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UK ABWR

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UK ABWR Generic Design Assessment

Prospective Dose Modelling

Hitachi-GE Nuclear Energy, Ltd.

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1. Acronym List

ABWR	Advanced Boiling Water Reactor
ADMS	Atmospheric Dispersion Modelling System
ALARA	As Low As Reasonably Achievable
ASSESSOR	The Dose Assessment Module Used in PC-CREAM 08®
BAT	Best Available Technique
Bq	Becquerel
BSS	Basis Safety Standards Directive
CERC	Cambridge Environmental Research Consultants
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CST	Condensate Storage Tank
DCFPAK	Dose Coefficient Data File Package
DCRL	Derived Consideration Reference Levels
DOE	United States Department of Energy (US)
DORIS	The Marine Dispersion Module Used in PC-CREAM 08®
DPUR	Dose Per Unit Release
EMCLs	Environmental Media Concentration Limits
EPR16	Environmental Permitting (England and Wales) Regulations 2016
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EU	European Union
FARMLAND	The Foodchain Module Used in PC-CREAM 08®
GDA	Generic Design Assessment
GEP	Generic Environmental Permit
GRANIS	The Ground Gamma Module Used in PC-CREAM 08®
Gy	Gray
Hitachi-GE	Hitachi-GE Nuclear Energy, Ltd.
HPA	Health Protection Agency
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW	Intermediate Level Waste
IRAT	Initial Radiological Assessment Tool
LLW	Low Level Waste
MCNP	Monte Carlo N-Particle
NDAWG	National Dose Assessment Working Group
NERC	Natural Environment Research Council
NHS	Non-Human Species
NRPB	National Radiological Protection Board

OPEX	Operating Experience Feedback
P&ID	Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs
PCSR	Pre-Construction Safety Report
PHE	Public Health England
PLUME	The Atmospheric Dispersion Module Used in PC-CREAM 08®
RAP	Reference Animals and Plants
REP	Radioactive Substances Regulation – Environmental Principle
RESUS	The Resuspension Module Used in PC-CREAM 08®
RGP	Relevant Good Practice
RQ	Risk Quotient
RSA	Radioactive Substances Act
RSR	Radioactive Substances Regulation
SA	Specific Activity
SFIS	Spent Fuel Interim Storage
SPT	Suppression Pool Water Surge Tank
Sv	Sievert
UF	Uncertainty Factor
UK	United Kingdom
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
US	United States

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3. Introduction

This document presents the methodology and results of the modelling undertaken for the prospective doses associated with the UK ABWR, and forms part of Hitachi-GE's Generic Environmental Permit (GEP) application for the Environment Agency's consideration as part of the Generic Design Assessment (GDA). The Environment Agency's requirements for undertaking radiological assessment for the GDA submission are defined within its Process and Information Document (P&ID) [Ref-1]: a prospective radiological assessment is required at the proposed limits for discharges to the environment.

The radiological assessments undertaken in this document seek to demonstrate that the UK ABWR complies with the applicable requirements of the Environmental Permitting (England and Wales) Regulations 2016 (EPR16) [Ref-2]. The method of calculation of the UK ABWR's source term (i.e. the radioactivity present within its systems) has been reviewed and revised since Step 2 of the GDA; a more realistic and rigorous approach has been made, based on detailed modelling and supported by OPEX. The source term and associated discharge rates used as the basis for the dose modelling are presented in [Ref-3].

The Hitachi-GE's radiological assessments for the UK ABWR have been developed with the UK regulatory system and P&ID requirements in mind. This document describes the radiological assessments undertaken to assess the prospective radiological impact on members of the public and Non-Human Species (NHS) as a result of radioactive discharges and direct exposure due to normal operation of the proposed UK ABWR. The potential impacts on future use of surrounding land due to the build-up of radioactive discharges into the local environment, and the collective dose to the UK, European and World populations as a result of these discharges are also assessed. In addition, this document presents an assessment of the potential radiological impact of planned short-term discharges.

4. Regulatory Context

4.1 Legislative Background

The 1996 Euratom Basic Safety Standards Directive ('the BSS Directive') [Ref-4] provides the mechanism for the implementation of the 1990 recommendations of ICRP [Ref-5] within the European Union. The 1996 BSS Directive has recently been revised (Council Directive 2013/59/Euratom of 5 December 2013) to include implementation of the 2007 Recommendations of the International Commission on Radiological Protection (ICRP) [Ref-6]. The new 2013 BSS will be enacted into national legislation in due course.

Many of the 1996 BSS Directive's provisions are implemented by the 1999 Ionising Radiations Regulations [Ref-7] and, with respect to the control of radioactive waste, have been implemented within the UK through the Environmental Permitting Regulations 2016 (EPR16) [Ref-2] for England and Wales, and regulations amending the Radioactive Substances Act 1993 (RSA 93) [Ref-8], [Ref-9] in Scotland and Northern Ireland. The principal aims of this legislation are to require that, when exercising their duties and functions under radioactive substances legislation, the UK Environment Agencies (the Environment Agency, Natural Resources Wales, Northern Ireland Environment Agency and the Scottish Environmental Protection Agency) ensure that:

- All public ionising radiation exposures from radioactive waste disposal are kept as low as reasonably achievable (ALARA) with economic and social factors taken into account;
- The sum of the doses arising from such exposures does not exceed the individual public dose limit of 1 mSv a year;
- The individual dose received from any new discharge source since 13th May 2000 (1st May 2003 in Northern Ireland), does not exceed 0.3 mSv a year;
- The individual dose received from any single site does not exceed 0.5 mSv a year; and,
- Estimates of doses are as realistic as possible (by requiring that Article 45 of the BSS Directive is observed).

The Health Protection Agency (HPA) (now known as Public Health England (PHE)) advised the Government (including the Devolved Administrations) that a lower dose constraint not exceeding 0.15 mSv/y should be applied at the design stage of new nuclear power stations and waste disposal facilities [Ref-10]. This advice will be taken into account where relevant.

The UK Environment Agencies collaborated with PHE and the Food Standards Agency to publish principles and guidance for the prior assessment of doses to the public arising from exposure to ionising radiation which may result from planned discharges to the atmosphere and to the aquatic environment [Ref-11]. The guidance document outlines the regulatory framework that currently applies to radioactive discharges into the environment and describes 13 principles which relate to the following:

- Population groups to be considered in assessments and the use of the representative person concept;
- Exposure pathways to be included for comparison of doses against the source constraint, site constraint and dose limit;
- Accumulation of radionuclides in the environment;

- The need for realistic dose assessments, based upon the selection of realistic habits, but taking account of reasonably likely changes over a period of about five years; and,

- The need to assess doses from short-term releases, assessment of collective doses and investigation of variability and uncertainty in the assessment.

A staged approach to dose assessments recommended as part of this guidance and which incorporates these principles is outlined in section 5.2.

4.2 Radioactive Substances Regulation – Environmental Principles

The methodologies presented in this report are consistent with industry Relevant Good Practice (RGP) and take into account the relevant Radioactive Substances Regulation – Environmental Principles (REPs)[Ref-12]. Hitachi-GE's 'Alignment with the Radioactive Substances Regulation Environmental Principles' document [Ref-13] details the approach undertaken by Hitachi-GE to reviewing and showing compliance with each of the relevant REPs within the GDA submission, highlighting the REPs specifically addressed within each report.

The REPs considered most relevant to dose modelling, as far as is covered in the scope of this GDA report, are: Fundamental Principle E (Protecting Human Health and the Environment); and, Generic REPs RPDP1, RPDP2, RPDP3, RPDP4, SEDP2, ENDP1.

