.002
I-131	0.43	0.20	Kr-85	0.0009	0.0008
Xe-131m	0.29	0.14	H-3	0.0008	0.0004
Ba-140	0.27	0.13	Sr-90	0.0003	0.0004
Cs-136	0.26	0.12	Cs-137	0.0003	0.0002
Cr-51	0.12	0.059	C-14	0.0000	0.0001

TABLE VII–3. ELEMENT-SPECIFIC TRANSFER FACTORS

Elements	Atmospheric case A		Atmospheric case C	
	F_m , d/l	F_f , d/kg	F_m , d/l	F_f , d/kg
H	–	–	–	–
C	–	–	–	–
Cr	4.3E-4	9.0E-2	2.0E-3	3.0E-2
Mn	4.1E-5	6.0E-4	1.0E-4	5.0E-4
Fe	3.5E-5	1.4E-2	3.0E-4	3.0E-2
Co	1.1E-4	4.3E-4	2.0E-3	3.0E-2
Sr	1.3E-3	1.3E-3	2.0E-3	3.0E-4
Zr	3.6E-6	1.2E-6	6.0E-7	1.0E-6
Nb	4.1E-7	2.6E-7	4.0E-7	3.0E-7
Ru	9.4E-6	3.3E-3	1.0E-4	1.0E-3
Sb	3.8E-5	1.2E-3	3.8E-5	1.2E-3
I	5.4E-3	6.7E-3	3.0E-3	1.0E-3
Cs	4.6E-3	2.2E-2	3.0E-3	1.0E-2
Ba	1.6E-4	1.4E-4	5.0E-4	2.0E-4
Ce	2.0E-5	2.0E-4	2.0E-5	8.0E-4

In the atmospheric case C, the annual average adult breathing rate was equal to 8108 m^3/a [VII–6, VII–7]. This is ~3.5% lower than the breathing rate provided in SRS-19 [VII–1]. This difference cannot change the ranking based on the total dose from all pathways. Compared to SRS-19 [VII–1], the national regulations [6] provide more sophisticated approach for food chain modeling. Only 'animal' element-specific transfer factors[18] from Ref. [VII–6] can be used directly in the SRS-19 procedures. The specified values used for atmospheric cases A and C are presented in Table VII–3. It should be noted that transfer factors for I were higher in

[18] Fractions of the animal's daily intake of the radionuclide that appear in each litre of milk or kg of flesh.

atmospheric case A. Table VII–4 provides a comparison of consumption rates used in atmospheric case A and those used in atmospheric case C. Latter values are defined in Ref. [VII–6] and they are lower than consumption rates from atmospheric case A.

TABLE VII–4. CONSUMPTION RATES

Foodstuff	Atmospheric case A	Atmospheric case C
Milk (cow), l/a	250	90
Meat, kg/a	100	55
All vegetables, kg/a	410	154
Green vegetables, kg/a	115	18
Root vegetables, kg/a	187	70
Domestic fruits, kg/a	108	66

In the marine discharges scenario only case A was considered. Ukraine currently has no NPPs at the seashore and country-specific data on transfer coefficients for marine discharges were not available. For the marine case A, only the dose from ingestion of contaminated fish and shellfish by adults was considered. The source terms were derived from data provided by Korea and pre-calculated concentrations of radionuclides in the water at 1 km from the discharge point were used. The ingestion dose coefficients are taken from Ref. [VII–8]. All calculated doses from Ag-110 are equal to 0 because the corresponding ingestion dose coefficient in Ref. [VII–8] is 0. SRS-19 [VII–1] does not specify the transfer factors 'water–fish' and 'water–shellfish'[19] for H-3, La-140, Pr-143, Pr-144, W-187. All calculated doses from these five radionuclides are equal to 0.

In the riverine discharge scenarios only the ingestion of contaminated fish was considered. Pre-calculated concentrations in the water at 1 km from the discharge were used for the dose assessments by all participants. These values were derived from data provided by Ukraine.

TABLE VII–5. BIOACCUMULATION FACTORS FOR FRESHWATER FISH

Element	Bioaccumulation factors, l/kg		Element	Bioaccumulation factors, l/kg	
	Riverine case A	Riverine case B		Riverine case A	Riverine case B
H	–	0.8	Zr	95	300
Cr	200	200	Nb	300	300
Mn	450	500	Ru	10	1.9
Fe	140	2 000	Ag	110	10
Co	400	300	I	650	40
Zn	4 700	1 000	Cs	3 000	1 000
Sr	190	60	Ce	12	640

In the riverine case A, the equilibrium ratios of the concentration of the radionuclides in fish (fresh weight) to their dissolved concentrations in water, i.e. transfer factors 'water–fish', were taken from SRS-19 [VII–1]. SRS-19 does not define this transfer factor for H-3 so the dose from ingestion of fish for this radionuclide was equal to 0.

In the riverine case B, the same radionuclide activity concentrations were applied as in the riverine case A. The country-specific transfer coefficients 'water–fish' from [VII–6] were used as presented in Table VII–5. Bioaccumulation factors of Cr and Nb are the same as for riverine case A. Factors of H, Mn, Fe, Zr and Ce are higher than in case A; the rest of factors are lower than in case A. According to Ref. [VII–6], the consumption of fish is 14 kg/a which is 47% of

[19] The equilibrium ratio of the concentration of radionuclide in aquatic food (fresh weight) to its dissolved concentration in water.

the value provided in SRS-19 [VII–1]. Varying the consumption rate of fish can change only the dose value and cannot affect ranking.

VII–3. RESULTS OF ASSESSMENT

Calculations were performed for atmospheric cases A, B and C. Tables VII–6, VII–8 and VII–10 provide the annual adult doses in μSv/a from individual radionuclides for each of the pathways for atmospheric cases A, B and C. Tables VII–7, VII–9 and VII–11 give the percentage contribution of each radionuclide within each pathway for atmospheric cases A, B and C. Table VII–12 gives the percentage contribution of total dose from the various pathways for all atmospheric cases A, B and C.

TABLE VII–6. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE A

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
H-3	7.8E-03	5.1E-07	-	-	-	-	-	7.8E-03
C-14	2.1E-05	3.3E-08	-	-	-	-	-	2.1E-05
Ar-41	-	2.1E-03	-	-	-	-	-	2.1E-03
Cr-51	1.7E-09	2.6E-10	8.9E-09	3.5E-07	2.3E-07	5.9E-07	1.5E-07	7.4E-07
Mn-54	4.0E-08	4.1E-09	2.8E-08	1.2E-07	4.9E-06	5.1E-06	2.6E-05	3.1E-05
Fe-59	5.2E-08	2.9E-09	1.2E-08	1.0E-06	4.1E-06	5.2E-06	2.5E-06	7.7E-06
Co-57	3.8E-09	7.2E-11	2.0E-09	2.2E-09	2.1E-07	2.1E-07	4.2E-07	6.3E-07
Co-58	4.7E-07	4.0E-08	3.1E-07	3.0E-07	3.4E-05	3.5E-05	5.7E-05	9.2E-05
Co-60	1.6E-06	2.7E-08	8.0E-07	9.3E-07	4.9E-05	5.1E-05	8.8E-04	9.4E-04
Kr-85	-	2.2E-03	-	-	-	-	-	2.2E-03
Kr-85m	-	5.7E-05	-	-	-	-	-	5.7E-05
Kr-87	-	1.3E-04	-	-	-	-	-	1.3E-04
Kr-88	-	1.3E-03	-	-	-	-	-	1.3E-03
Sr-89	5.9E-07	1.2E-10	4.2E-06	9.8E-07	3.6E-05	4.1E-05	9.8E-07	4.3E-05
Sr-90	4.7E-06	1.1E-11	2.1E-04	6.2E-05	2.8E-04	5.5E-04	4.1E-05	6.0E-04
Zr-95	2.7E-08	6.1E-10	2.5E-10	2.0E-11	8.9E-07	8.9E-07	1.7E-06	2.6E-06
Nb-95	3.5E-08	2.8E-09	6.1E-11	8.0E-12	1.8E-06	1.8E-06	2.0E-06	3.8E-06
Ru-103	2.4E-08	6.7E-10	7.4E-10	5.6E-08	9.5E-07	1.0E-06	5.6E-07	1.6E-06
Ru-106	2.4E-08	1.6E-11	5.0E-10	5.1E-08	6.7E-07	7.2E-07	1.8E-07	9.2E-07
Sb-125	3.4E-09	2.2E-11	2.6E-10	2.4E-09	8.5E-08	8.8E-08	4.8E-07	5.7E-07
Xe-131m	-	3.7E-04	-	-	-	-	-	3.7E-04
Xe-133	-	1.9E-03	-	-	-	-	-	1.9E-03
Xe-133m	-	2.2E-05	-	-	-	-	-	2.2E-05
Xe-135	-	7.5E-04	-	-	-	-	-	7.5E-04
Xe-135m	-	2.9E-06	-	-	-	-	-	2.9E-06
Xe-138	-	4.8E-06	-	-	-	-	-	4.8E-06
I-131	1.3E-04	1.2E-06	1.3E-02	9.7E-04	1.2E-02	2.6E-02	1.9E-04	2.7E-02
I-132	4.6E-06	2.1E-05	7.6E-09	5.9E-69	3.0E-49	7.6E-09	4.0E-05	6.6E-05
I-133	7.3E-05	5.5E-06	6.0E-04	5.6E-11	4.9E-08	6.0E-04	1.0E-04	7.8E-04
I-134	1.8E-06	2.0E-05	7.2E-15	7.0E-172	1.4E-121	7.2E-15	1.5E-05	3.7E-05
I-135	2.6E-05	2.5E-05	1.3E-05	8.1E-27	2.1E-19	1.3E-05	1.3E-04	1.9E-04
Cs-134	1.5E-07	6.4E-09	4.8E-05	6.8E-05	1.1E-04	2.3E-04	8.6E-05	3.2E-04
Cs-136	1.8E-08	6.2E-09	1.9E-06	9.8E-07	3.1E-06	5.9E-06	1.6E-06	7.6E-06
Cs-137	1.9E-07	4.3E-09	9.9E-05	1.4E-04	1.5E-04	3.9E-04	3.0E-04	6.9E-04
Ba-140	9.9E-09	6.0E-11	7.0E-09	6.5E-10	3.3E-07	3.4E-07	2.5E-07	6.0E-07
Ce-141	2.3E-08	7.0E-11	1.1E-09	2.2E-09	6.4E-07	6.4E-07	5.6E-08	7.2E-07
Total	8.0E-03	8.9E-03	1.4E-02	1.2E-03	1.3E-02	2.8E-02	1.9E-03	4.7E-02

TABLE VII–7. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE A

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
H-3	9.7E+01	5.7E-03	-	-	-	-	-	1.6E+01
C-14	2.6E-01	3.7E-04	-	-	-	-	-	4.4E-02
Ar-41	-	2.4E+01	-	-	-	-	-	4.5E+00
Cr-51	2.1E-05	2.9E-06	6.2E-05	2.8E-02	1.8E-03	2.1E-03	7.8E-03	1.6E-03
Mn-54	4.9E-04	4.6E-05	1.9E-04	9.3E-03	3.9E-02	1.8E-02	1.4E+00	6.5E-02
Fe-59	6.5E-04	3.3E-05	8.1E-05	8.4E-02	3.2E-02	1.8E-02	1.3E-01	1.6E-02
Co-57	4.7E-05	8.1E-07	1.4E-05	1.8E-04	1.6E-03	7.4E-04	2.2E-02	1.3E-03
Co-58	5.8E-03	4.4E-04	2.1E-03	2.4E-02	2.7E-01	1.2E-01	3.0E+00	2.0E-01
Co-60	2.0E-02	3.1E-04	5.6E-03	7.5E-02	3.8E-01	1.8E-01	4.7E+01	2.0E+00
Kr-85	-	2.4E+01	-	-	-	-	-	4.6E+00
Kr-85m	-	6.4E-01	-	-	-	-	-	1.2E-01
Kr-87	-	1.4E+00	-	-	-	-	-	2.7E-01
Kr-88	-	1.5E+01	-	-	-	-	-	2.8E+00
Sr-89	7.3E-03	1.4E-06	2.9E-02	7.8E-02	2.8E-01	1.4E-01	5.2E-02	9.0E-02
Sr-90	5.8E-02	1.2E-07	1.4E+00	5.0E+00	2.2E+00	1.9E+00	2.2E+00	1.3E+00
Zr-95	3.4E-04	6.8E-06	1.7E-06	1.6E-06	6.9E-03	3.1E-03	8.9E-02	5.5E-03
Nb-95	4.4E-04	3.1E-05	4.2E-07	6.4E-07	1.4E-02	6.2E-03	1.0E-01	8.0E-03
Ru-103	2.9E-04	7.5E-06	5.2E-06	4.5E-03	7.5E-03	3.6E-03	3.0E-02	3.4E-03
Ru-106	3.0E-04	1.7E-07	3.5E-06	4.1E-03	5.2E-03	2.5E-03	9.4E-03	1.9E-03
Sb-125	4.2E-05	2.4E-07	1.8E-06	2.0E-04	6.6E-04	3.1E-04	2.6E-02	1.2E-03
Xe-131m	-	4.1E+00	-	-	-	-	-	7.8E-01
Xe-133	-	2.2E+01	-	-	-	-	-	4.1E+00
Xe-133m	-	2.4E-01	-	-	-	-	-	4.6E-02
Xe-135	-	8.3E+00	-	-	-	-	-	1.6E+00
Xe-135m	-	3.3E-02	-	-	-	-	-	6.2E-03
Xe-138	-	5.4E-02	-	-	-	-	-	1.0E-02
I-131	1.6E+00	1.3E-02	9.3E+01	7.8E+01	9.5E+01	9.3E+01	1.0E+01	5.7E+01
I-132	5.7E-02	2.3E-01	5.3E-05	4.7E-64	2.4E-45	2.7E-05	2.1E+00	1.4E-01
I-133	9.1E-01	6.2E-02	4.1E+00	4.5E-06	3.9E-04	2.1E+00	5.4E+00	1.6E+00
I-134	2.3E-02	2.2E-01	5.0E-11	5.6E-167	1.1E-117	2.5E-11	7.8E-01	7.7E-02
I-135	3.2E-01	2.8E-01	8.8E-02	6.4E-22	1.7E-15	4.5E-02	6.8E+00	4.0E-01
Cs-134	1.8E-03	7.1E-05	3.4E-01	5.5E+00	9.0E-01	8.1E-01	4.6E+00	6.7E-01
Cs-136	2.3E-04	6.9E-05	1.3E-02	7.8E-02	2.4E-02	2.1E-02	8.5E-02	1.6E-02
Cs-137	2.4E-03	4.8E-05	6.9E-01	1.1E+01	1.2E+00	1.4E+00	1.6E+01	1.5E+00
Ba-140	1.2E-04	6.7E-07	4.9E-05	5.2E-05	2.6E-03	1.2E-03	1.3E-02	1.3E-03
Ce-141	2.9E-04	7.8E-07	7.6E-06	1.8E-04	5.0E-03	2.3E-03	3.0E-03	1.5E-03
Total	100	100	100	100	100	100	100	100

TABLE VII–8. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE B

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
H-3	2.9E-02	1.9E-06	-	-	-	-	-	2.9E-02
C-14	7.9E-05	1.2E-07	-	-	-	-	-	7.9E-05
Ar-41	-	1.2E-02	-	-	-	-	-	1.2E-02
Cr-51	6.3E-09	9.7E-10	3.4E-08	1.3E-06	8.8E-07	2.2E-06	5.6E-07	2.8E-06
Mn-54	1.5E-07	1.5E-08	1.0E-07	4.4E-07	1.9E-05	1.9E-05	9.8E-05	1.2E-04
Fe-59	2.0E-07	1.1E-08	4.4E-08	4.0E-06	1.6E-05	2.0E-05	9.5E-06	2.9E-05

TABLE VII–8. TOTAL ANNUAL DOSE, µSv/a, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
Co-57	1.4E-08	2.7E-10	7.6E-09	8.5E-09	7.8E-07	8.0E-07	1.6E-06	2.4E-06
Co-58	1.8E-06	1.5E-07	1.2E-06	1.1E-06	1.3E-04	1.3E-04	2.2E-04	3.5E-04
Co-60	6.0E-06	1.0E-07	3.0E-06	3.5E-06	1.9E-04	1.9E-04	3.3E-03	3.5E-03
Kr-85	-	8.2E-03	-	-	-	-	-	8.2E-03
Kr-85m	-	2.6E-04	-	-	-	-	-	2.6E-04
Kr-87	-	9.2E-04	-	-	-	-	-	9.2E-04
Kr-88	-	6.7E-03	-	-	-	-	-	6.7E-03
Sr-89	2.2E-06	4.7E-10	1.6E-05	3.7E-06	1.4E-04	1.6E-04	3.7E-06	1.6E-04
Sr-90	1.8E-05	4.1E-11	7.9E-04	2.4E-04	1.1E-03	2.1E-03	1.5E-04	2.3E-03
Zr-95	1.0E-07	2.3E-09	9.5E-10	7.7E-11	3.4E-06	3.4E-06	6.3E-06	9.8E-06
Nb-95	1.3E-07	1.0E-08	2.3E-10	3.0E-11	6.7E-06	6.7E-06	7.4E-06	1.4E-05
Ru-103	8.9E-08	2.6E-09	2.8E-09	2.1E-07	3.6E-06	3.8E-06	2.1E-06	6.0E-06
Ru-106	9.0E-08	5.9E-11	1.9E-09	1.9E-07	2.5E-06	2.7E-06	6.7E-07	3.5E-06
Sb-125	1.3E-08	8.3E-11	9.9E-10	9.3E-09	3.2E-07	3.3E-07	1.8E-06	2.2E-06
Xe-131m	-	1.4E-03	-	-	-	-	-	1.4E-03
Xe-133	-	7.4E-03	-	-	-	-	-	7.4E-03
Xe-133m	-	8.4E-05	-	-	-	-	-	8.4E-05
Xe-135	-	3.1E-03	-	-	-	-	-	3.1E-03
Xe-135m	-	2.8E-04	-	-	-	-	-	2.8E-04
Xe-138	-	5.9E-04	-	-	-	-	-	5.9E-04
I-131	4.8E-04	4.5E-06	5.1E-02	3.7E-03	4.6E-02	1.0E-01	7.4E-04	1.0E-01
I-132	2.5E-05	1.1E-04	4.1E-08	3.2E-68	1.6E-48	4.1E-08	2.2E-04	3.6E-04
I-133	2.9E-04	2.2E-05	2.4E-03	2.2E-10	1.9E-07	2.4E-03	4.0E-04	3.1E-03
I-134	1.7E-05	1.9E-04	6.9E-14	6.8E-171	1.4E-120	6.9E-14	1.4E-04	3.5E-04
I-135	1.1E-04	1.1E-04	5.4E-05	3.5E-26	9.1E-19	5.4E-05	5.5E-04	8.2E-04
Cs-134	5.6E-07	2.4E-08	1.8E-04	2.6E-04	4.3E-04	8.8E-04	3.2E-04	1.2E-03
Cs-136	6.9E-08	2.3E-08	7.1E-06	3.7E-06	1.2E-05	2.3E-05	6.1E-06	2.9E-05
Cs-137	7.3E-07	1.6E-08	3.7E-04	5.4E-04	5.8E-04	1.5E-03	1.1E-03	2.6E-03
Ba-140	3.7E-08	2.3E-10	2.7E-08	2.5E-09	1.2E-06	1.3E-06	9.5E-07	2.3E-06
Ce-141	8.7E-08	2.7E-10	4.2E-09	8.3E-09	2.4E-06	2.4E-06	2.1E-07	2.7E-06
Total	3.0E-02	4.2E-02	5.5E-02	4.7E-03	4.8E-02	1.1E-01	7.4E-03	1.9E-01

TABLE VII–9. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
H-3	9.7E+01	4.6E-03	-	-	-	-	-	1.6E+01
C-14	2.6E-01	3.0E-04	-	-	-	-	-	4.2E-02
Ar-41	-	3.0E+01	-	-	-	-	-	6.7E+00
Cr-51	2.1E-05	2.3E-06	6.2E-05	2.8E-02	1.8E-03	2.1E-03	7.5E-03	1.5E-03
Mn-54	4.9E-04	3.7E-05	1.9E-04	9.3E-03	3.9E-02	1.8E-02	1.3E+00	6.2E-02
Fe-59	6.5E-04	2.7E-05	8.1E-05	8.4E-02	3.2E-02	1.8E-02	1.3E-01	1.6E-02
Co-57	4.7E-05	6.5E-07	1.4E-05	1.8E-04	1.6E-03	7.4E-04	2.2E-02	1.3E-03
Co-58	5.8E-03	3.6E-04	2.1E-03	2.4E-02	2.7E-01	1.2E-01	2.9E+00	1.9E-01
Co-60	2.0E-02	2.5E-04	5.5E-03	7.4E-02	3.8E-01	1.8E-01	4.5E+01	1.9E+00
Kr-85	-	2.0E+01	-	-	-	-	-	4.4E+00
Kr-85m	-	6.2E-01	-	-	-	-	-	1.4E-01
Kr-87	-	2.2E+00	-	-	-	-	-	4.9E-01

TABLE VII–9. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE B (cont.)

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
Kr-88	-	1.6E+01	-	-	-	-	-	3.6E+00
Sr-89	7.3E-03	1.1E-06	2.9E-02	7.8E-02	2.8E-01	1.4E-01	5.0E-02	8.6E-02
Sr-90	5.8E-02	9.7E-08	1.4E+00	5.0E+00	2.2E+00	1.9E+00	2.1E+00	1.2E+00
Zr-95	3.4E-04	5.5E-06	1.7E-06	1.6E-06	6.9E-03	3.1E-03	8.6E-02	5.2E-03
Nb-95	4.4E-04	2.5E-05	4.2E-07	6.4E-07	1.4E-02	6.2E-03	1.0E-01	7.6E-03
Ru-103	2.9E-04	6.1E-06	5.1E-06	4.5E-03	7.5E-03	3.5E-03	2.9E-02	3.2E-03
Ru-106	3.0E-04	1.4E-07	3.5E-06	4.1E-03	5.2E-03	2.5E-03	9.1E-03	1.9E-03
Sb-125	4.2E-05	2.0E-07	1.8E-06	2.0E-04	6.6E-04	3.1E-04	2.5E-02	1.2E-03
Xe-131m	-	3.3E+00	-	-	-	-	-	7.4E-01
Xe-133	-	1.8E+01	-	-	-	-	-	3.9E+00
Xe-133m	-	2.0E-01	-	-	-	-	-	4.5E-02
Xe-135	-	7.4E+00	-	-	-	-	-	1.6E+00
Xe-135m	-	6.6E-01	-	-	-	-	-	1.5E-01
Xe-138	-	1.4E+00	-	-	-	-	-	3.1E-01
I-131	1.6E+00	1.1E-02	9.3E+01	7.8E+01	9.5E+01	9.3E+01	1.0E+01	5.4E+01
I-132	8.2E-02	2.7E-01	7.5E-05	6.7E-64	3.3E-45	3.8E-05	3.0E+00	1.9E-01
I-133	9.5E-01	5.2E-02	4.3E+00	4.6E-06	4.0E-04	2.2E+00	5.4E+00	1.6E+00
I-134	5.7E-02	4.6E-01	1.3E-10	1.4E-166	2.8E-117	6.4E-11	1.9E+00	1.9E-01
I-135	3.6E-01	2.5E-01	9.9E-02	7.3E-22	1.9E-15	5.0E-02	7.4E+00	4.3E-01
Cs-134	1.8E-03	5.8E-05	3.3E-01	5.4E+00	9.0E-01	8.1E-01	4.4E+00	6.4E-01
Cs-136	2.3E-04	5.6E-05	1.3E-02	7.8E-02	2.4E-02	2.1E-02	8.3E-02	1.5E-02
Cs-137	2.4E-03	3.9E-05	6.8E-01	1.1E+01	1.2E+00	1.4E+00	1.5E+01	1.4E+00
Ba-140	1.2E-04	5.4E-07	4.8E-05	5.2E-05	2.6E-03	1.2E-03	1.3E-02	1.2E-03
Ce-141	2.9E-04	6.4E-07	7.6E-06	1.8E-04	5.0E-03	2.3E-03	2.9E-03	1.5E-03
Total	100	100	100	100	100	100	100	100

TABLE VII–10. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE C

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
H-3	7.5E-03	5.1E-07	-	-	-	-	-	7.5E-03
C-14	2.0E-05	3.3E-08	-	-	-	-	-	2.0E-05
Ar-41	-	2.1E-03	-	-	-	-	-	2.1E-03
Cr-51	1.6E-09	2.6E-10	1.5E-08	6.4E-08	8.7E-08	1.7E-07	1.5E-07	3.1E-07
Mn-54	3.8E-08	4.1E-09	2.4E-08	5.3E-08	1.9E-06	1.9E-06	2.6E-05	2.8E-05
Fe-59	5.0E-08	2.9E-09	3.6E-08	1.2E-06	1.5E-06	2.8E-06	2.5E-06	5.4E-06
Co-57	3.7E-09	7.2E-11	1.3E-08	8.6E-08	7.7E-08	1.8E-07	4.2E-07	6.0E-07
Co-58	4.5E-07	4.0E-08	2.0E-06	1.1E-05	1.3E-05	2.6E-05	5.7E-05	8.4E-05
Co-60	1.5E-06	2.7E-08	5.2E-06	3.6E-05	1.8E-05	6.0E-05	8.8E-04	9.4E-04
Kr-85	-	2.2E-03	-	-	-	-	-	2.2E-03
Kr-85m	-	5.7E-05	-	-	-	-	-	5.7E-05
Kr-87	-	1.3E-04	-	-	-	-	-	1.3E-04
Kr-88	-	1.3E-03	-	-	-	-	-	1.3E-03
Sr-89	5.6E-07	1.2E-10	2.3E-06	1.2E-07	1.3E-05	1.6E-05	9.8E-07	1.7E-05
Sr-90	4.5E-06	1.1E-11	1.2E-04	7.9E-06	1.1E-04	2.3E-04	4.1E-05	2.7E-04
Zr-95	2.6E-08	6.1E-10	1.5E-11	9.4E-12	3.3E-07	3.3E-07	1.7E-06	2.0E-06
Nb-95	3.4E-08	2.8E-09	2.1E-11	5.1E-12	6.6E-07	6.6E-07	2.0E-06	2.7E-06
Ru-103	2.3E-08	6.7E-10	2.8E-09	9.3E-09	3.6E-07	3.7E-07	5.6E-07	9.5E-07

TABLE VII–10. TOTAL ANNUAL DOSE, μSv/a, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
Ru-106	2.3E-08	1.6E-11	1.9E-09	8.5E-09	2.5E-07	2.6E-07	1.8E-07	4.6E-07
Sb-125	3.3E-09	2.2E-11	9.4E-11	1.3E-09	3.2E-08	3.3E-08	4.8E-07	5.2E-07
Xe-131m	-	3.7E-04	-	-	-	-	-	3.7E-04
Xe-133	-	1.9E-03	-	-	-	-	-	1.9E-03
Xe-133m	-	2.2E-05	-	-	-	-	-	2.2E-05
Xe-135	-	7.5E-04	-	-	-	-	-	7.5E-04
Xe-135m	-	2.9E-06	-	-	-	-	-	2.9E-06
Xe-138	-	4.8E-06	-	-	-	-	-	4.8E-06
I-131	1.2E-04	1.2E-06	2.7E-03	8.0E-05	4.5E-03	7.3E-03	1.9E-04	7.6E-03
I-132	4.4E-06	2.1E-05	1.5E-09	4.8E-70	1.1E-49	1.5E-09	4.0E-05	6.6E-05
I-133	7.0E-05	5.5E-06	1.2E-04	4.6E-12	1.9E-08	1.2E-04	1.0E-04	3.0E-04
I-134	1.7E-06	2.0E-05	1.4E-15	5.8E-173	5.4E-122	1.4E-15	1.5E-05	3.6E-05
I-135	2.5E-05	2.5E-05	2.5E-06	6.6E-28	8.0E-20	2.5E-06	1.3E-04	1.8E-04
Cs-134	1.4E-07	6.4E-09	1.1E-05	1.7E-05	4.3E-05	7.2E-05	8.6E-05	1.6E-04
Cs-136	1.8E-08	6.2E-09	4.4E-07	2.4E-07	1.2E-06	1.8E-06	1.6E-06	3.5E-06
Cs-137	1.9E-07	4.3E-09	2.3E-05	3.5E-05	5.7E-05	1.2E-04	3.0E-04	4.2E-04
Ba-140	9.5E-09	6.0E-11	7.9E-09	5.1E-10	1.2E-07	1.3E-07	2.5E-07	3.9E-07
Ce-141	2.2E-08	7.0E-11	4.0E-10	4.8E-09	2.4E-07	2.5E-07	5.6E-08	3.2E-07
Total	7.7E-03	8.9E-03	3.0E-03	1.9E-04	4.8E-03	8.0E-03	1.9E-03	2.7E-02