5. Approach to Dose Modelling

5.1 P&ID Requirements

The P&ID [Ref-1] stipulates that a prospective dose assessment is to include:

- *Annual dose to the most exposed members of the public for liquid discharges;*
- *Annual dose to the most exposed members of the public for gaseous discharges (identifying separately the dose associated with on-site incineration where applicable);*
- *Annual dose to the most exposed members of the public for all discharges from the facility;*
- *Annual dose from direct radiation to the most exposed member of the public;*
- *Annual dose to the representative person for the facility;*
- *Potential short-term doses, including via the food chain, based on the maximum anticipated short-term discharges from the facility in normal operation;*
- *A comparison of the calculated doses with the relevant dose constraints;*
- *An assessment of whether the build-up of radionuclides in the local environment of the facility, based on the anticipated lifetime discharges, might have the potential to prejudice legitimate users or uses of the land or sea;*
- *Collective dose truncated at 500 years to the UK, European and World populations;*
- *Dose-rate to NHS.*

Each of these requirements is addressed in this document as part of the GEP submission.

5.2 Overview of the Radiological Assessment Methodologies Used

As stipulated in the P&ID [Ref-1], the Environment Agency is to be informed which models are used to calculate the doses as part of the radiological assessment, as well as why they are appropriate (with all the data and reasoned assumptions that have been used as input to the models set out).

i. Assessment of Doses to Public

The Environment Agency has developed a simple and cautious assessment methodology of the representative person dose for the prospective assessment of public doses [Ref-14] [Ref-15], known as the Initial Radiological Assessment Tool (IRAT) methodology. The representative person is 'an individual receiving a dose that is representative of the more highly exposed individuals in the population'. ICRP and the HPA have stated that this term is the equivalent of and replaces the average member of the critical group [Ref-11].

The IRAT methodology supports a staged approach to the dose assessment process, representing RGP. Hitachi-GE has used the IRAT methodology for the first two stages of the dose modelling process, with more detailed modelling for the third stage, again in line with RGP. This is summarised as follows:

- Stage 1: uses the IRAT methodology and standard generic parameters which enable a cautious assessment of the radiological impact of discharges.

  If the assessed dose is > 20 μSv/y, then Stage 2 is undertaken to refine the dose assessment.

- Stage 2: uses the IRAT methodology and refined data with more realistic parameters. If the assessed dose is > 20 μSv/y, then Stage 3 is undertaken to further refine the dose assessment.

- Stage 3: uses more detailed site-specific data. In line with RGP, Stage 3 does not use the IRAT methodology but more detailed codes (in the case of Hitachi-GE, PC-CREAM 08®). The computer code PC-CREAM 08® comprises of a number of modules that predict the transfer of radionuclides in the environment and also estimate build-up of radionuclides in the environment and the effect on NHS.

The IRAT methodology used in Stages 1 and 2 enables the assessment of the release of 100 radionuclides via the following routes:

- Air;

- Estuarine/coastal waters;

- Rivers/streams; and,

- Public sewer.

The doses to the representative person can be calculated for 7 different public groups and 4 age groups (including offspring) which may receive doses as a result of discharges to these release routes. The methodology is based on published dose per unit release (DPUR) data, which are combined with assumed permitted discharge limits to calculate doses to members of the public. This is the methodology used by Hitachi-GE in this document to assess the radiological impact of discharges to air and to estuarine or coastal waters. The input parameters describing the physical characteristics of the site are described in [Ref-16]. Note that, as defined in the Generic Site Description [Ref-16], discharges will not be made into rivers or streams or into public sewers; therefore these routes are not assessed.

The IRAT methodology used in Stages 1 and 2 is not utilised for the Stage 3 assessment. Instead of using DPUR values, a more specific model using more realistic data is used.

For the Stage 1 and Stage 2 assessments of the radiological consequences of continuous gaseous discharges from the UK ABWR, Hitachi-GE defined receptor distances of 100m for the assessment of exposure due to immersion in the plume and 500m for the location of food subsequently ingested by members of the public. These distances are consistent with those assumed in the Environment Agency's IRAT methodology.

For the more detailed Stage 3 assessment, a receptor distance of 270m for the assessment of exposure due to immersion in the plume is now defined. This changed from the initial distance of 300m assumed in earlier versions of E8, as the site layout became more refined at the latter stages of the assessment [Ref-17]. The more refined site layout gave a distance from the main stack to the site boundary of 270m. The shorter distance was used in the subsequent Stage 3 dose assessments presented in this report as this would be more consistent with the distances to the site boundary presented in the topic report on direct radiation to the public [Ref-27]. The distances to the site boundary of the source buildings contributing to direct radiation (also referred as "shine") offsite are: reactor building 265m; turbine building 310m; radioactive waste building 243m; the condensate storage tank (CST) 240m and suppresion pool water surge tank (SPT) 350m.

Furthermore, for the assumed discharge height of 19m and a uniform wind rose with 70% category D meteorological condition, a distance of 270m would result in a slightly higher estimate of the ground level airborne activity concentration when compared with the ground level concentration at 300m. Therefore the assumption of a receptor distances of 270m for the assessment of exposure due to immersion in the plume would result is a slightly more conservative estimate of annual radiation exposure.

A number of models are available for the determination of the radiological impact of routine discharges of radioactive material to the environment, each of which have their own characteristics often due to the regulatory regime in country in which they are predominantly used. For example, the Japanese Nuclear Safety Commission published a guide on the evaluation of dose targets for surrounding areas of light water reactors [Ref-18]. However the Japanese methodology for gaseous discharges only considers discharges of noble gases and iodine. In addition, the Japanese methodology for liquid discharge only considers a small number of radionuclides. In the Japanese methodology, a case study for some radionuclides is provided and these radionuclides have been chosen as representative radionuclides where their dose contribution to human is higher.

The decision was taken for the UK ABWR Stage 3 assessment to utilise the off-site dose assessment code PC-CREAM 08® [Ref-19].

PC-CREAM 08® is a computer code comprising a suite of models and data that was developed by the HPA (now PHE) and tailored to UK legislative requirements. PC-CREAM 08® contains a number of modules to predict the transfer of radioactivity through the environment. These include models for atmospheric dispersion (PLUME); transport of radioactive material through the soil horizon (GRANIS); transfer through the food chain (FARMLAND) and re-suspension of deposited activity (RESUS). In modelling the transfer of activity in this way, the pathways by which people may be exposed to radiation can be assessed and the resulting radiation doses received calculated [Ref-19]. The methodology is closely based on that developed by a number of EU organisations for the European Commission and which was published in 1995 [Ref-20].

PC-CREAM 08® and its underlying dispersion models are seen to be robust, fit for purpose and have been verified against environmental data [Ref-15]. The modelling package has been used for many other assessments in the UK and overseas. Its strengths are that it includes a number of modules that assess the impact of continuous discharges of gaseous and liquid discharges of a large number of radionuclides over a large number of pathways (more than the Japanese method). PC-CREAM 08® enables the assessment of individual and collective dose due to gaseous and liquid discharges, including internal and external exposure, doses due to deposition and accumulation in the environment, inhalation of re-suspended material including sea spray and ingestion of contaminated foodstuffs [Ref-19] (it should be noted that assessment of the collective dose during normal operation has never been undertaken in Japan).