TABLE VII–11. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
H-3	9.7E+01	5.7E-03	-	-	-	-	-	2.8E+01
C-14	2.6E-01	3.7E-04	-	-	-	-	-	7.6E-02
Ar-41	-	2.4E+01	-	-	-	-	-	7.9E+00
Cr-51	2.1E-05	2.9E-06	5.0E-04	3.4E-02	1.8E-03	2.1E-03	7.8E-03	1.2E-03
Mn-54	4.9E-04	4.6E-05	8.2E-04	2.8E-02	3.9E-02	2.4E-02	1.4E+00	1.0E-01
Fe-59	6.5E-04	3.3E-05	1.2E-03	6.5E-01	3.2E-02	3.5E-02	1.3E-01	2.0E-02
Co-57	4.7E-05	8.1E-07	4.4E-04	4.5E-02	1.6E-03	2.2E-03	2.2E-02	2.3E-03
Co-58	5.8E-03	4.4E-04	6.7E-02	6.0E+00	2.7E-01	3.3E-01	3.0E+00	3.2E-01
Co-60	2.0E-02	3.1E-04	1.8E-01	1.9E+01	3.9E-01	7.5E-01	4.7E+01	3.6E+00
Kr-85	-	2.4E+01	-	-	-	-	-	8.2E+00
Kr-85m	-	6.4E-01	-	-	-	-	-	2.2E-01
Kr-87	-	1.4E+00	-	-	-	-	-	4.8E-01
Kr-88	-	1.5E+01	-	-	-	-	-	5.0E+00
Sr-89	7.3E-03	1.4E-06	7.9E-02	6.6E-02	2.8E-01	2.0E-01	5.2E-02	6.6E-02
Sr-90	5.8E-02	1.2E-07	3.9E+00	4.2E+00	2.2E+00	2.9E+00	2.2E+00	1.0E+00
Zr-95	3.4E-04	6.8E-06	5.1E-07	5.0E-06	6.9E-03	4.2E-03	8.9E-02	7.7E-03
Nb-95	4.4E-04	3.1E-05	7.2E-07	2.7E-06	1.4E-02	8.3E-03	1.0E-01	1.0E-02
Ru-103	2.9E-04	7.5E-06	9.6E-05	4.9E-03	7.5E-03	4.7E-03	3.0E-02	3.6E-03
Ru-106	3.0E-04	1.7E-07	6.5E-05	4.5E-03	5.2E-03	3.3E-03	9.4E-03	1.7E-03
Sb-125	4.2E-05	2.4E-07	3.2E-06	7.1E-04	6.6E-04	4.2E-04	2.6E-02	2.0E-03
Xe-131m	-	4.1E+00	-	-	-	-	-	1.4E+00
Xe-133	-	2.2E+01	-	-	-	-	-	7.3E+00
Xe-133m	-	2.4E-01	-	-	-	-	-	8.2E-02
Xe-135	-	8.3E+00	-	-	-	-	-	2.8E+00

TABLE VII–11. CONTRIBUTION TO TOTAL ANNUAL DOSE, %, ATMOSPHERIC CASE C (cont.)

Nuclide	Inhalation	Plume immersion	Ingestion			Total ingestion	Ground deposition	Total
			Milk	Meat	Vegetables			
Xe-135m	-	3.3E-02	-	-	-	-	-	1.1E-02
Xe-138	-	5.4E-02	-	-	-	-	-	1.8E-02
I-131	1.6E+00	1.3E-02	9.0E+01	4.2E+01	9.5E+01	9.2E+01	1.0E+01	2.9E+01
I-132	5.7E-02	2.3E-01	5.1E-05	2.5E-64	2.4E-45	1.9E-05	2.1E+00	2.5E-01
I-133	9.1E-01	6.2E-02	4.0E+00	2.4E-06	3.9E-04	1.5E+00	5.4E+00	1.1E+00
I-134	2.3E-02	2.2E-01	4.8E-11	3.0E-167	1.1E-117	1.8E-11	7.8E-01	1.4E-01
I-135	3.2E-01	2.8E-01	8.5E-02	3.5E-22	1.7E-15	3.2E-02	6.8E+00	6.8E-01
Cs-134	1.8E-03	7.1E-05	3.8E-01	9.0E+00	9.0E-01	9.0E-01	4.6E+00	5.9E-01
Cs-136	2.3E-04	6.9E-05	1.5E-02	1.3E-01	2.4E-02	2.3E-02	8.5E-02	1.3E-02
Cs-137	2.4E-03	4.8E-05	7.8E-01	1.9E+01	1.2E+00	1.5E+00	1.6E+01	1.6E+00
Ba-140	1.2E-04	6.7E-07	2.7E-04	2.7E-04	2.6E-03	1.7E-03	1.3E-02	1.5E-03
Ce-141	2.9E-04	7.8E-07	1.3E-05	2.6E-03	5.0E-03	3.1E-03	3.0E-03	1.2E-03
Total	100	100	100	100	100	100	100	100

TABLE VII–12. CONTRIBUTION OF PATHWAYS TO THE TOTAL DOSE FROM ALL RADIONUCLIDES (ATMOSPHERIC CASES A, B and C)

Pathway	Atmospheric case A		Atmospheric case B		Atmospheric case C	
	Dose, μSv/a	Contrib., %	Dose, μSv/a	Contrib., %	Dose, μSv/a	Contrib., %
Inhalation	8.0E-03	17	3.0E-02	16	7.7E-03	29
Plume immersion	8.9E-03	19	4.2E-02	22	8.9E-03	34
Ingestion	2.8E-02	60	1.1E-01	58	8.0E-03	30
Ground deposition	1.9E-03	4.0	7.4E-03	3.9	1.9E-03	7.1
Total dose	4.7E-02	100	1.9E-01	100	2.7E-02	100

Figures VII–1 to VII–18 help to compare contributions from different radionuclides and different pathways in atmospheric cases A, B and C.

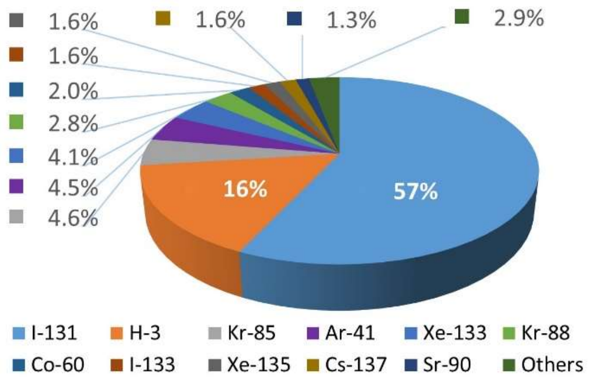

FIG. VII-1. Total dose contribution per radionuclide, %. Atmospheric case A

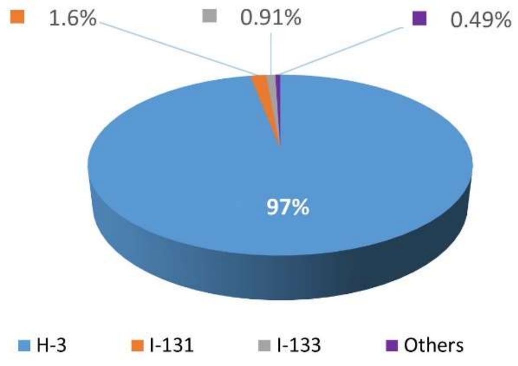

FIG. VII-2. Inhalation dose contribution per radionuclide, %. Atmospheric case A

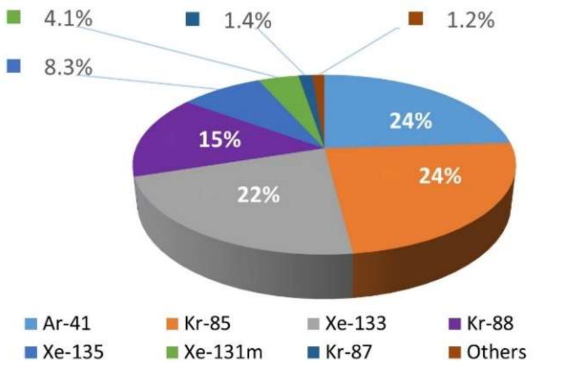

FIG. VII-3. Immersion dose contribution per radionuclide, %. Atmospheric case A

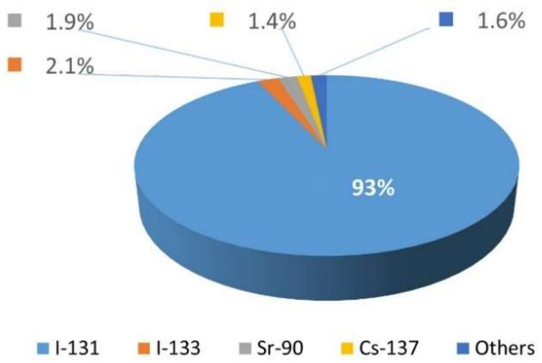

FIG. VII-4. Ingestion dose contribution per radionuclide, %. Atmospheric case A

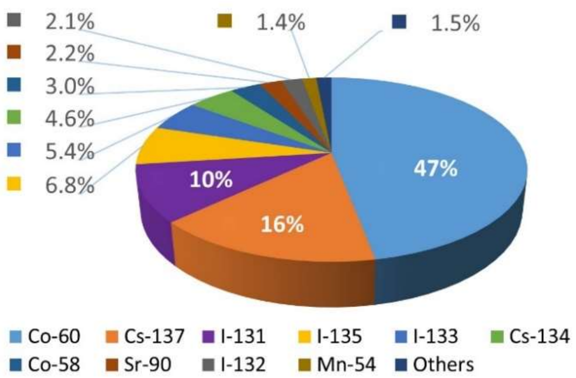

FIG. VII-5. Ground deposition contribution per radionuclide, %. Atmospheric case A

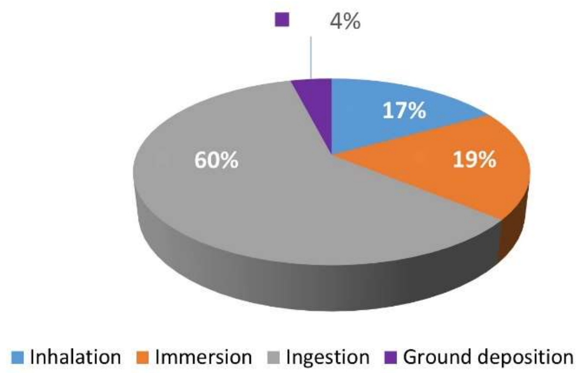

FIG. VII-6. Total dose contribution per pathway, %. Atmospheric case A

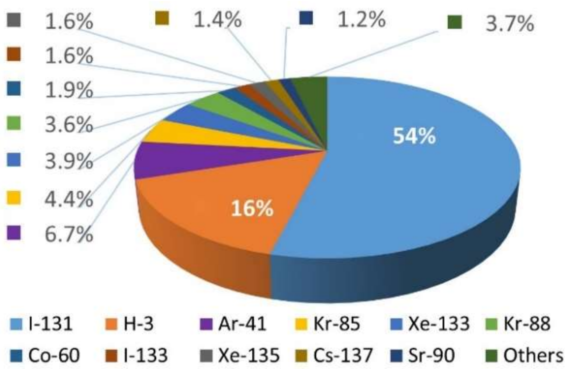

FIG. VII–7. Total dose contribution per radionuclide, %. Atmospheric case B

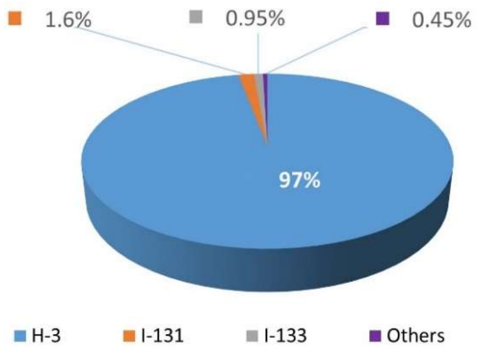

FIG. VII–8. Inhalation dose contribution per radionuclide, %. Atmospheric case B

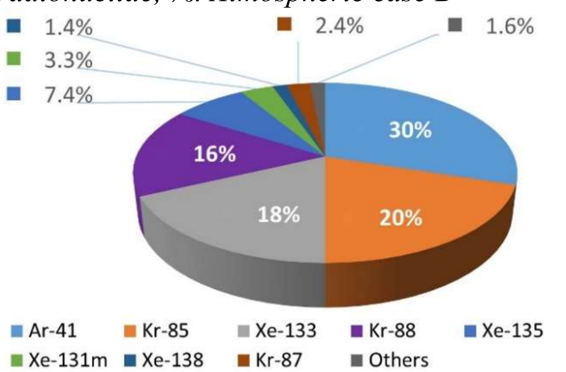

FIG. VII–9. Immersion dose contribution per radionuclide, %. Atmospheric case B

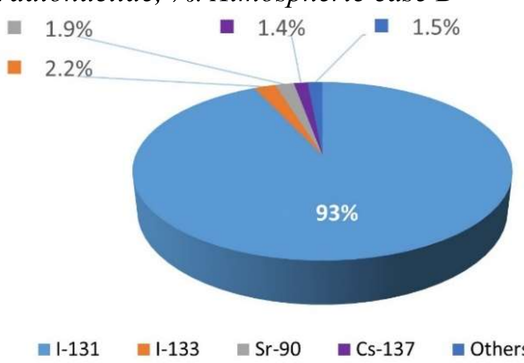

FIG. VII–10. Ingestion dose contribution per radionuclide, %. Atmospheric case B

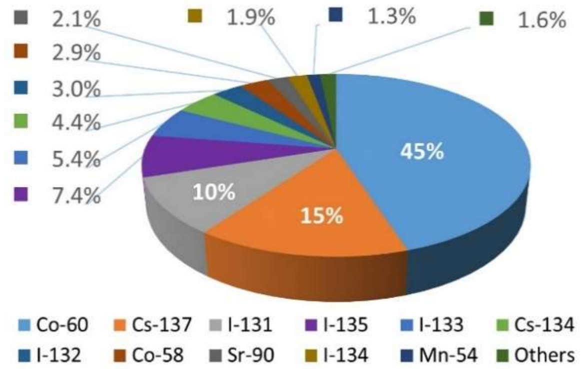

FIG. VII–11. Ground deposition contribution per radionuclide, %. Atmospheric case B