Whilst acknowledging its strengths, an area where PC-CREAM 08® could be improved is in the use of a specific activity model for the assessment of the radiological impact of H-3 and C-14. In addition, PC-CREAM 08® is not appropriate for the assessment of short-term releases, therefore a separate methodology should be used. The current version is maintained by PHE who provide support and updates to the software.

ii. Assessment of Doses to NHS

NHS may be exposed to radiation from a number of pathways. For terrestrial species, exposure to radiation may come from radionuclides accumulated in soil over a period of 60 years (whether the NHS are above soil or in soil) or due to immersion in the plume itself. For marine species, exposure to radiation may arise from immersion in the sea water or in seabed sediment that has accumulated radioactivity due to discharge of liquid wastes over a period of 60 years.

Two computational tools have been used to assess the impact on NHS: ERICA and R&D128. Summary details on each are provided below.

The ERICA tool [Ref-21] is a software system that has a structure based upon the tiered ERICA integrated approach to assessing the radiological risk to terrestrial, freshwater and marine biota. The Tool guides the user through the assessment process, recording information and decisions and allowing the necessary calculations to be performed to estimate risks to selected animals and plants. Tier 1 assessments are media concentration based and use pre-calculated environmental media concentration limits (EMCLs) to estimate risk quotients (RQ). Tier 2 calculates dose rates but allows the user to examine and edit most of the parameters used in the calculation including concentration ratios, distribution coefficients, percentage dry weight soil or sediment, dose conversion coefficients, radiation weighting factors and occupancy factors. Tier 3 offers the same flexibility as Tier 2 but allows the option to run the assessment probabilistically if the underling parameter probability distribution functions are defined.

An updated version of the ERICA tool [Ref-22] was published in 2014. The updated version of the ERICA tool has been used in the assessment of the radiological risk to terrestrial, freshwater and marine biota. The changes incorporated in the updated version include an increase in the number of default radionuclides, improvements to the reference organisms and improvements in the transfer parameters databases. Further details can be found in the associated release notes [Ref-22].

R&D128 is an assessment code developed by the Environment Agency for the impact assessment of ionising radiation on wildlife [Ref-23]. It is a spreadsheet based model that uses a similar approach to that of the ERICA tool though for a smaller range of organisms and radionuclides. Importantly, it includes the assessment of noble gases released into the atmosphere, which is not included in the ERICA tool.

R&D128 has also been updated since the first publication of this report. The latest version of R&D128 has been used in the assessment of the radiation exposure of NHS due to the discharge of radioactive noble gases. The updated version of R&D128 now includes the ability to calculate doses for all the environmentally relevant Argon, Krypton and Xenon isotopes, and covers not only the original R&D 128 organisms but also the ICRP reference animals and plants that the ERICA tool considers.

5.2.1 Stage 1 Assessment Methodology

The default parameters on which the Stage 1 assessment is based are presented in Table 6.3-1.

5.2.1.1 Liquid Discharges

The IRAT identifies that the Fisherman family is the representative public group for this assessment. The relevant exposure pathways are:

- External irradiation from radionuclides deposited in shore sediments;
- Consumption of seafood incorporating discharged radionuclides.

The detailed calculations to derive the DPUR factors for a fisherman are provided in [Ref-14]. A key assumption in the calculation of the DPUR factors is that all shellfish and 50% of the fish are caught from a 'local compartment', which might be an estuary, modelled as a 'theoretical box' along the coast. The other 50% of the fish are assumed to be caught in the adjacent regional compartment. The minimum exchange rate for most large estuaries and coastal areas, particularly on the west coast of Britain (where tidal height changes are greater), is likely to be $100m^3/s$.

The initial assessment is made by multiplying the discharge rate of a particular isotope as given in Table 6.3-3 for the proposed annual discharge limit by the corresponding DPUR value [Ref-14]. Where a DPUR value was not available for a particular radionuclide then Cs-137 was used as a surrogate and the corresponding DPUR value used. Cs-137 has been used as a surrogate for Te-123m, Sb-122 and Sb-124 because it is a fission product with the highest DPUR value. Therefore it was considered to give a conservative bounding estimate of the dose from these three radionuclides.

5.2.1.2 Gaseous Discharges

The IRAT Local Resident family is the representative public group for this assessment. The relevant exposure pathways are:

- Inhalation of radionuclides in the effluent plume;
- External irradiation from radionuclides in the effluent plume and deposited to the ground; and,
- Consumption of terrestrial food incorporating radionuclides deposited to the ground.

The detailed calculations to derive the DPUR factors for a member of the Local Resident family are provided in [Ref-14]. Key assumptions in the calculations are: the release is at ground level; the Local Resident is assumed to be located at a distance of 100m from the release point; and, the food consumed is produced at a distance of 500 m from the release point.

The initial assessment is made by multiplying the discharge rate of a particular isotope as given in Table 6.3-4 (representing the proposed annual discharge limit) by the corresponding DPUR value from the exposure pathways of food consumption, external irradiation and inhalation. The overall dose from gaseous discharges is then found by summing the contribution from all radionuclides.

For a number of the noble gases that are discharged, no DPUR factor is given by the IRAT methodology [Ref-14]. In these instances, the use of the default DPUR factors given in [Ref-14] are not appropriate as this will lead to estimates of inhalation and ingestion doses that are not viable exposure pathways for noble gases, and hence could potentially lead to an overestimation of the dose to a member of the public.

It was therefore decided that where no DPUR value was available for a noble gas isotope then the DPUR value for that noble gas isotope would be derived using the methodology described in section D4 and D6 of [Ref-15]. The calculation of DPUR values used in the assessment for noble gases is presented in Appendix C of this document.

Where DPUR values were not available for particulate radionuclides, i.e. Sb-122, Sb-124 and Te-123m, then the DPUR for a surrogate radionuclide was used. In this case Cs-137 was selected as the surrogate radionuclide as Cs-137 is a beta-gamma emitter, has a longer half-life and has the highest DPUR value for the fission products considered in this document.

5.2.2 Stage 2 Assessment Methodology

The default parameters on which the Stage 2 assessment is based are presented in Table 6.3-2.

5.2.2.1 Liquid Discharges

The methodology for the Stage 2 assessment is the same as that used for the Stage 1 assessment with the exception that a more refined volumetric exchange rate, i.e. the volumetric rate of water exchange between the local and regional compartment, has been used (justification is provided in [Ref-16]). An investigation on the sensitivity of the predicted dose to marine parameters is reported in section 15.3.

5.2.2.2 Gaseous Discharges

The methodology for the Stage 2 assessment is the same as that used for the Stage 1 assessment with the exception that factors have been applied to account for an effective release height of 19m, based on 1/3rd of the shortest stack for a Japanese ABWR of 57m (see section 16.2).

5.2.3 Stage 3 Assessment Methodology

As discussed in section 5.2, the off-site dose assessment code PC-CREAM 08® has been used for the Stage 3 Assessment.

5.2.3.1 Liquid Discharges

In PC-CREAM 08® the assessment of the radiological impact of liquid discharges is undertaken in two stages:

i. Firstly a DORIS model is generated. The DORIS module calculates the concentration of radionuclides in the specified foodstuffs and environmental media for a unit annual liquid release rate of the radionuclides of interest. The site parameters, such as local compartment volumetric exchange rate, suspended sediment load and other parameters, are also defined. For this assessment the default values for the generic site were used (justification is provided in the Generic Site Description document [Ref-16]). An investigation on the sensitivity of the predicted dose to marine parameters is reported in section 15.3 of this document.

ii. The DORIS module is then called up in the ASSESSOR marine individual dose module. The annual discharge rates and exposure routes are defined and the individual doses for each age group are calculated for both high and mean consumption rates.