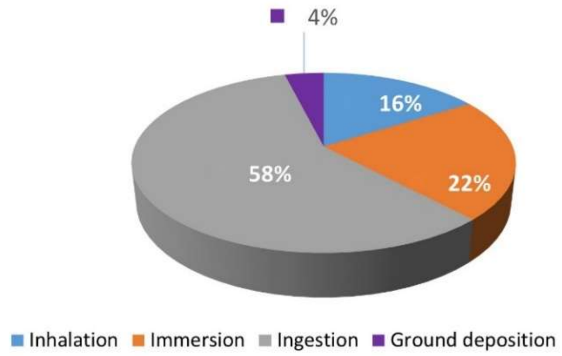

FIG. VII–12. Total dose contribution per pathway, %. Atmospheric case B

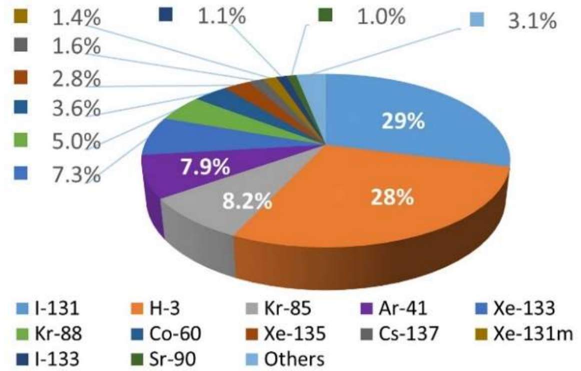

FIG. VII–13. Total dose contribution per radionuclide, %. Atmospheric case C

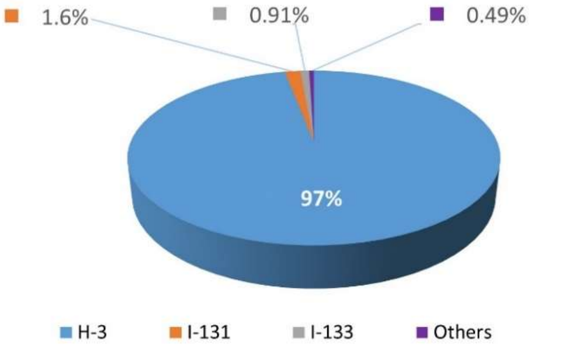

FIG. VII–14. Inhalation dose contribution per radionuclide, %. Atmospheric case C

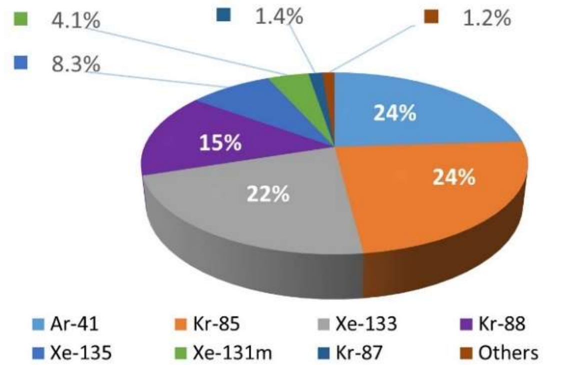

FIG. VII–15. Immersion dose contribution per radionuclide, %. Atmospheric case C

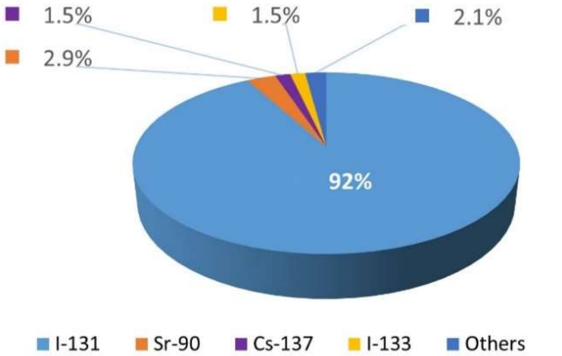

FIG. VII–16. Ingestion dose contribution per radionuclide, %. Atmospheric case C

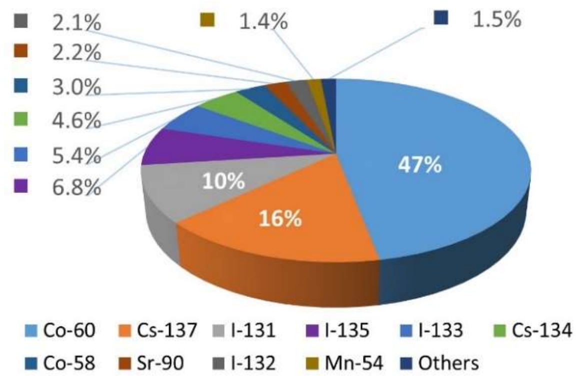

FIG. VII–17. Ground deposition contribution per radionuclide, %. Atmospheric case C

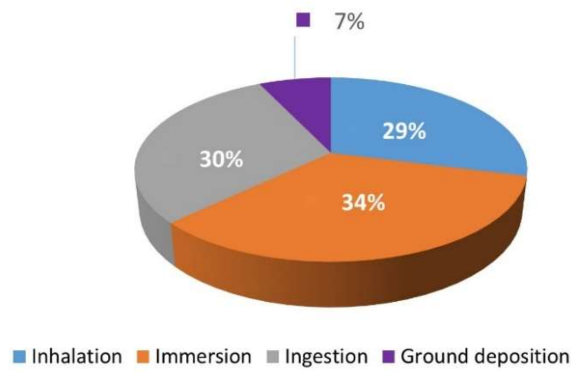

FIG. VII–18. Total dose contribution per pathway, %. Atmospheric case C

Tables VII–13, VII–14 and VII–15 provide the rankings of radionuclides based on their contribution to the total dose from a given pathway and to the total dose from all pathways in atmospheric cases A, B and C. Table VII–16 summarizes the data provided in Tables VII–13, VII–14 and VII–15 for 'significant' radionuclides and for specific pathways, and compares the ranking results among atmospheric cases A, B and C. Table VII–17 summarizes information from Tables VII–13, VII–14 and VII–15 for 'significant' radionuclides and for the total dose from all pathways, and compares the ranking results among atmospheric cases A, B and C. Variations of conditions among atmospheric cases A, B and C provide very modest influence on the outcome of such a ranking approach.

TABLE VII–13. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE A

Rank	Inhalation		Immersion		Ingestion		Ground deposition		All pathways	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.7E+01	Kr-85	2.4E+01	I-131	9.3E+01	Co-60	4.7E+01	I-131	5.7E+01
2	I-131	1.6E+00	Ar-41	2.4E+01	I-133	2.1E+00	Cs-137	1.6E+01	H-3	1.6E+01
3	I-133	9.1E-01	Xe-133	2.2E+01	Sr-90	1.9E+00	I-131	1.0E+01	Kr-85	4.6E+00
4	I-135	3.2E-01	Kr-88	1.5E+01	Cs-137	1.4E+00	I-135	6.8E+00	Ar-41	4.5E+00
5	C-14	2.6E-01	Xe-135	8.3E+00	Cs-134	8.1E-01	I-133	5.4E+00	Xe-133	4.1E+00
6	Sr-90	5.8E-02	Xe-131m	4.1E+00	Co-60	1.8E-01	Cs-134	4.6E+00	Kr-88	2.8E+00
7	I-132	5.7E-02	Kr-87	1.4E+00	Sr-89	1.4E-01	Co-58	3.0E+00	Co-60	2.0E+00
8	I-134	2.3E-02	Kr-85m	6.4E-01	Co-58	1.2E-01	Sr-90	2.2E+00	I-133	1.6E+00
9	Co-60	2.0E-02	I-135	2.8E-01	I-135	4.5E-02	I-132	2.1E+00	Xe-135	1.6E+00
10	Sr-89	7.3E-03	Xe-133m	2.4E-01	Cs-136	2.1E-02	Mn-54	1.4E+00	Cs-137	1.5E+00
11	Co-58	5.8E-03	I-132	2.3E-01	Fe-59	1.8E-02	I-134	7.8E-01	Sr-90	1.3E+00
12	Cs-137	2.4E-03	I-134	2.2E-01	Mn-54	1.8E-02	Fe-59	1.3E-01	Xe-131m	7.8E-01
13	Cs-134	1.8E-03	I-133	6.2E-02	Nb-95	6.2E-03	Nb-95	1.0E-01	Cs-134	6.7E-01
14	Fe-59	6.5E-04	Xe-138	5.4E-02	Ru-103	3.6E-03	Zr-95	8.9E-02	I-135	4.0E-01
15	Mn-54	4.9E-04	Xe-135m	3.3E-02	Zr-95	3.1E-03	Cs-136	8.5E-02	Kr-87	2.7E-01
16	Nb-95	4.4E-04	I-131	1.3E-02	Ru-106	2.5E-03	Sr-89	5.2E-02	Co-58	2.0E-01
17	Zr-95	3.4E-04	H-3	5.7E-03	Ce-141	2.3E-03	Ru-103	3.0E-02	I-132	1.4E-01
18	Ru-106	3.0E-04	Co-58	4.4E-04	Cr-51	2.1E-03	Sb-125	2.6E-02	Kr-85m	1.2E-01
19	Ru-103	2.9E-04	C-14	3.7E-04	Ba-140	1.2E-03	Co-57	2.2E-02	Sr-89	9.0E-02
20	Ce-141	2.9E-04	Co-60	3.1E-04	Co-57	7.4E-04	Ba-140	1.3E-02	I-134	7.7E-02
21	Cs-136	2.3E-04	Cs-134	7.1E-05	Sb-125	3.1E-04	Ru-106	9.4E-03	Mn-54	6.5E-02
22	Ba-140	1.2E-04	Cs-136	6.9E-05	I-132	2.7E-05	Cr-51	7.8E-03	Xe-133m	4.6E-02
23	Co-57	4.7E-05	Cs-137	4.8E-05	I-134	2.5E-11	Ce-141	3.0E-03	C-14	4.4E-02
24	Sb-125	4.2E-05	Mn-54	4.6E-05	H-3		H-3		Fe-59	1.6E-02
25	Cr-51	2.1E-05	Fe-59	3.3E-05	C-14		C-14		Cs-136	1.6E-02
26	Ar-41		Nb-95	3.1E-05	Ar-41		Ar-41		Xe-138	1.0E-02
27	Kr-85		Ru-103	7.5E-06	Kr-85		Kr-85		Nb-95	8.0E-03
28	Kr-85m		Zr-95	6.8E-06	Kr-85m		Kr-85m		Xe-135m	6.2E-03
29	Kr-87		Cr-51	2.9E-06	Kr-87		Kr-87		Zr-95	5.5E-03
30	Kr-88		Sr-89	1.4E-06	Kr-88		Kr-88		Ru-103	3.4E-03
31	Xe-131m		Co-57	8.1E-07	Xe-131m		Xe-131m		Ru-106	1.9E-03
32	Xe-133		Ce-141	7.8E-07	Xe-133		Xe-133		Cr-51	1.6E-03
33	Xe-133m		Ba-140	6.7E-07	Xe-133m		Xe-133m		Ce-141	1.5E-03
34	Xe-135		Sb-125	2.4E-07	Xe-135		Xe-135		Co-57	1.3E-03
35	Xe-135m		Ru-106	1.7E-07	Xe-135m		Xe-135m		Ba-140	1.3E-03
36	Xe-138		Sr-90	1.2E-07	Xe-138		Xe-138		Sb-125	1.2E-03

TABLE VII–14. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE B

Rank	Inhalation		Immersion		Ingestion		Ground deposition		All pathways	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.7E+01	Ar-41	3.0E+01	I-131	9.3E+01	Co-60	4.5E+01	I-131	5.4E+01
2	I-131	1.6E+00	Kr-85	2.0E+01	I-133	2.2E+00	Cs-137	1.5E+01	H-3	1.6E+01
3	I-133	9.5E-01	Xe-133	1.8E+01	Sr-90	1.9E+00	I-131	1.0E+01	Ar-41	6.7E+00
4	I-135	3.6E-01	Kr-88	1.6E+01	Cs-137	1.4E+00	I-135	7.4E+00	Kr-85	4.4E+00
5	C-14	2.6E-01	Xe-135	7.4E+00	Cs-134	8.1E-01	I-133	5.4E+00	Xe-133	3.9E+00
6	I-132	8.2E-02	Xe-131m	3.3E+00	Co-60	1.8E-01	Cs-134	4.4E+00	Kr-88	3.6E+00
7	Sr-90	5.8E-02	Kr-87	2.2E+00	Sr-89	1.4E-01	I-132	3.0E+00	Co-60	1.9E+00
8	I-134	5.7E-02	Xe-138	1.4E+00	Co-58	1.2E-01	Co-58	2.9E+00	Xe-135	1.6E+00
9	Co-60	2.0E-02	Xe-135m	6.6E-01	I-135	5.0E-02	Sr-90	2.1E+00	I-133	1.6E+00
10	Sr-89	7.3E-03	Kr-85m	6.2E-01	Cs-136	2.1E-02	I-134	1.9E+00	Cs-137	1.4E+00
11	Co-58	5.8E-03	I-134	4.6E-01	Fe-59	1.8E-02	Mn-54	1.3E+00	Sr-90	1.2E+00
12	Cs-137	2.4E-03	I-132	2.7E-01	Mn-54	1.8E-02	Fe-59	1.3E-01	Xe-131m	7.4E-01
13	Cs-134	1.8E-03	I-135	2.5E-01	Nb-95	6.2E-03	Nb-95	1.0E-01	Cs-134	6.4E-01
14	Fe-59	6.5E-04	Xe-133m	2.0E-01	Ru-103	3.5E-03	Zr-95	8.6E-02	Kr-87	4.9E-01
15	Mn-54	4.9E-04	I-133	5.2E-02	Zr-95	3.1E-03	Cs-136	8.3E-02	I-135	4.3E-01
16	Nb-95	4.4E-04	I-131	1.1E-02	Ru-106	2.5E-03	Sr-89	5.0E-02	Xe-138	3.1E-01
17	Zr-95	3.4E-04	H-3	4.6E-03	Ce-141	2.3E-03	Ru-103	2.9E-02	I-132	1.9E-01
18	Ru-106	3.0E-04	Co-58	3.6E-04	Cr-51	2.1E-03	Sb-125	2.5E-02	I-134	1.9E-01
19	Ru-103	2.9E-04	C-14	3.0E-04	Ba-140	1.2E-03	Co-57	2.2E-02	Co-58	1.9E-01
20	Ce-141	2.9E-04	Co-60	2.5E-04	Co-57	7.4E-04	Ba-140	1.3E-02	Xe-135m	1.5E-01
21	Cs-136	2.3E-04	Cs-134	5.8E-05	Sb-125	3.1E-04	Ru-106	9.1E-03	Kr-85m	1.4E-01
22	Ba-140	1.2E-04	Cs-136	5.6E-05	I-132	3.8E-05	Cr-51	7.5E-03	Sr-89	8.6E-02
23	Co-57	4.7E-05	Cs-137	3.9E-05	I-134	6.4E-11	Ce-141	2.9E-03	Mn-54	6.2E-02
24	Sb-125	4.2E-05	Mn-54	3.7E-05	H-3		H-3		Xe-133m	4.5E-02
25	Cr-51	2.1E-05	Fe-59	2.7E-05	C-14		C-14		C-14	4.2E-02
26	Ar-41		Nb-95	2.5E-05	Ar-41		Ar-41		Fe-59	1.6E-02
27	Kr-85		Ru-103	6.1E-06	Kr-85		Kr-85		Cs-136	1.5E-02
28	Kr-85m		Zr-95	5.5E-06	Kr-85m		Kr-85m		Nb-95	7.6E-03
29	Kr-87		Cr-51	2.3E-06	Kr-87		Kr-87		Zr-95	5.2E-03
30	Kr-88		Sr-89	1.1E-06	Kr-88		Kr-88		Ru-103	3.2E-03
31	Xe-131m		Co-57	6.5E-07	Xe-131m		Xe-131m		Ru-106	1.9E-03
32	Xe-133		Ce-141	6.4E-07	Xe-133		Xe-133		Cr-51	1.5E-03
33	Xe-133m		Ba-140	5.4E-07	Xe-133m		Xe-133m		Ce-141	1.5E-03
34	Xe-135		Sb-125	2.0E-07	Xe-135		Xe-135		Co-57	1.3E-03
35	Xe-135m		Ru-106	1.4E-07	Xe-135m		Xe-135m		Ba-140	1.2E-03
36	Xe-138		Sr-90	9.7E-08	Xe-138		Xe-138		Sb-125	1.2E-03