The doses were calculated assuming a continuous discharge over a period of 60 years, corresponding to the design life of the UK ABWR.

Although the P&ID [Ref-1] does not define the ages of the representative persons to be considered, Principle 4 of the principles document [Ref-11] states that doses to the most affected age group should be assessed for the purpose of determining discharge permits or authorisations. Assessment of doses to a 1 year old (an Infant), a 10 year old (a Child) and Adults (plus offspring when appropriate) should provide adequate age group coverage. Guidance from the HPA (now PHE) [Ref-24] shows that doses to the foetus need only be considered for four radionuclides (i.e. P-32, P-33, Ca-45 and Sr-89) in assessments where these radionuclides form a significant part of any release to the environment. In the case of other radionuclides, assessment of the annual exposure to the Adult, Child and Infant age groups are sufficiently low such that assessment of the doses to offspring is not warranted.

The proposed limits for the discharge of activity into the environment as presented in Table 6.3-3 do identify Sr-89 as a constituent of the discharged radioisotopes. However Sr-89 forms a very small part (very much less than 0.1%) of the release to the environment and so it is concluded that detailed consideration of offspring exposure is not necessary.

5.2.3.2 Gaseous Discharges

In PC-CREAM 08® the assessment of the radiological impact of gaseous discharges is undertaken in five stages:

i. A PLUME model is set up: This PLUME module calculates the airborne activity concentrations and deposition rates of radionuclides as a function of distance from the release point and effective release height of the discharge;

ii. A GRANIS model is produced: The GRANIS model calculates the gamma dose rate and soil concentrations for the discharged radionuclides that deposit on the ground;

iii. A FARMLAND model is set up: The FARMLAND model calculates the concentration of radioactivity in foodstuffs for the radionuclides that are discharged to atmosphere;

iv. A RESUS model is produced: The RESUS model calculates the time integrated air concentration due to the re-suspension of activity that deposit on the ground; then,

v. The above models are then called up in the ASSESSOR atmospheric individual dose assessment module. The annual discharge rates and exposure routes are defined and the individual doses for each age group calculated for both high and mean consumption rates.

The doses were calculated at 270m (distance from the main stack to the site boundary) for exposure pathways associated with exposure to the plume and deposited activity, and at 500m (default food production location assume in the IRAT) for ingestion pathways assuming a continuous discharge over a period of 60 years, corresponding to the design life of the UK ABWR.

As described in section 5.2.3.1 assessment of doses to an Infant, Child and Adults (and foetus when appropriate) should provide adequate age group coverage. Guidance from the HPA (now PHE) [Ref-24] shows that doses to the foetus need only be considered for four radionuclides (i.e. P-32, P-33, Ca-45 and Sr-89) in assessments where these radionuclides form a significant part of any release to the environment. A detailed assessment of offspring exposure indicates that offspring exposure is bounded by the assessment of doses to Infants.

The proposed limits for the discharge of activity into the environment as presented in Table 6.3-4 do identify Sr-89 as a constituent of the discharged radioisotopes. However Sr-89 forms a very small part (very much less than 0.1%) of the release to the environment and so it is concluded that detailed consideration of offspring exposure is not necessary.

5.2.3.3 Stage 3 Representative Person

Estimation of the dose to the representative person for liquid discharges has been made for the Fisherman family by adding the results due to the consumption of terrestrial foodstuffs at the mean rate to the corresponding results due to exposure to all marine pathways including the consumption of marine foods at the high rates.

In a similar manner, estimation of the dose to the representative person for gaseous discharges has been made for the Local Resident family by adding the results due to the consumption of marine foodstuffs at the mean rate to the corresponding results due to exposure to all terrestrial pathways, including the consumption of terrestrial foods at the 'top two' rates. The methodology and data used for derivation of the 'top two' foodstuffs are presented in Appendix D.

5.2.4 Direct Dose Assessment

Buildings containing radioactive substances, such as the reactor building, turbine building and radioactive waste building, may lead to the exposure of members of the public to direct radiation. In the UK, assessments of direct radiation are usually carried out by monitoring radiation levels at the site boundary. This result is then combined with a realistically conservative occupancy rate for the most exposed member of the public to determine the annual dose from direct radiation for this person. This direct dose is then added to the doses due to discharges to allow comparison with the appropriate constraints and limits.

The radiation transport code MCNP version 5 [Ref-25] has been used to model an idealised building representing the source building.

5.2.4.1 Occupancy Pattern

Based on the occupancy pattern described in the IRAT methodology the scenario adopted for the assessment of direct dose is a member of the public present at the location for 8,760 hours per year, spending 50% of their time indoors. The dose to this 'most exposed person' is then calculated by multiplying the annual exposure time by the calculated dose rate and application of the appropriate location factors.

A location factor is the ratio between the external dose rate indoors to the external dose rate outdoors. An indoor location factor is considered appropriate in this situation [Ref-19].

The overall dose at the receptor location is equal to the dose rate at this location multiplied by the exposure time, taking into account the reduced dose rate while indoors.

$$Dose = D_i \times (LF_i \times O_i + LF_o \times O_o)$$

Where

D_i : External dose rate, μSv/h

LF_i : Indoor location factor = 0.1

LF_o : Outdoor location factor = 1

O_i : Hours per year spent indoors

O_o : Hours per year spent outdoors

5.2.5 Short-term Discharges

External dose from submersion in the plume during a short-term release was calculated using the following formula:

$$Dose_{\ cloud\beta/\gamma} = AirC \times T \times DC_{cloud\beta/\gamma} \times (LF_{cloud\ i} \times O_i + LF_{cloud\ o} \times O_o)$$

Where:

AirC : Air concentration (Bq/m^3)
T : Exposure time (s)
$DC_{cloud\beta/\gamma}$: External beta or gamma dose coefficient for submersion for each radionuclide (Sv/s per Bq/m^3) taking daughters into account
$LF_{cloud\ i,o}$: Cloud gamma location factor for indoors and outdoors occupancy
$O_{i,o}$: Occupancy factor for indoors and outdoors occupancy

The resulting potential dose due to short-term discharges are summed with the predicted dose due to normal operational discharges and then compared with the source dose constraint of 0.3 mSv/y and the annual dose limit of 1 mSv/y [Ref-11].

5.2.6 Build-up

Using Stage 1 IRAT parameters, the general method used to calculate environmental soil and water concentrations is based on PC-CREAM 08® methodology, as described in [Ref-19]. This model was used to carry out the assessments of concentrations in soil and water.

5.2.6.1 Marine Environment

All liquid discharges were made into the local compartment with parameters appropriate for the generic site using Stage 1 IRAT parameters. The parameters for this generic site are given in Table 6.3-1.

The DORIS module within the modelling code PC-CREAM08® was used to calculate the activity concentrations in the marine environment after 60 years of continuous discharge in seabed sediments and unfiltered seawater.

5.2.6.2 Terrestrial Environment

All gaseous discharges were assessed with parameters appropriate for the generic site using Stage 1 IRAT parameters. The parameters for this generic site are given in Table 6.3-1.

The PLUME and FARMLAND modules within the modelling code PC-CREAM08® were used to calculate the activity concentrations in soil at 100m from a ground level release after 60 years of continuous discharge into the terrestrial environment:

- PLUME was used to determine the air concentration per unit release rate (Bq/m^3 per Bq/y) and the deposition rate per unit release rate ($Bq/m^2/s$ per Bq/y) for the radionuclides discharged. The meteorological conditions were those defined in the IRAT methodology, i.e 50% category D and a uniform wind rose.

- FARMLAND was used to calculate the concentration in soil resulting from a unit deposition rate over a period of 60 years (Bq/kg per Bq/m^2/s).

The product of the annual release rate (Bq/y), PLUME (Bq/m^2/s per Bq/y) and FARMLAND (Bq/kg per Bq/m^2/s) results gives the activity concentration in soil Bq/kg.

The exception to this approach is the calculation of concentration of C-14 and H-3 where a specific activity model is used to determine the radiological consequences of the discharge to atmosphere of these radionuclides. The details of the specific activity model are presented in Appendix E of this document.

5.2.7 Collective Dose

PC-CREAM 08® was used to determine the collective dose due to liquid and gaseous discharges to the various population groups.

6. Discussion of Input Parameters

This section describes the input data and parameters that have been used in the prospective dose assessment. It also discusses the effect of discharge duration on the build-up of activity in the environment and subsequent impact on the prospective dose.

6.1 Discharge Rates

Discharges associated with the normal operation of the UK ABWR are presented in Table 6.3-3 and Table 6.3-4. These rates are at the proposed discharge limits that have been derived by Hitachi-GE [Ref-3] based on the anticipated coolant inventory, treatment processes of gaseous and liquid arisings and engineered abatement measures expected to be put in place to manage normal operational discharges.

The limits for the gaseous releases include an additional source term associated with the release of volatile fission products into the coolant due to a defined expected event. An expected event is an event that is likely to occur at least once over the operating lifetime of the reactor which also causes a release of activity. The expected event considered here is a pin-hole failure of the cladding of a fuel pin [Ref-26]. Further information on how its effect is considered is provided in section 6.3.4.1.

The proposed annual discharge limits outlined in Table 6.3-3 and Table 6.3-4 are those expected to apply to the operation of an individual UK ABWR unit. There is no intention to install an on-site incinerator; therefore no assessment of the impact of the use of an on-site incinerator is required.

6.2 Discharge Duration

The build-up of activity in environmental media will be dependent on, amongst other things, the duration of the discharge of radioactive substances into the environment. The Environment Agency IRAT methodology assumes a 50 year continuous discharge duration. The planned operating life-time of the UK ABWR, and hence duration of normal operational discharges, is 60 years. A brief assessment was undertaken in order to determine if there is any discernible effect on the radiological impact of a 50 or 60 year discharge regime. This assessment calculated the concentration of the radionuclides discharged by the UK ABWR as a function of time in representative environmental media that will accumulate activity.

To examine the effect of liquid discharges, the activity concentration in seabed sediment for the more significant radionuclides was calculated to determine the build-up of activity over time using the PC-CREAM 08® DORIS marine model. The radionuclides selected were: Fe-55, Co-60, Mn-54 and Zn-65 as these are the most radiologically significant radionuclides as presented in Table A.3 in Appendix A. Also plotted were: radionuclides that are representative of the main groups - C-14; the fission products Ce-144, Cs-137, I-131, Sr-90; and the actinides Am-241, Cm-243 and Pu-239. H-3 was included as it has a numerically large annual discharge. The results of this calculation are presented in Figure 6.2-1 below.

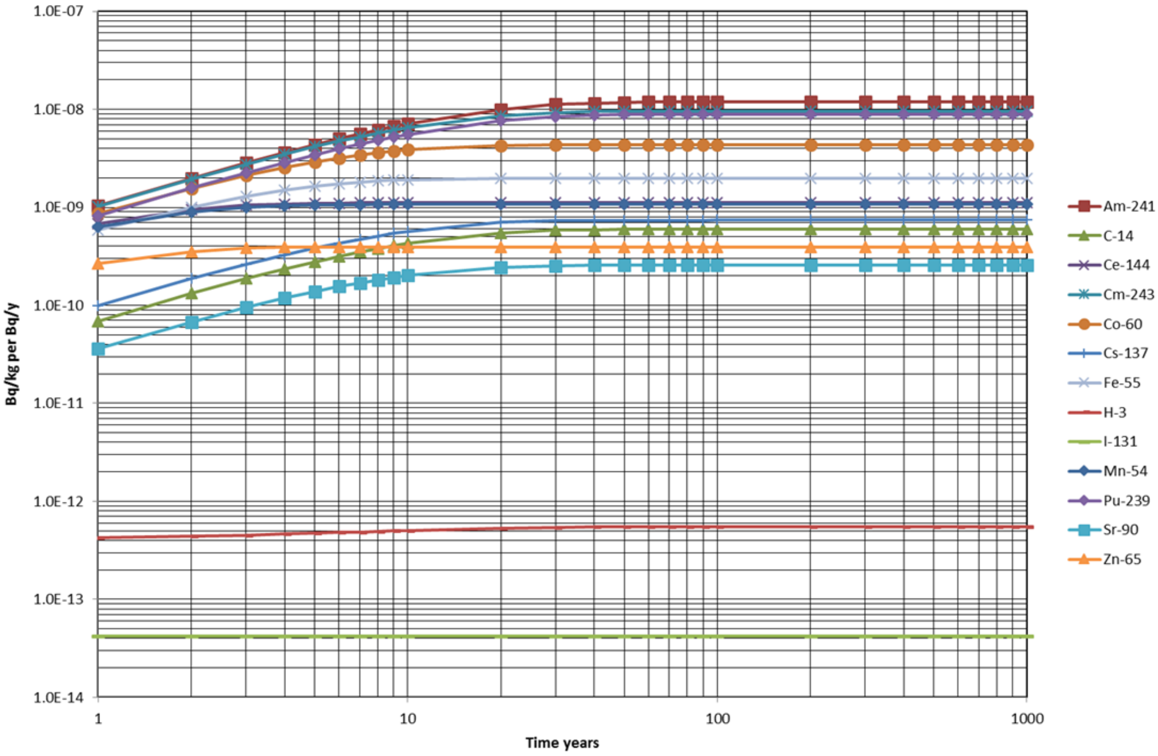

Figure 6.2-1: Seabed Sediment Concentration, Bq/kg, vs. Time for a Continuous Unit Annual Discharge Rate, Bq/y

As can be seen in Figure 6.2-1 the activity concentration in seabed sediment has achieved equilibrium concentrations within 30 years for the radionuclides of interest.

To examine the effect of gaseous discharges over a 50 or 60 year period the activity concentration in soil was calculated to determine the build-up of activity over time using the PLUME and FARMLAND models within PC-CREAM 08®. The radionuclides selected were: C-14, H-3 and I-131 as these radionuclides are the most important contributors to the predicted ingestion dose, as presented in Table A.11 in Appendix A. C-14 and H-3 also have a relatively large annual discharge rate.

Noble gases are the major contributor to the annual activity discharge rate; they do not deposit on the ground and they do not accumulate in soil. However Rb-88, the radioactive daughter of Kr-88, has been included as Rb-88 deposits on the ground and is the main contributor to the annual beta dose from radionuclides deposited on the ground. Also plotted were radionuclides that are representative of the main groups: the activation and fission products: Co-60, Cs-137, Ce-144, Sr-90 and the actinides: Am-241, Cm-243 and Pu-239.