TABLE VII–15. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C

Rank	Inhalation		Immersion		Ingestion		Ground deposition		All pathways	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
1	H-3	9.7E+01	Kr-85	2.4E+01	I-131	9.2E+01	Co-60	4.7E+01	I-131	2.9E+01
2	I-131	1.6E+00	Ar-41	2.4E+01	Sr-90	2.9E+00	Cs-137	1.6E+01	H-3	2.8E+01
3	I-133	9.1E-01	Xe-133	2.2E+01	I-133	1.5E+00	I-131	1.0E+01	Kr-85	8.2E+00
4	I-135	3.2E-01	Kr-88	1.5E+01	Cs-137	1.5E+00	I-135	6.8E+00	Ar-41	7.9E+00
5	C-14	2.6E-01	Xe-135	8.3E+00	Cs-134	9.0E-01	I-133	5.4E+00	Xe-133	7.3E+00
6	Sr-90	5.8E-02	Xe-131m	4.1E+00	Co-60	7.5E-01	Cs-134	4.6E+00	Kr-88	5.0E+00

TABLE VII–15. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM A GIVEN PATHWAY, ATMOSPHERIC CASE C (cont.)

Rank	Inhalation		Immersion		Ingestion		Ground deposition		All pathways	
	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%	Nuclide	Contr.,%
7	I-132	5.7E-02	Kr-87	1.4E+00	Co-58	3.3E-01	Co-58	3.0E+00	Co-60	3.6E+00
8	I-134	2.3E-02	Kr-85m	6.4E-01	Sr-89	2.0E-01	Sr-90	2.2E+00	Xe-135	2.8E+00
9	Co-60	2.0E-02	I-135	2.8E-01	Fe-59	3.5E-02	I-132	2.1E+00	Cs-137	1.6E+00
10	Sr-89	7.3E-03	Xe-133m	2.4E-01	I-135	3.2E-02	Mn-54	1.4E+00	Xe-131m	1.4E+00
11	Co-58	5.8E-03	I-132	2.3E-01	Mn-54	2.4E-02	I-134	7.8E-01	I-133	1.1E+00
12	Cs-137	2.4E-03	I-134	2.2E-01	Cs-136	2.3E-02	Fe-59	1.3E-01	Sr-90	1.0E+00
13	Cs-134	1.8E-03	I-133	6.2E-02	Nb-95	8.3E-03	Nb-95	1.0E-01	I-135	6.8E-01
14	Fe-59	6.5E-04	Xe-138	5.4E-02	Ru-103	4.7E-03	Zr-95	8.9E-02	Cs-134	5.9E-01
15	Mn-54	4.9E-04	Xe-135m	3.3E-02	Zr-95	4.2E-03	Cs-136	8.5E-02	Kr-87	4.8E-01
16	Nb-95	4.4E-04	I-131	1.3E-02	Ru-106	3.3E-03	Sr-89	5.2E-02	Co-58	3.2E-01
17	Zr-95	3.4E-04	H-3	5.7E-03	Ce-141	3.1E-03	Ru-103	3.0E-02	I-132	2.5E-01
18	Ru-106	3.0E-04	Co-58	4.4E-04	Co-57	2.2E-03	Sb-125	2.6E-02	Kr-85m	2.2E-01
19	Ru-103	2.9E-04	C-14	3.7E-04	Cr-51	2.1E-03	Co-57	2.2E-02	I-134	1.4E-01
20	Ce-141	2.9E-04	Co-60	3.1E-04	Ba-140	1.7E-03	Ba-140	1.3E-02	Mn-54	1.0E-01
21	Cs-136	2.3E-04	Cs-134	7.1E-05	Sb-125	4.2E-04	Ru-106	9.4E-03	Xe-133m	8.2E-02
22	Ba-140	1.2E-04	Cs-136	6.9E-05	I-132	1.9E-05	Cr-51	7.8E-03	C-14	7.6E-02
23	Co-57	4.7E-05	Cs-137	4.8E-05	I-134	1.8E-11	Ce-141	3.0E-03	Sr-89	6.6E-02
24	Sb-125	4.2E-05	Mn-54	4.6E-05	H-3		H-3		Fe-59	2.0E-02
25	Cr-51	2.1E-05	Fe-59	3.3E-05	C-14		C-14		Xe-138	1.8E-02
26	Ar-41		Nb-95	3.1E-05	Ar-41		Ar-41		Cs-136	1.3E-02
27	Kr-85		Ru-103	7.5E-06	Kr-85		Kr-85		Xe-135m	1.1E-02
28	Kr-85m		Zr-95	6.8E-06	Kr-85m		Kr-85m		Nb-95	1.0E-02
29	Kr-87		Cr-51	2.9E-06	Kr-87		Kr-87		Zr-95	7.7E-03
30	Kr-88		Sr-89	1.4E-06	Kr-88		Kr-88		Ru-103	3.6E-03
31	Xe-131m		Co-57	8.1E-07	Xe-131m		Xe-131m		Co-57	2.3E-03
32	Xe-133		Ce-141	7.8E-07	Xe-133		Xe-133		Sb-125	2.0E-03
33	Xe-133m		Ba-140	6.7E-07	Xe-133m		Xe-133m		Ru-106	1.7E-03
34	Xe-135		Sb-125	2.4E-07	Xe-135		Xe-135		Ba-140	1.5E-03
35	Xe-135m		Ru-106	1.7E-07	Xe-135m		Xe-135m		Ce-141	1.2E-03
36	Xe-138		Sr-90	1.2E-07	Xe-138		Xe-138		Cr-51	1.2E-03

TABLE VII–16. SUMMARY OF RANKINGS BASED ON CONTRIBUTION TO THE TOTAL DOSE THROGH DIFFERENT PATHWAYS

Pathway	Rank	Atmospheric case A		Atmospheric case B		Atmospheric case C	
		Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
Inhalation	1	H-3	97	H-3	97	H-3	97
	2	I-131	1.6	I-131	1.6	I-131	1.6
	3	I-133	0.91	I-133	0.95	I-133	0.91
	4	I-135	0.32	I-135	0.36	I-135	0.32
	5	C-14	0.26	C-14	0.26	C-14	0.26

TABLE VII–16. SUMMARY OF RANKINGS BASED ON CONTRIBUTION TO THE TOTAL DOSE THROGH DIFFERENT PATHWAYS (cont.)

Pathway	Rank	Atmospheric case A		Atmospheric case B		Atmospheric case C	
		Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
Plume immersion	1	Kr-85	24	Ar-41	30	Kr-85	24
	2	Ar-41	24	Kr-85	20	Ar-41	24
	3	Xe-133	22	Xe-133	18	Xe-133	22
	4	Kr-88	15	Kr-88	16	Kr-88	15
	5	Xe-135	8.3	Xe-135	7.4	Xe-135	8.3
	6	Xe-131m	4.1	Xe-131m	3.3	Xe-131m	4.1
	7	Kr-87	1.4	Kr-87	2.2	Kr-87	1.4
	8	Kr-85m	0.64	Xe-138	1.4	Kr-85m	0.64
	9	I-135	0.28	Xe-135m	0.66	I-135	0.28
	10	Xe-133m	0.24	Kr-85m	0.62	Xe-133m	0.24
Ingestion	1	I-131	93	I-131	93	I-131	92
	2	I-133	2.1	I-133	2.2	Sr-90	2.9
	3	Sr-90	1.9	Sr-90	1.9	I-133	1.5
	4	Cs-137	1.4	Cs-137	1.4	Cs-137	1.5
	5	Cs-134	0.81	Cs-134	0.81	Cs-134	0.90
	6	Co-60	0.18	Co-60	0.18	Co-60	0.75
Ground deposition	1	Co-60	47	Co-60	45	Co-60	47
	2	Cs-137	16	Cs-137	15	Cs-137	16
	3	I-131	10	I-131	10	I-131	10
	4	I-135	6.8	I-135	7.4	I-135	6.8
	5	I-133	5.4	I-133	5.4	I-133	5.4
	6	Cs-134	4.6	Cs-134	4.4	Cs-134	4.6
	7	Co-58	3.0	I-132	3.0	Co-58	3.0
	8	Sr-90	2.2	Co-58	2.9	Sr-90	2.2
	9	I-132	2.1	Sr-90	2.1	I-132	2.1
	10	Mn-54	1.4	I-134	1.9	Mn-54	1.4
	11	I-134	0.78	Mn-54	1.3	I-134	0.78

TABLE VII–17. SUMMARY OF RANKINGS BASED ON CONTRIBUTION TO THE TOTAL DOSE FROM ALL PATHWAYS

Rank	Atmospheric case A		Atmospheric case B		Atmospheric case C	
	Nuclide	Contrib., %	Nuclide	Contrib., %	Nuclide	Contrib., %
1	I-131	57	I-131	54	I-131	29
2	H-3	16	H-3	16	H-3	28
3	Kr-85	4.6	Ar-41	6.7	Kr-85	8.2
4	Ar-41	4.5	Kr-85	4.4	Ar-41	7.9
5	Xe-133	4.1	Xe-133	3.9	Xe-133	7.3
6	Kr-88	2.8	Kr-88	3.6	Kr-88	5.0
7	Co-60	2.0	Co-60	1.9	Co-60	3.6
8	I-133	1.6	Xe-135	1.6	Xe-135	2.8
9	Xe-135	1.6	I-133	1.6	Cs-137	1.6
10	Cs-137	1.5	Cs-137	1.4	Xe-131m	1.4
11	Sr-90	1.3	Sr-90	1.2	I-133	1.1
12	Xe-131m	0.78	Xe-131m	0.74	Sr-90	1.0
13	Cs-134	0.67	Cs-134	0.64	I-135	0.68
14	I-135	0.40	Kr-87	0.49	Cs-134	0.59
15	Kr-87	0.27	I-135	0.43	Kr-87	0.48

Tables VII–18, VII–19 and VII–20 provide the rankings of radionuclides based on contribution from each radionuclide and pathway to the total dose from all pathways combined in atmospheric cases A, B and C. Some radionuclides can have more than one rank here since they contribute through different pathways. This ranking approach includes the ranking categories depending on the value of contribution. Summary of data provided in Tables VII–18, VII–19 and VII–20 and comparison of ranking results among atmospheric cases A, B and C is presented in Table VII–21.

TABLE VII–18. RANKING BASED ON CONTRIBUTION FROM EACH RADIONUCLIDE AND PATHWAY TO TOTAL DOSE FROM ALL PATHWAYS COMBINED, ATMOSPHERIC CASE A

Radionuclide	Pathway	Dose through a pathway, µSv/a	Contr. to total dose from all pathways, %	Rank	Rank category
I-131	Ingestion	2.6E-02	56.04	1	B_{75}
H-3	Inhalation	7.8E-03	16.41	2	E_{25}
Kr-85	Plume	2.2E-03	4.58	3	G_5
Ar-41	Plume	2.1E-03	4.46	4	G_5
Xe-133	Plume	1.9E-03	4.11	5	G_5
Kr-88	Plume	1.3E-03	2.80	6	G_5
Co-60	Ground	8.8E-04	1.87	7	H_2
Xe-135	Plume	7.5E-04	1.58	8	H_2
I-133	Ingestion	6.0E-04	1.26	9	H_2
Sr-90	Ingestion	5.5E-04	1.17	10	H_2
Cs-137	Ingestion	3.9E-04	0.83	11	H_2
Xe-131m	Plume	3.7E-04	0.78	12	H_2
Cs-137	Ground	3.0E-04	0.64	13	H_2
Others		1.6E-03	3.47		
Total		4.7E-02	100		

TABLE VII–19. RANKING BASED ON CONTRIBUTION FROM EACH RADIONUCLIDE AND PATHWAY TO TOTAL DOSE FROM ALL PATHWAYS COMBINED, ATMOSPHERIC CASE B

Radionuclide	Pathway	Dose through a pathway, µSv/a	Contr. to total dose from all pathways, %	Rank	Rank category
I-131	Ingestion	1.0E-01	53.64	1	B_{75}
H-3	Inhalation	2.9E-02	15.64	2	E_{25}
Ar-41	Plume	1.2E-02	6.66	3	F_{10}
Kr-85	Plume	8.2E-03	4.37	4	G_5
Xe-133	Plume	7.4E-03	3.95	5	G_5
Kr-88	Plume	6.7E-03	3.56	6	G_5
Co-60	Ground	3.3E-03	1.78	7	H_2
Xe-135	Plume	3.1E-03	1.65	8	H_2
I-133	Ingestion	2.4E-03	1.25	9	H_2
Sr-90	Ingestion	2.1E-03	1.12	10	H_2
Cs-137	Ingestion	1.5E-03	0.79	11	H_2
Xe-131m	Plume	1.4E-03	0.74	12	H_2
Cs-137	Ground	1.1E-03	0.61	13	H_2
Others		8.0E-03	4.25		
Total		1.9E-01	100		

TABLE VII–20. RANKING BASED ON CONTRIBUTION FROM EACH RADIONUCLIDE AND PATHWAY TO TOTAL DOSE FROM ALL PATHWAYS COMBINED, ATMOSPHERIC CASE C

Radionuclide	Pathway	Dose through a pathway, μSv/a	Contr. to total dose from all pathways, %	Rank	Rank category
H-3	Inhalation	7.5E-03	28.23	1	D_{33}
I-131	Ingestion	7.3E-03	27.54	2	D_{33}
Kr-85	Plume	2.2E-03	8.17	3	F_{10}
Ar-41	Plume	2.1E-03	7.95	4	F_{10}
Xe-133	Plume	1.9E-03	7.33	5	F_{10}
Kr-88	Plume	1.3E-03	4.99	6	G_5
Co-60	Ground	8.8E-04	3.33	7	G_5
Xe-135	Plume	7.5E-04	2.81	8	G_5
Xe-131m	Plume	3.7E-04	1.38	9	H_2
Cs-137	Ground	3.0E-04	1.13	10	H_2
Sr-90	Ingestion	2.3E-04	0.86	11	H_2
I-131	Ground	1.9E-04	0.73	12	H_2
Others		1.5E-03	5.52		
Total		2.7E-02	100		

TABLE VII–21. SUMMARY OF RANKINGS BASED ON CONTRIBUTION FROM EACH RADIONUCLIDE AND PATHWAY TO TOTAL DOSE FROM ALL PATHWAYS COMBINED

Atmospheric case A			Atmospheric case B			Atmospheric case C		
Nuclide	Pathway	Contr., %	Nuclide	Pathway	Contr., %	Nuclide	Pathway	Contr., %
I-131	Ingestion	56.04	I-131	Ingestion	53.64	-	-	-
NRG[a]:	Plume	18.23	NRG[a]:	Plume	20.93	NRG[a]:	Plume	32.63
Kr-85	–//–	4.58	Ar-41	–//–	6.66	Kr-85	–//–	8.17
Ar-41	–//–	4.46	Kr-85	–//–	4.37	Ar-41	–//–	7.95
Xe-133	–//–	4.11	Xe-133	–//–	3.95	Xe-133	–//–	7.33
Kr-88	–//–	2.80	Kr-88	–//–	3.56	Kr-88	–//–	4.99
Xe-135	–//–	1.58	Xe-135	–//–	1.65	Xe-135	–//–	2.81
Xe-131m	–//–	0.78	Xe-131m	–//–	0.74	Xe-131m	–//–	1.38
H-3	Inhalation	16.41	H-3	Inhalation	15.64	H-3	Inhalation	28.23
Co-60	Ground	1.87	Co-60	Ground	1.78	I-131	Ingestion	27.53
I-133	Ingestion	1.26	I-133	Ingestion	1.25	Co-60	Ground	3.33
Sr-90	Ingestion	1.17	Sr-90	Ingestion	1.12	Cs-137	Ground	1.13
Cs-137	Ingestion	0.83	Cs-137	Ingestion	0.79	Sr-90	Ingestion	0.86
Cs-137	Ground	0.64	Cs-137	Ground	0.61	I-131	Ground	0.73

Note: a – contribution from noble radioactive gases (NRG) here calculated as a sum of contributions from six NRG radionuclides presented in this type of ranking.

Table VII–22 presents effects of the special consideration for H-3 and C-14 on rankings based on contribution from each radionuclide and pathway to total dose from all pathways combined. Effects are presented for all atmospheric cases A, B and C.

The major reason of different results between atmospheric cases A and B was a significant decrease in the plume transport time necessary to achieve the distance where doses were calculated (transport time for case B is 6.7 times shorter than for A). In atmospheric case B the short-lived radionuclides could achieve higher rankings than in case A. The main contributions to the dose from plume immersion appear from noble radioactive gases (NRG). There are many short-lived radionuclides among them, so changes were expected for atmospheric case B, arising from the reduced transit time. Tables for plume immersion demonstrate that the dose contributions from Ar-41, Kr-87, and Xe-138 rise in atmospheric case B. For example, Ar-41 and Kr-85 provide similar contributions in case A, however in the atmospheric case B Ar-41 contributes approx. 1.5 higher dose than Kr-85. However, the ranking of radionuclides contributing through the ground deposition pathway in atmospheric case B is less sensitive to such effects. The three radionuclides contributing most of the total adult dose (Co-60, Cs-137, and I-131) remain the same for all cases with very little variation of their contributions.

In atmospheric case C the model parameterization was different from two other cases. Breathing rate, transfer factors and consumption rates have been changed. Generally, such changes can affect the ingestion doses, the 'ingestion ranking' and the total ranking. The ranking for inhalation was almost the same for all three cases with H-3 as the dominant radionuclide (approx. 97%). It turns out that the influence of changes in transfer factors and consumption rates in the atmospheric case C was not so considerable. The main result was a dose reduction, but the contribution of I-131 to the adult dose was very high for all cases (more than 90%). Only I-133 and Sr-90 were swapped in the 'ingestion' ranking of the case C. However, the reduction of the ingestion dose (and the reduction of its contribution to the total adult dose from 60% to 30%) led to essential changes in the total ranking. The main leaders (I-131 and H-3) remained in their positions, but the difference between them almost disappeared (57% and 16% in atmospheric case A; 29% and 28% in case C).

It is interesting to compare the rankings on the bases of the total dose contribution of each radionuclide by pathway. In the atmospheric cases A and B the leaders were the same: I-131 (ingestion) – more than 50%; noble radioactive gases as a group (plume immersion) – about 20%; H-3 (inhalation) – about 16%. All radionuclides became almost equal in the atmospheric case C: noble radioactive gases (plume immersion) – approx. one third; I-131 (ingestion) and H-3 (inhalation) – approx. 28%.

TABLE VII–22. EFFECTS OF SPECIAL CONSIDERATION FOR H-3 AND C-14 ON RANKINGS BASED ON CONTRIBUTION FROM EACH RADIONUCLIDE AND PATHWAY TO TOTAL DOSE FROM ALL PATHWAYS COMBINED

Atm. case	No special consideration for H-3 and C-14				With special consideration for H-3 and C-14			
	Nuclide	Pathway	Dose, μSv/a	Contr., %	Nuclide	Pathway	Dose, μSv/a	Contr., %
A	-	-	-	-	H-3	Inhalation	2.2E-01	57.43
	-	-	-	-	C-14	Ingestion	1.3E-01	32.36
	I-131	Ingestion	2.6E-02	56.04	I-131	Ingestion	2.6E-02	6.84
	H-3	Inhalation	7.8E-03	16.41	-	-	-	-
	Kr-85	Plume	2.2E-03	4.58	Kr-85	Plume	2.2E-03	0.56
	Ar-41	Plume	2.1E-03	4.46	Ar-41	Plume	2.1E-03	0.54
	Xe-133	Plume	1.9E-03	4.11	Xe-133	Plume	1.9E-03	0.50
	Kr-88	Plume	1.3E-03	2.80	Kr-88	Plume	1.3E-03	0.34
	Co-60	Ground	8.8E-04	1.87	Co-60	Ground	8.8E-04	0.23
	Xe-135	Plume	7.5E-04	1.58	Xe-135	Plume	7.5E-04	0.19
	I-133	Ingestion	6.0E-04	1.26	I-133	Ingestion	6.0E-04	0.15
	Sr-90	Ingestion	5.5E-04	1.17	Sr-90	Ingestion	5.5E-04	0.14
	Cs-137	Ingestion	3.9E-04	0.83	Cs-137	Ingestion	3.9E-04	0.10
	Xe-131m	Plume	3.7E-04	0.78	Xe-131m	Plume	3.7E-04	0.09
	Cs-137	Ground	3.0E-04	0.64	Cs-137	Ground	3.0E-04	0.08
	Others	-	1.6E-03	3.47	Others	-	1.6E-03	0.42
	Total	-	4.7E-02	100	Total	-	3.9E-01	100

TABLE VII–22. EFFECTS OF SPECIAL CONSIDERATION FOR H-3 AND C-14 ON RANKINGS BASED ON CONTRIBUTION FROM EACH RADIONUCLIDE AND PATHWAY TO TOTAL DOSE FROM ALL PATHWAYS COMBINED (cont.)

Atm. case	No special consideration for H-3 and C-14				With special consideration for H-3 and C-14			
	Nuclide	Pathway	Dose, μSv/a	Contr., %	Nuclide	Pathway	Dose, μSv/a	Contr., %
B	-	-	-	-	H-3	Inhalation	8.4E-01	57.09
	-	-	-	-	C-14	Ingestion	4.7E-01	32.17
	I-131	Ingestion	1.0E-01	53.64	I-131	Ingestion	1.0E-01	6.83
	H-3	Inhalation	2.9E-02	15.64	-	-	-	-
	Ar-41	Plume	1.2E-02	6.66	Ar-41	Plume	1.2E-02	0.85
	Kr-85	Plume	8.2E-03	4.37	Kr-85	Plume	8.2E-03	0.56
	Xe-133	Plume	7.4E-03	3.95	Xe-133	Plume	7.4E-03	0.50
	Kr-88	Plume	6.7E-03	3.56	Kr-88	Plume	6.7E-03	0.45
	Co-60	Ground	3.3E-03	1.78	Co-60	Ground	3.3E-03	0.23
	Xe-135	Plume	3.1E-03	1.65	Xe-135	Plume	3.1E-03	0.21
	I-133	Ingestion	2.4E-03	1.25	I-133	Ingestion	2.4E-03	0.16
	Sr-90	Ingestion	2.1E-03	1.12	Sr-90	Ingestion	2.1E-03	0.14
	Cs-137	Ingestion	1.5E-03	0.79	Cs-137	Ingestion	1.5E-03	0.10
	Xe-131m	Plume	1.4E-03	0.74	Xe-131m	Plume	1.4E-03	0.09
	Cs-137	Ground	1.1E-03	0.61	Cs-137	Ground	1.1E-03	0.08
	Others	-	8.0E-03	4.25	Others	-	7.9E-03	0.54
	Total	-	1.9E-01	100	Total	-	1.5E+00	100
C	H-3	Inhalation	7.5E-03	28.23	H-3	Inhalation	2.2E-01	60.64
	-	-	-	-	C-14	Ingestion	1.3E-01	34.17
	I-131	Ingestion	7.3E-03	27.54	I-131	Ingestion	7.3E-03	1.99
	Kr-85	Plume	2.2E-03	8.17	Kr-85	Plume	2.2E-03	0.59
	Ar-41	Plume	2.1E-03	7.95	Ar-41	Plume	2.1E-03	0.58
	Xe-133	Plume	1.9E-03	7.33	Xe-133	Plume	1.9E-03	0.53
	Kr-88	Plume	1.3E-03	4.99	Kr-88	Plume	1.3E-03	0.36
	Co-60	Ground	8.8E-04	3.33	Co-60	Ground	8.8E-04	0.24
	Xe-135	Plume	7.5E-04	2.81	Xe-135	Plume	7.5E-04	0.20
	Xe-131m	Plume	3.7E-04	1.38	Xe-131m	Plume	3.7E-04	0.10
	Cs-137	Ground	3.0E-04	1.13	Cs-137	Ground	3.0E-04	0.08
	Sr-90	Ingestion	2.3E-04	0.86	Sr-90	Ingestion	2.3E-04	0.06
	I-131	Ground	1.9E-04	0.73	I-131	Ground	1.9E-04	0.05
	Others	-	1.5E-03	5.52	Others	-	1.4E-03	0.39
	Total	-	2.7E-02	100	Total	-	3.7E-01	100

In general, the dose calculation scheme used in this study did not apply the special considerations for H-3 and C-14 described in SRS-19 [VII–1]. However, the evaluation of effects of the special consideration in this exercise was performed for completeness. Table VII–22 demonstrates comparisons of rankings for the three atmospheric cases without and with the special consideration for H-3 and C-14. The simplification of not applying the special considerations resulted in the underestimation of inhalation doses from H-3 and ingestion doses from C-14, leading to more than an order of magnitude difference in the total dose (Table VII–22). In all three atmospheric cases, when special consideration is involved the contribution from inhalation of H-3 to the total dose was approx. 60%. The contribution from ingestion of C-14 was approx. one third of the total dose. The contribution from all other radionuclides and all other pathways was from ~5% (atmospheric case C) to ~10% (atmospheric cases A and B). These evaluations demonstrate that the application of special consideration for H-3 and C-14 is necessary in every practical task; otherwise the total dose will be significantly underestimated.

Table VII–23 gives the results of dose calculations (absolute values) and the percentage contribution of each radionuclide for the marine case A. Figures VII–19 to VII–21 illustrate results provided in Table VII–23. Table VII–24 provides the ranking of radionuclides based on their contribution to the total dose from ingestion of fish and shellfish in the marine case A. Table VII–25 provides the ranking of radionuclides based on contribution from each radionuclide and pathway to the total dose from all pathways (ingestion of fish and shellfish) combined in marine case A.

The main result of the dose evaluations in a marine scenario was the revelation of the very high contribution of Ru-106. Intake of this radionuclide with shellfish formed about two thirds of the total dose from all radionuclides arising from the ingestion of aquatic food. This phenomenon was a result of the combination of the following high values for Ru-106:

- High discharge concentration (second highest after H-3);
- High bioaccumulation factor for shellfish (67 times higher than for Cs);
- High ingestion dose coefficient (fifth place after Sr-90, I-131, Cs-134 and Cs-137).