The results of this calculation are presented in Figure 6.2-2 below:

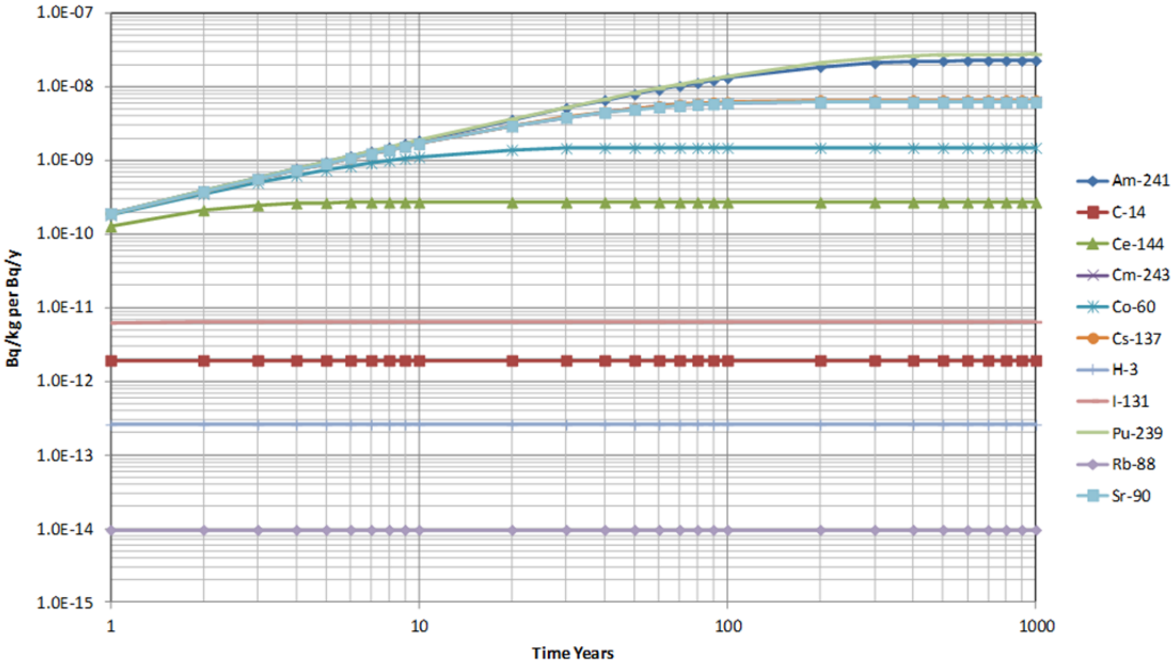

Figure 6.2-2: Predicted Soil Concentration, Bq/kg, vs. Time for a Continuous Unit Annual Discharge Rate, Bq/y

It can be seen in Figure 6.2-2 above that the activity concentration in soil for the most radiologically significant radionuclides C-14, H-3 and I-131 show little dependency on time. This is due to the specific activity model used to determine the concentration of C-14 and H-3 in soil as well as the short physical half-life of I-131 of 8.04 days. For the other radionuclides, with the exception of the actinides, Sr-90 and Cs-137, equilibrium is attained within about 30 years. For Sr-90 and Cs-137, the increase in the predicted activity concentration in soil from 50 years to 60 years of continuous discharge is about 7%. For the actinides, the increase in the predicted activity concentration in soil from 50 years to 60 years of continuous discharge is about 15%. This difference is not significant as the actinides make a very small contribution to the overall exposure due to discharges to atmosphere.

Therefore, it is concluded that the predicted radiological consequences (based on the significant radionuclides examined above) will be independent of the duration of either the liquid or gaseous discharges beyond 30 years and there is little effect on the predicted build-up in the environment and doses whether a 50 or 60 year discharge duration is used in the assessment, For the purposes of assessment the discharge duration for the Stage 1 and Stage 2 assessment is 50 years as this is the value used in the IRAT methodology [Ref-14]. For the Stage 3 assessment a discharge duration of 60 years is assumed.

6.3 Default Input Data

6.3.1 Continuous Discharges

6.3.1.1 Liquid Discharge Stage 1 Assessment

The IRAT methodology [Ref-14] has compiled DPUR factors for external irradiation and seafood consumption to enable the radiological assessment of liquid radioactive discharges to the coastal environment.

The generic habits of the most exposed members of the public for the coastal release scenario are represented by the Fisherman family. The Fisherman family comprises of an Adult, Child, Infant and offspring members of the family to enable consideration of the dose to these age groups. For the purposes of this work the term "offspring" is used to describe the embryo, foetus and new born infant in the first few months after birth [Ref-14]. The parameters used to derive the DPUR for liquid discharges used to assess the exposure of the Fisherman family are summarised in Table 6.3-5 (taken from Appendix E of [Ref-15]).

These generic habit data, in conjunction with the generic site parameters, were used to derive the DPUR values to assess the radiological impact on the most exposed members of the public due to liquid discharges. The parameters used for this dose assessment are considered conservative for any potential site in England and Wales.

The annual rate of liquid discharges used in this assessment is presented in Table 6.3-3.

6.3.1.2 Gaseous Discharge Stage 1 Assessment

The most exposed member of the public for the gaseous discharges is represented by the Local Resident family. The IRAT methodology [Ref-14] has compiled DPUR factors for the Local Resident family representative person. The Local Resident family comprises an Adult, Child, Infant and offspring members of the family to enable consideration of the dose to these age groups. Terrestrial food consumption, external irradiation and inhalation are considered to enable the assessment of gaseous radioactive discharges to the terrestrial environment.

The habits of the members of the public used to derive the DPUR for gaseous discharges are summarised in Table 6.3-6.

The annual rate of gaseous discharges used in this assessment is presented in Table 6.3-4.

6.3.1.3 Liquid Discharge Stage 2 Assessment

Scaling factors, as described in [Ref-14], were used to estimate the dose to the Fisherman family using refined site data (to enhance the validity of the model, data relevant to the North Wales coast was used). The scaling factor was based on the volumetric exchange rate as appropriate for the North Wales coastal environment of 1300m^3/s (Table 4 of [Ref-14] rather than the default value of 100m^3/s used in the Stage 1 assessment). Other sites in England and Wales may not have such a high volumetric exchange rate; however, the generic data in Stage 1 assessment bounds all possible coastal nuclear new build locations, see [Ref-16] for justification of the parameters used. This dataset is used because it is more representative of the dispersion in a location at which a UK ABWR may actually operate in future than the available generic data.

For consistency with the data used in Stage 2 modelling, the Stage 3 radiological assessment defined the corresponding regional marine compartment as Irish Sea West. The value for the North Wales coast is within the range seen across all of the possible sites in England and Wales and does not represent extreme or unusual values. A comparison of each site's marine compartment data is provided in [Ref-16].

6.3.1.4 Gaseous Discharge Stage 2 Assessment

The input data for the Stage 2 assessment are the same as that used for the Stage 1 assessment with the exception that corrections based on a refined effective release height of 19m are used.

6.3.1.5 Liquid Discharge Stage 3 Assessment

The input data used to assess the dose to members of the public in the three age groups, Adult, Child and Infant, are presented in Appendix B. Generic habit data was used in the assessment at both the high and mean consumption rates. PC-CREAM 08® default local compartment parameters for the Reference Site [Ref-16] were used as these values are the result of numerous studies into the behaviour of radionuclides in the marine environment [Ref-19].

6.3.1.6 Gaseous Discharge Stage 3 Assessment

The input data used to assess the dose to members of the public in the three age groups Adult, Child and Infant, are presented in Appendix B. Where appropriate, PC-CREAM 08® default parameters were used [Ref-19]. Generic habit data was used in the assessment at both the high and mean consumption rates. For high ingestion rates the 'top two' approach for generic dose assessments was used. The methodology and data used for derivation of the 'top two' foodstuffs are presented in Appendix D.

The preceding estimates of the dose to the Local Resident family due to gaseous discharges have been based on the default parameters embedded within the IRAT Stage 1 and Stage 2 methodologies. The default receptor locations are 100m from the release location for the assessment of doses due to exposure to the plume and deposited activity and 500m for the production of foodstuffs that are subsequently ingested.

For the generic site [Ref-16] the distance from the main stack to the site boundary is 270m. Therefore, for the Stage 3 assessment, it is assumed that the members of the Local Resident family are located at a distance of 270m from the release point whilst food is produced at a distance of 500m from the release point.

6.3.2 Direct Dose

Measurement data of the site boundary direct dose rate around operating nuclear power plant is difficult to obtain. This is because it is not possible to distinguish the direct dose contribution of photon emission from the operating plant from the natural environmental background dose rate. The Japanese regulator has set the target dose rate of gamma direct and 'sky shine' from all of buildings in the power station to 50μGy/y [Ref-18]. This target dose rate corresponds to approximately 6nGy/h and this radiation dose rate cannot be detected in isolation as it is lower than the natural background radiation dose rate level. In general, the dose rate from the buildings containing radiation sources, such as the turbine building, is as low as the natural background level at distances greater than 300m from the source building [Ref-27].

A number of source buildings have been identified for inclusion in the direct dose assessment for the UK ABWR [Ref-27]. This topic report describes the source terms (radiation emission rate broken down into energy bins), the structure of the buildings in which the sources are present as well as dimensional and material data. The external dose rate was determined from each source building in isolation, i.e. no benefit is claimed for the shielding provided by surrounding buildings. External dose rates including the neutron contribution from the reactor building were calculated for set distances from the source building and at the site boundary. The distance to the site boundary for each building is shown in [Ref-27].

The source buildings that contribute to direct radiation exposure off-site which are considered in this submission are

- Reactor Building
- Turbine Building
- Radioactive Waste Building
- Condensate Storage Tank (CST)
- Suppression Pool Water Surge Tank (SPT)

Other auxiliary facilities may be present on site that contain radioactive sources which could contribute to direct radiation off site. These auxiliary facilities include a SFIS (Spent Fuel Interim Storage) facility, ILW (Intermediate Level Waste) / LLW (Low Level Waste) storage and processing facilities. However the inventory and location of these buildings are not set during the GDA phase and therefore are out of the scope of the assessment presented in this report. The direct radiation, from these auxiliary facilities and the source buildings listed above, will be assessed in detail at site specific permitting.

6.3.3 Representative Person

The input parameters on which the annual dose to Representative persons was calculated are as presented in the previous sections 6.3.1.5 and 6.3.1.6.

The annual dose to the representative person has been determined for the following population groups:

i. A Local Resident family for gaseous discharges who consume locally grown terrestrial foodstuffs at the high rate also consume locally sourced seafoods at average rate.

ii. A Fisherman family for liquid discharges who consume locally caught seafoods at the high rate also consume locally sourced terrestrial foods at average rate.

In addition the annual exposure due to direct shine form sources on site has been included in the calculation of the dose to representative persons.

Individual doses due to exposure pathways associated with liquid discharges into the marine environment, including ingestion of marine foodstuffs consumed at the high rates, are presented in Table A.3, Table A.4 and Table A.5 for the Adult, Child and Infant members of the public. Table A.6, Table A.7 and Table A.8 present the individual doses for the Adult, Child and Infant members of the public consuming marine foodstuffs at the mean rates (all in Appendix A).

Individual doses due to exposure pathways associated with gaseous discharges into the terrestrial environment, including ingestion of terrestrial foodstuffs consumed at the 'top two' rates, are presented in Table A.11, Table A.12 and Table A.13 for the Adult, Child and Infant members of the public. Table A.14, Table A.15 and Table A.16 present the individual doses for the Adult, Child and Infant members of the public consuming terrestrial foodstuffs at the mean rates (all in Appendix A).

6.3.4 Short-term Discharge

6.3.4.1 Source Term

The proposed annual limits account for additional activity released from any 'events that are expected to occur' (as defined in the Environment Agency's GDA P&ID [Ref-1]), i.e. expected events (as previously introduced in section 6.1).

Hitachi-GE has undertaken a study to identify and assess the events that are likely to occur during normal operation of the UK ABWR which would have a bearing on the discharges [Ref-26]. The study has identified one such expected event, specifically a pin hole fuel pin failure.

In a fuel pin failure, gaseous fission products such as noble gases and iodine may be released into the reactor coolant, along with other particulate and soluble fission products such as caesium. The soluble and particulate species will remain in the water phase and be removed by the reactor water treatment system (liquid discharges are held up in discharge tanks and assayed prior to release into the environment to ensure that discharge limits are not exceeded, if the activity concentration exceeds permitted values then the tank contents are recirculated through the clean-up systems until the activity concentrations are acceptable [Ref-28].). However, the volatile fission products released as a result of the event could be carried over with the steam and so could be potentially discharged into the environment via the gaseous system, which does not include a waste treatment re-circulation loop.

For these reasons, the assessment of the potential dose due to short-term discharges considers gaseous discharges only.

The time between the start of the expected event discharge, manipulation of the control system to isolate the pin and cessation of the discharge could be up to 14 days. During this period, the discharge may fluctuate due to changes in the reactor state. However for the purposes of the short-term assessment it is conservatively assumed that the total discharge is released uniformly over a period of 24 hours.

The activities and radionuclides released during the short-term event are presented in Table A.23 in Appendix A. It can be seen that the discharge associated with the expected event forms a large proportion (up to 90%) of the proposed annual discharge limit for the radionuclides concerned.

6.3.4.2 Atmospheric Dispersion

The dispersion of gaseous radioactivity discharged in a short period of time has been considered in [Ref-29] and [Ref-30]. In [Ref-29] it is stated that the range of possible meteorological conditions is represented by atmospheric stability category D, wind speed 3m/s, boundary layer height 800m and a continuous rainfall rate of 0.1mm/hr. These meteorological conditions are described as being 'realistically cautious'. ADMS 5 [Ref-31] was used to model the dispersion of the aerial discharges (assuming the above meteorological conditions) and calculate atmospheric dispersion of the plume.

Further discussion regarding short-term atmospheric dispersion is presented in Appendix F, including: justification of the selection of the atmospheric dispersion parameters; and, the findings of a sensitivity study on the effect of cloud cover on the dispersion of short-term releases of gaseous discharges.

An effective discharge height of 19m was assumed for the assessment of the short-term discharge.

6.3.4.3 Habit Data and Consumption Rates

For the purposes of the short-term assessment the individuals are assumed to be present full time at 270m from the point of release.

For the 24 hour discharge scenario, occupancy for Adults, Children and Infants is described below.

6.3.4.4 Occupancy Factor

The indoor occupancy factors are taken from [Ref-15].

a. Adult

An Adult spends 12 hours per day outdoors, based on an indoors fraction of 0.5.

b. Child

A Child spends 4.8 hours per day outdoors, based on indoors fraction of 0.8.

c. Infant

An Infant spends 2.4 hours per day outdoors, based on indoors fraction of 0.9.

6.3.4.5 Indoor Occupancy Reduction Factor

Whilst the representative person is indoors, the building will provide a degree of protection from the inhalation of depositing radionuclides. The indoor occupancy reduction factor is 0.5 for depositing radionuclides [Ref-29]. There is no reduction for non-depositing radionuclides. Since noble gases do not deposit, an indoor occupancy reduction factor of 1 is assumed for noble gases. This factor is also used in the assessment of beta skin cloud dose.