The discharge concentration of H-3 was 2800 times higher than that of Ru-106, but the H-3 bioaccumulation factor for shellfish was equal to 0, so Ru-106 had the highest estimated activity concentration in shellfish (240 times higher than Cs-137 and 330 times higher than Cs-134). Higher ingestion dose coefficients for Cs-137 (1.9 times) and Cs-134 (2.7 times) did not change the outcome essentially.

Apparently, the consideration of other pathways (external exposure from the sediment and water submersion) would change the total ranking in the marine scenario.

TABLE VII–23. DOSES FROM INGESTION AND CONTRIBUTION OF RADIONUCLIDES TO THE TOTAL DOSE DUE TO INGESTION, MARINE CASE A

Radionuclide	Dose from ingestion of		Total	Contribution to total dose from		Total
	Fish, μSv/a	Shellfish, μSv/a	dose, μSv/a	Fish, %	Shellfish, %	contribution, %
H-3	-	-	-	-	-	-
Na-24	9.0E-09	8.1E-09	1.7E-08	1.5E-04	3.5E-05	5.9E-05
P-32	3.6E-04	7.1E-05	4.3E-04	6.1E+00	3.1E-01	1.5E+00
Cr-51	1.7E-06	2.0E-06	3.7E-06	2.9E-02	8.7E-03	1.3E-02
Mn-54	2.9E-06	1.1E-05	1.4E-05	4.9E-02	4.7E-02	4.7E-02
Fe-55	9.1E-08	3.0E-07	3.9E-07	1.6E-03	1.3E-03	1.3E-03
Fe-59	1.4E-07	4.7E-07	6.2E-07	2.4E-03	2.0E-03	2.1E-03
Co-58	9.7E-05	1.5E-04	2.4E-04	1.7E+00	6.3E-01	8.4E-01
Co-60	3.5E-04	5.3E-04	8.8E-04	6.0E+00	2.3E+00	3.0E+00
Ni-63	5.9E-06	3.5E-06	9.4E-06	1.0E-01	1.5E-02	3.2E-02
Zn-65	7.6E-05	1.1E-03	1.2E-03	1.3E+00	4.9E+00	4.2E+00
Br-84	4.2E-11	4.2E-11	8.4E-11	7.2E-07	1.8E-07	2.9E-07
Rb-88	2.2E-10	1.3E-11	2.3E-10	3.7E-06	5.6E-08	7.9E-07
Sr-89	5.9E-08	1.8E-08	7.7E-08	1.0E-03	7.6E-05	2.6E-04
Sr-90	6.5E-08	1.9E-08	8.4E-08	1.1E-03	8.4E-05	2.9E-04
Sr-91	3.0E-09	9.0E-10	3.9E-09	5.1E-05	3.9E-06	1.3E-05
Y-90	2.5E-09	3.7E-08	4.0E-08	4.3E-05	1.6E-04	1.4E-04
Y-91m	1.0E-11	1.6E-10	1.7E-10	1.8E-07	6.7E-07	5.7E-07
Y-91	1.3E-08	2.0E-07	2.1E-07	2.3E-04	8.6E-04	7.3E-04
Y-93	2.5E-08	3.8E-07	4.0E-07	4.3E-04	1.6E-03	1.4E-03
Zr-95	5.0E-08	3.7E-06	3.8E-06	8.5E-04	1.6E-02	1.3E-02
Nb-95	1.4E-07	1.4E-06	1.5E-06	2.4E-03	6.0E-03	5.3E-03
Mo-99	9.8E-07	2.9E-06	3.9E-06	1.7E-02	1.3E-02	1.3E-02

TABLE VII–23. DOSES FROM INGESTION AND CONTRIBUTION OF RADIONUCLIDES TO THE TOTAL DOSE DUE TO INGESTION, MARINE CASE A (cont.)

Radionuclide	Dose from ingestion of		Total	Contribution to total dose from		Total
	Fish, µSv/a	Shellfish, µSv/a	dose, µSv/a	Fish, %	Shellfish, %	contribution, %
Tc-99m	8.4E-08	8.4E-07	9.2E-07	1.4E-03	3.6E-03	3.2E-03
Ru-103	4.9E-07	1.5E-04	1.5E-04	8.3E-03	6.3E-01	5.1E-01
Ru-106	6.3E-05	1.9E-02	1.9E-02	1.1E+00	8.2E+01	6.6E+01
Rh-103m	1.8E-07	5.3E-07	7.1E-07	3.0E-03	2.3E-03	2.5E-03
Rh-106m	9.5E-05	2.8E-04	3.8E-04	1.6E+00	1.2E+00	1.3E+00
Ag-110	-	-	-	-	-	-
Ag-110m	1.5E-04	9.1E-04	1.1E-03	2.6E+00	3.9E+00	3.6E+00
Sb-124	1.2E-05	3.5E-06	1.5E-05	2.0E-01	1.5E-02	5.2E-02
Te-129m	1.1E-06	1.1E-05	1.2E-05	1.8E-02	4.6E-02	4.0E-02
Te-129	7.6E-09	7.6E-08	8.4E-08	1.3E-04	3.3E-04	2.9E-04
Te-131	7.7E-10	7.7E-09	8.4E-09	1.3E-05	3.3E-05	2.9E-05
Te-131m	9.3E-07	9.3E-06	1.0E-05	1.6E-02	4.0E-02	3.5E-02
Te-132	5.5E-06	5.5E-05	6.1E-05	9.4E-02	2.4E-01	2.1E-01
I-131	1.1E-03	3.4E-04	1.5E-03	2.0E+01	1.5E+00	5.1E+00
I-132	4.5E-07	1.3E-07	5.8E-07	7.6E-03	5.8E-04	2.0E-03
I-133	1.1E-04	3.4E-05	1.5E-04	1.9E+00	1.5E-01	5.1E-01
I-134	1.9E-08	5.7E-09	2.5E-08	3.2E-04	2.5E-05	8.5E-05
I-135	9.8E-06	2.9E-06	1.3E-05	1.7E-01	1.3E-02	4.4E-02
Cs-134	1.7E-03	1.5E-04	1.9E-03	2.9E+01	6.7E-01	6.4E+00
Cs-136	1.7E-05	1.5E-06	1.8E-05	2.8E-01	6.5E-03	6.3E-02
Cs-137	1.6E-03	1.5E-04	1.8E-03	2.8E+01	6.3E-01	6.1E+00
Ba-135m	4.1E-16	1.2E-17	4.3E-16	7.1E-12	5.4E-14	1.5E-12
Ba-140	1.8E-05	5.5E-07	1.9E-05	3.1E-01	2.4E-03	6.5E-02
La-140	-	-	-	-	-	-
Ce-141	1.8E-08	5.3E-07	5.5E-07	3.0E-04	2.3E-03	1.9E-03
Ce-143	6.2E-08	1.9E-06	1.9E-06	1.1E-03	8.0E-03	6.6E-03
Ce-144	3.0E-06	9.0E-05	9.3E-05	5.1E-02	3.9E-01	3.2E-01
Pr-143	-	-	-	-	-	-
Pr-144	-	-	-	-	-	-
W-187	-	-	-	-	-	-
Np-239	3.9E-07	4.6E-06	5.0E-06	6.6E-03	2.0E-02	1.7E-02
Total	5.9E-03	2.3E-02	2.9E-02	100	100	100

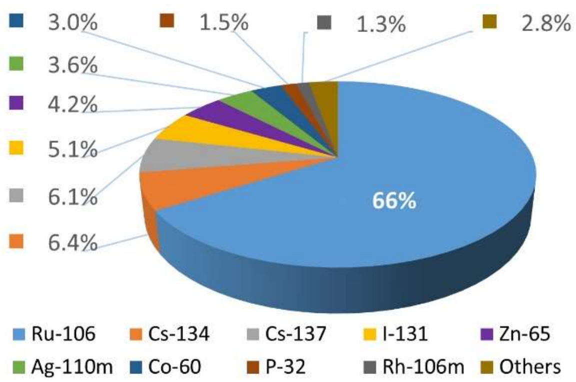

FIG. VII–19. Contribution of radionuclides to the dose from ingestion. Marine case A

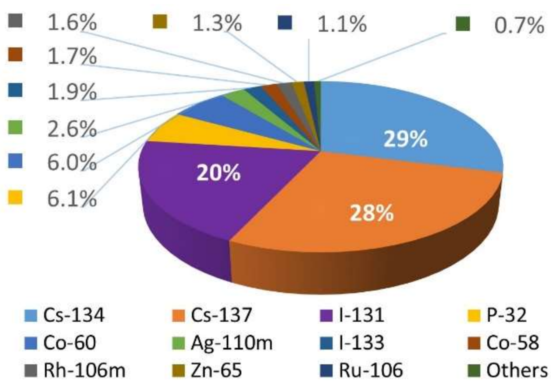

FIG. VII–20. Contribution of radionuclides to the dose from ingestion of fish. Marine case A

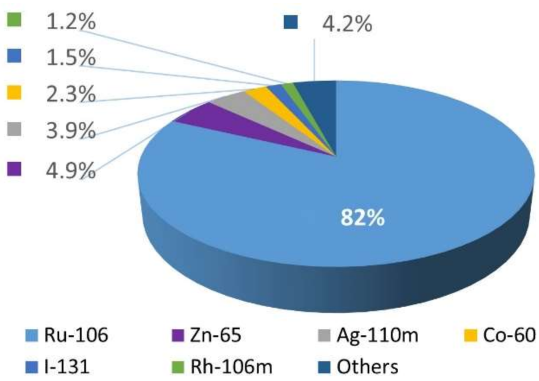

FIG. VII–21. Contribution of radionuclides to the dose from ingestion of shellfish. Marine case A

TABLE VII–24. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM INGESTION, MARINE CASE A

Rank	Ingestion of fish		Ingestion of shellfish		Ingestion total	
	Nuclide	Contribution, %	Nuclide	Contribution, %	Nuclide	Contribution, %
1	Cs-134	2.9E+01	Ru-106	8.2E+01	Ru-106	6.6E+01
2	Cs-137	2.8E+01	Zn-65	4.9E+00	Cs-134	6.4E+00
3	I-131	2.0E+01	Ag-110m	3.9E+00	Cs-137	6.1E+00
4	P-32	6.1E+00	Co-60	2.3E+00	I-131	5.1E+00
5	Co-60	6.0E+00	I-131	1.5E+00	Zn-65	4.2E+00
6	Ag-110m	2.6E+00	Rh-106m	1.2E+00	Ag-110m	3.6E+00
7	I-133	1.9E+00	Cs-134	6.7E-01	Co-60	3.0E+00
8	Co-58	1.7E+00	Ru-103	6.3E-01	P-32	1.5E+00
9	Rh-106m	1.6E+00	Cs-137	6.3E-01	Rh-106m	1.3E+00
10	Zn-65	1.3E+00	Co-58	6.3E-01	Co-58	8.4E-01
11	Ru-106	1.1E+00	Ce-144	3.9E-01	I-133	5.1E-01
12	Ba-140	3.1E-01	P-32	3.1E-01	Ru-103	5.1E-01
13	Cs-136	2.8E-01	Te-132	2.4E-01	Ce-144	3.2E-01
14	Sb-124	2.0E-01	I-133	1.5E-01	Te-132	2.1E-01
15	I-135	1.7E-01	Mn-54	4.7E-02	Ba-140	6.5E-02
16	Ni-63	1.0E-01	Te-129m	4.6E-02	Cs-136	6.3E-02
17	Te-132	9.4E-02	Te-131m	4.0E-02	Sb-124	5.2E-02
18	Ce-144	5.1E-02	Np-239	2.0E-02	Mn-54	4.7E-02
19	Mn-54	4.9E-02	Zr-95	1.6E-02	I-135	4.4E-02
20	Cr-51	2.9E-02	Ni-63	1.5E-02	Te-129m	4.0E-02
21	Te-129m	1.8E-02	Sb-124	1.5E-02	Te-131m	3.5E-02
22	Mo-99	1.7E-02	Mo-99	1.3E-02	Ni-63	3.2E-02
23	Te-131m	1.6E-02	I-135	1.3E-02	Np-239	1.7E-02
24	Ru-103	8.3E-03	Cr-51	8.7E-03	Mo-99	1.3E-02
25	I-132	7.6E-03	Ce-143	8.0E-03	Zr-95	1.3E-02
26	Np-239	6.6E-03	Cs-136	6.5E-03	Cr-51	1.3E-02
27	Rh-103m	3.0E-03	Nb-95	6.0E-03	Ce-143	6.6E-03
28	Fe-59	2.4E-03	Tc-99m	3.6E-03	Nb-95	5.3E-03
29	Nb-95	2.4E-03	Ba-140	2.4E-03	Tc-99m	3.2E-03
30	Fe-55	1.6E-03	Rh-103m	2.3E-03	Rh-103m	2.5E-03
31	Tc-99m	1.4E-03	Ce-141	2.3E-03	Fe-59	2.1E-03
32	Sr-90	1.1E-03	Fe-59	2.0E-03	I-132	2.0E-03
33	Ce-143	1.1E-03	Y-93	1.6E-03	Ce-141	1.9E-03

TABLE VII–24. RANKING BASED ON CONTRIBUTION TO TOTAL DOSE FROM INGESTION, MARINE CASE A (cont.)

Rank	Ingestion of fish		Ingestion of shellfish		Ingestion total	
	Nuclide	Contribution, %	Nuclide	Contribution, %	Nuclide	Contribution, %
34	Sr-89	1.0E-03	Fe-55	1.3E-03	Y-93	1.4E-03
35	Zr-95	8.5E-04	Y-91	8.6E-04	Fe-55	1.3E-03
36	Y-93	4.3E-04	I-132	5.8E-04	Y-91	7.3E-04
37	I-134	3.2E-04	Te-129	3.3E-04	Sr-90	2.9E-04
38	Ce-141	3.0E-04	Y-90	1.6E-04	Te-129	2.9E-04
39	Y-91	2.3E-04	Sr-90	8.4E-05	Sr-89	2.6E-04
40	Na-24	1.5E-04	Sr-89	7.6E-05	Y-90	1.4E-04
41	Te-129	1.3E-04	Na-24	3.5E-05	I-134	8.5E-05
42	Sr-91	5.1E-05	Te-131	3.3E-05	Na-24	5.9E-05
43	Y-90	4.3E-05	I-134	2.5E-05	Te-131	2.9E-05
44	Te-131	1.3E-05	Sr-91	3.9E-06	Sr-91	1.3E-05
45	Rb-88	3.7E-06	Y-91m	6.7E-07	Rb-88	7.9E-07
46	Br-84	7.2E-07	Br-84	1.8E-07	Y-91m	5.7E-07
47	Y-91m	1.8E-07	Rb-88	5.6E-08	Br-84	2.9E-07
48	Ba-135m	7.1E-12	Ba-135m	5.4E-14	Ba-135m	1.5E-12
49	H-3		H-3		H-3	
50	Ag-110		Ag-110		Ag-110	
51	La-140		La-140		La-140	
52	Pr-143		Pr-143		Pr-143	
53	Pr-144		Pr-144		Pr-144	
54	W-187		W-187		W-187	

TABLE VII–25. RANKING BASED ON CONTRIBUTION FROM EACH RADIONUCLIDE AND PATHWAY TO TOTAL DOSE FROM ALL PATHWAYS COMBINED, MARINE CASE A

Radionuclide	Pathway	Dose, µSv/a	Contribution, %	Rank	Rank category
Ru-106	Shellfish	1.9E-02	65.62	1	B_{75}
Cs-134	Fish	1.7E-03	5.92	2	F_{10}
Cs-137	Fish	1.6E-03	5.59	3	F_{10}
I-131	Fish	1.1E-03	3.95	4	G_5
Zn-65	Shellfish	1.1E-03	3.93	5	G_5
Ag-110m	Shellfish	9.1E-04	3.12	6	G_5
Co-60	Shellfish	5.3E-04	1.82	7	H_2
P-32	Fish	3.6E-04	1.23	8	H_2
Co-60	Fish	3.5E-04	1.21	9	H_2
I-131	Shellfish	3.4E-04	1.19	10	H_2
Rh-106m	Shellfish	2.8E-04	0.98	11	H_2
Cs-134	Shellfish	1.5E-04	0.53	12	H_2
Ag-110m	Fish	1.5E-04	0.52	13	H_2
Ru-103	Shellfish	1.5E-04	0.51	14	H_2
Cs-137	Shellfish	1.5E-04	0.50	15	H_2
Co-58	Shellfish	1.5E-04	0.50	16	H_2
Others		8.4E-04	2.89		
Total		2.9E-02	100		

Table VII–26 gives the results of dose calculations (absolute values) and percentage contribution of radionuclides to the total dose in the riverine cases A and B. Figures VII–22 and VII–23 illustrate results provided in Table VII–26. Table VII–27 provides ranking of radionuclides based on their contribution to the total dose from ingestion of fish in the riverine cases A and B.

The first three radionuclides in the rankings for both cases were the same: I-131, Cs-137, and Cs-134. The use of country-specific transfer coefficients (bioaccumulation factors for freshwater fish) re-ordered those radionuclides in the riverine case B. These coefficients reduced the contribution to total adult dose of I-131 by more than a factor of 4 and moved it to the group of 'less important' radionuclides (with Zn-65 and Ce-144). Country-specific consumption of fish has changed only the dose value and didn't change the ranking.

It should be noted that consideration of other pathways (external exposure from sediment and water submersion, internal exposure from drinking water, irrigation etc.) can change the total ranking in the riverine scenario.

TABLE VII–26. DOSES FROM INGESTION OF FISH. RIVERINE CASES A AND B

Radionuclide	Riverine case A		Riverine case B	
	Dose, μSv/a	Contribution, %	Dose, μSv/a	Contribution, %
H-3			5.6E-04	4.7E+00
Cr-51	6.3E-06	6.5E-03	3.0E-06	2.5E-02
Mn-54	5.3E-05	5.4E-02	2.7E-05	2.3E-01
Fe-59	6.1E-05	6.3E-02	4.1E-04	3.4E+00
Co-58	3.9E-05	4.0E-02	1.4E-05	1.2E-01
Co-60	4.0E-04	4.1E-01	1.4E-04	1.2E+00
Zn-65	1.0E-02	1.1E+01	1.0E-03	8.7E+00
Sr-90	3.3E-03	3.4E+00	4.9E-04	4.1E+00
Zr-95	4.2E-05	4.4E-02	6.3E-05	5.2E-01
Nb-95	5.6E-05	5.7E-02	2.6E-05	2.2E-01
Ru-106	1.5E-04	1.5E-01	1.3E-05	1.1E-01
Ag-110m	7.9E-05	8.1E-02	3.3E-06	2.8E-02
I-131	3.6E-02	3.7E+01	1.0E-03	8.8E+00
Cs-134	2.2E-02	2.3E+01	3.4E-03	2.9E+01
Cs-137	2.4E-02	2.5E+01	3.8E-03	3.2E+01
Ce-144	3.7E-05	3.8E-02	9.2E-04	7.7E+00
Total	9.7E-02	100	1.2E-02	100

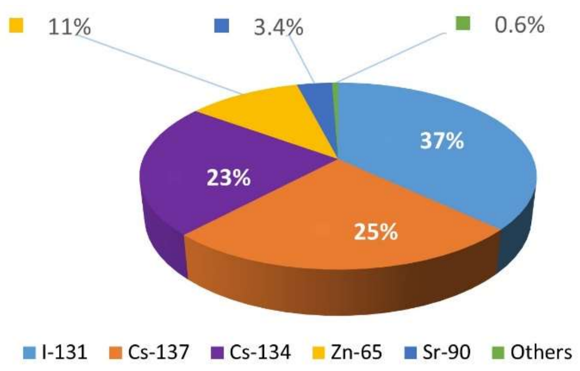

FIG. VII–22. Contribution of radionuclides to the dose from ingestion. Riverine case A

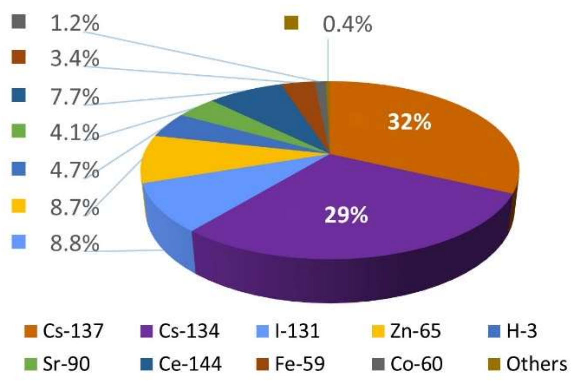

FIG. VII–23. Contribution of radionuclides to the dose from ingestion. Riverine case B

TABLE VII–27. RANKINGS BASED ON CONTRIBUTION TO THE TOTAL DOSE FROM INGESTION OF FISH

Rank	Riverine case A		Riverine case B	
	Radionuclide	Contribution, %	Radionuclide	Contribution, %
1	I-131	37	Cs-137	32
2	Cs-137	25	Cs-134	29
3	Cs-134	23	I-131	8.8
4	Zn-65	11	Zn-65	8.7
5	Sr-90	3.4	Ce-144	7.7
6	Co-60	0.41	H-3	4.7
7	Ru-106	0.15	Sr-90	4.1
8	Ag-110m	0.081	Fe-59	3.4
9	Fe-59	0.063	Co-60	1.2
10	Nb-95	0.057	Zr-95	0.52
11	Mn-54	0.054	Mn-54	0.23
12	Zr-95	0.044	Nb-95	0.22
13	Co-58	0.040	Co-58	0.12
14	Ce-144	0.038	Ru-106	0.11
15	Cr-51	0.0065	Ag-110m	0.028
16	H-3	-	Cr-51	0.025

The consideration of the ranking results presented in this report in all atmospheric and aquatic release scenarios concentrates on the potential goals and applications of ranking (generally, monitoring or assessment of discharges). The radionuclide orders can be different in different cases due to the different dose coefficients and intake values used. The rationale is that a ranking procedure should not be a simple ‘sorting’, it is more appropriate to be considered as ‘risk categorization tool’ for the radionuclides released. Suggestions on ranking procedures are the result of such an exercise.

Table VII–23 presents the list of 54 radionuclides in the marine discharge case A with their proportional contributions to the total dose from ingestion of fish. Theoretically, this list could be essentially longer, however a ‘significant’ component which comprises the radionuclides contributing in total more than 95% of the total dose would remain the same. Other radionuclides can be presented in the list, but their contribution to the dose is negligible. In many situations the analysis of complete list of radionuclides can be redundant. The 43 radionuclides in Table VII–23 contribute less than 1% of the total dose each and their combined contribution comprises only 1.4% of the total annual dose. For instance, there is no sense in discussing which radionuclide has a higher rank: Sr-90 or Ce-143. This example gives rise to the possibility of reporting “cut-off level” for the radionuclides that provide a low contribution to the total adult dose. The suggestion was to use a 0.5% contribution to dose (total, or within any exposure pathway) as a cut-off level. Radionuclides with lower contribution would be compiled into a single contribution from other radionuclides (“others”).

Table VII–23 needs to be clarified. Should Cs-134 have a higher rank than Cs-137? Difference between the doses from these radionuclides is less than 6%. Small changes in discharge assessment approaches or parameterization can swap their ranks. The same question would remain after such a swap.

Another example considering I-131 and H-3 is presented in Table VII–28 for the total dose from the atmospheric discharge. Comparison of ordered lists (rankings) demonstrates a non-equivalence of places with the same number (rank). I-131 from the ‘inhalation list’ and H-3 from the ‘total dose list’ have the same rank 2, however ‘significance’ of these radionuclides in their lists is quite different. I-131 having second rank in the ‘inhalation list’ contributes two order of magnitude less than first ranked radionuclide. H-3 having second rank in the 'total dose list' contributes approximately the same dose as the first ranked radionuclide.

TABLE VII–28. COMPARISON OF RANKS AND CATEGORIES

Inhalation (Atm. cases A, C)				Ingestion (Atm. case A)				Total dose (Atm. case C)			
Nuclide	Contr.,%	Rank	Category	Nuclide	Contr.,%	Rank	Category	Nuclide	Contr.,%	Rank	Category
H-3	96.8	1	A_{100}	I-131	93.2	1	A_{100}	I-131	28.7	1	D_{33}
I-131	1.58	2	H_2	I-133	2.10	2	G_5	H-3	28.2	2	D_{33}
I-133	0.91	3	H_2	Sr-90	1.95	3	H_2	Kr-85	8.17	3	F_{10}
Others	0.76	-	-	Cs-137	1.39	4	H_2	Ar-41	7.95	4	F_{10}
				Cs-134	0.81	5	H_2	Xe-133	7.33	5	F_{10}
				Others	0.57	-	-	Kr-88	4.99	6	G_5
								Co-60	3.56	7	G_5
								Xe-135	2.81	8	G_5
								Cs-137	1.57	9	H_2
								Xe-131m	1.38	10	H_2
								I-133	1.12	11	H_2
								Sr-90	1.03	12	H_2
								I-135	0.68	13	H_2
								Cs-134	0.59	14	H_2
								Others	1.83	-	-

TABLE VII–29. RANKINGS FOR ATMOSPHERIC DISCHARGES

Rank	Inhalation	Plume immersion		Ground deposition	Ingestion		Total dose		
		Cases A, C	Case B		Cases A, B	Case C	Case A	Case B	Case C
A_{100}	H-3				I-131	I-131			
B_{75}							I-131	I-131	
C_{50}				Co-60					
D_{33}			Ar-41						H-3, I-131
E_{25}		Ar-41, Kr-85, Kr-88, Xe-133	Kr-85, Kr-88, Xe-133	I-131, Cs-137			H-3	H-3	
F_{10}		Xe-135	Xe-135	I-133, I-135				Ar-41	Ar-41, Kr-85, Xe-133
G_5		Xe-131m	Kr-87, Xe-131m	Co-58, Sr-90, I-132, Cs-134	I-133	Sr-90	Ar-41, Kr-85, Kr-88, Xe-133	Kr-85, Kr-88, Xe-133	Co-60, Kr-85, Xe-135
H_2	I-131, I-133	Kr-85m, Kr-87	Kr-85m, Xe-135m, Xe-138	Mn-54, I-134	Sr-90, Cs-134, Cs-137	Co-60, I-133, Cs-134, Cs-137	Co-60, Sr-90, I-133, Xe-131m, Xe-135, Cs-134, Cs-137	Co-60, Sr-90, I-133, Xe-131m, Xe-135, Cs-134, Cs-137	Sr-90, I-133, I-135, Xe-131m, Cs-134, Cs-137

These examples show that simple 'sorting' mechanism is not effective in identifying the risks posed by various radionuclides via a range of exposure pathways. The second suggestion was to treat the ranking procedure as a 'categorization' using letters which seems to be more appropriate for such purposes than numbers. For visual comprehension it can be useful to add a corresponding ‘contribution level’ as subscript or superscript. The use of a cut-off level allows for exclusion from consideration of any radionuclides with a negligible contribution to the total dose. A proposed categorization for ranking is presented in the report. Examples of application of ranking procedures are provided in Table VII–28.

According to these suggestions, the ranking results reported in Tables VII–13, VII–14, VII–15, VII–16, VII–17, VII–21, VII–24, VII–27, were revised. The results of application of the proposed ranking procedures are presented in Tables VII–18, VII–19, VII–20, VII–25, VII–29 and VII–30.

TABLE VII–30. RANKINGS FOR AQUATIC DISCHARGES

Rank	Marine discharges. Marine case A			Riverine discharges	
	Fish	Shellfish	Total dose (ingestion)	Riverine case A	Riverine case B
A_{100}	-	Ru-106	-	-	-
B_{75}	-	-	Ru-106	-	-
C_{50}	-	-	-	I-131	-
D_{33}	Cs-134, Cs-137	-	-		Cs-134, Cs-137
E_{25}	I-131	-	-	Zn-65, Cs-134, Cs-137	-
F_{10}	P-32, Co-60	-	I-131, Cs-134, Cs-137	-	Zn-65, I-131, Ce-144
G_5	Ag-110m	Co-60, Zn-65, Ag-110m	Co-60, Zn-65, Ag-110m	Sr-90	H-3, Fe-59, Sr-90
H_2	Co-58, Zn-65, Ru-106, Rh-106m, I-133	Co-58, Ru-103, Rh-106m, I-131, Cs-134, Cs-137	P-32, Co-58, Ru-103, Rh-106m, I-133	-	Co-60, Zr-95

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ABBREVIATIONS

HTO	tritiated water - hydrogen tritium oxide
ICRP	International Commission on Radiological Protection
NPP	nuclear power plant
OBT	organically bound tritium
PWR	pressurized water reactor

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