6.3.4.6 Location Factor

A location factor is a factor applied to external exposure, due to either cloud gamma or deposited gamma. It is a factor that provides a correction to outdoor dose rate to allow for the shielding to gamma radiation provided by a building. The location factor for cloud gamma is 0.2 [Ref-30]. This is to be applied when an individual is indoors. The location factor for deposited gamma is 0.1. This is to be applied when an individual is indoors. In both cases a location factor of 1 is applied for outdoor exposures.

6.3.5 Build-up

For the purposes of this assessment, the build-up of activity is based on the continuous operation of an individual ABWR unit over a period of 60 years. Section 6.2 discusses the lack of numerical difference in the predicted concentrations in the various environmental media considered between a discharge duration of 50 or 60 years.

6.3.5.1 Liquid Discharges

The assessment of the build-up of activity in unfiltered seawater and seabed sediment due to liquid discharges is based on the proposed annual discharge limit that is presented in Table 6.3-3.

6.3.5.2 Gaseous Discharges

The assessment of the build-up of activity in soil due to gaseous discharges is based on the proposed annual discharge limit that is presented in Table 6.3-4.

6.3.6 Collective Dose

This assessment of collective dose is per year of operation of an individual ABWR unit. The annual liquid and gaseous discharges on which this assessment is based are presented in Table 6.3-3 and Table 6.3-4 respectively.

Default parameters were applied in the majority of cases. The exceptions were in the assessment of liquid discharges, where the UK, EU12 and World populations were selected, rather than those of individual countries. The EU12 population represent those European countries that were member states when the European Union was first established in 1993. These countries include those that have coastal regions and so may be impacted by liquid discharges. For the assessment of gaseous discharges, UK or EU populations were selected as appropriate and the standard 70% D meteorological conditions were used as appropriate for a location on the UK coast [Ref-32].

6.3.7 Summary of Default Input Parameters

Tables 6.3-1 to 6.3-6 provide a summary of the numerical input data used for the initial radiological dose modelling, at the proposed limits, using the assumptions described in the previous sections.

Table 6.3-1: Default Parameters Defining the Generic Site and Release Conditions (Used for Stage 1 Assessment)

Parameter	Value
Duration of discharge (y)	50
Effective release height (m)	0
Public receptor point aerial discharges (m)	100
Food production receptor point (m)	500
Site boundary (m)	100
Windrose	Uniform
Pasquill stability category	50% D
Local marine compartment details:	
Volume (m^3)	10^8
Depth (m)	10
Coastline length (m)	10^4
Volumetric exchange rate (m^3/y)	3.16×10^9
Suspended sediment load (t/m^3)	10^{-5}
Sedimentation rate ($t/m^2/y$)	4.9×10^{-3}
Sediment density (t/m^3)	2.6
Diffusion rate (m^2/y)	3.15×10^{-2}

Data source: [Ref-15]

Table 6.3-2: Default Parameters Defining the Generic Site and Release Conditions (Used for Stage 2 Assessment)

Parameter	**Value**
Duration of discharge (y)	50
Effective release height (m)	19
Public receptor point aerial discharges (m)	100
Food production receptor point (m)	500
Site boundary (m)	100
Windrose	Uniform
Pasquill stability category	50% D
Local marine compartment details:	
Volume (m^3)	10^8
Depth (m)	10
Coastline length (m)	10^4
Volumetric exchange rate (m^3/y)	4.0×10^{10}
Suspended sediment load (t/m^3)	10^{-5}
Sedimentation rate (t/m^2/y)	4.9×10^{-3}
Sediment density (t/m^3)	2.6
Diffusion rate (m^2/y)	3.15×10^{-2}

Data source: [Ref-15] and section 5.2.2.2 (Effective release height)

Table 6.3-3: Liquid Discharge Rates Used Stages 1, 2 and 3 Assessment

(Proposed Annual Discharge Limit)

Radionuclide	Proposed Annual Discharge Limit (Bq/y)
Ag-110m	5.7E+00
Am-241	1.1E-01
Ba-140	6.2E+03
Ce-141	4.5E+04
Ce-144	2.4E+05
Cm-242	2.1E+00
Cm-243	4.9E-03
Cm-244	4.5E-01
Co-58	8.2E+04
Co-60	8.2E+05
Cr-51	3.7E+04
Cs-134	5.7E+03
Cs-137	6.6E+03
Fe-55	9.4E+06
Fe-59	2.1E+04
H-3	7.6E+11
I-131	6.0E+04
La-140	7.0E+03
Mn-54	4.0E+05
Nb-95	1.8E+05
Ni-63	8.6E+05
Pu-238	3.6E+00
Pu-239	5.7E-01
Pu-240	9.0E-01
Ru-103	2.7E+04
Ru-106	1.9E+04
Sb-122	1.2E+02
Sb-124	5.3E+04
Sb-125	8.2E+04
Sr-89	9.0E+03
Sr-90	4.5E+03
Te-123m	6.2E+01
Zn-65	1.1E+05
Zr-95	8.2E+04

Data source: [Ref-3]

Table 6.3-4: Gaseous Discharge Rate Used Stages 1, 2 and 3 Assessment (Proposed Annual Discharge Limit)

Radionuclide	Proposed Annual Discharge Limit (Bq/y)
Ag-110m	3.9E+01
Am-241	6.6E-04
Ar-41	5.2E+12
Ba-140	3.5E+04
C-14	1.7E+12
Ce-141	4.9E+04
Ce-144	4.5E+04
Cm-242	4.9E-01
Cm-243	4.9E-05
Cm-244	6.2E-03
Co-58	1.5E+05
Co-60	1.5E+05
Cr-51	1.3E+05
Cs-134	9.4E+03
Cs-137	5.7E+03
Fe-59	2.4E+04
H-3	1.0E+13
I-131	3.2E+08
I-132	1.1E+08
I-133	7.3E+07
I-135	4.3E+07
Kr-85	1.3E+09
Kr-85m	1.0E+10
Kr-87	9.8E+03
Kr-88	9.3E+08
La-140	4.1E+04
Mn-54	9.0E+04
Nb-95	1.1E+05
Pu-238	9.4E-03
Pu-239	1.2E-03
Pu-240	1.9E-03
Sb-122	4.9E+02
Sb-124	4.9E+04
Sb-125	9.8E+03
Sr-89	4.1E+04
Sr-90	2.6E+03
Xe-131m	2.9E+09
Xe-133	2.0E+11
Xe-133m	1.8E+07
Zn-65	4.1E+04
Zr-95	5.3E+04

Data source: [Ref-3]

Table 6.3-5: Summary of Habit Data for Marine Discharges

Parameter	Adult	Child	Infant
Fraction of time spent in local compartment	1	1	1
Fraction of time spent in regional compartment	0	0	0
Fraction of fish caught in local compartment	0.5	0.5	0.5
Fraction of fish caught in regional compartment	0.5	0.5	0.5
Fraction of crustaceans and molluscs caught in local compartment	1	1	1
Fraction of crustaceans and molluscs caught in regional compartment	0	0	0
Beach occupancy (h/y)	2000	300	30
Breathing rate marine (m^3/h)	0.92	0.64	0.22
Ingestion of sea fish (kg/y) high rates	100	20	5
Ingestion of crustacea (kg/y) high rates	20	5	0
Ingestion of mollusca (kg/y) high rates	20	5	0

Data source: [Ref-15]

Table 6.3-6: Summary of Habit Data for Terrestrial Discharges

Parameter	Adult	Child	Infant
Cloud shielding factor gamma	0.2	0.2	0.2
Shielding factor for deposited radionuclides gamma	0.1	0.1	0.1
Fraction of food locally produced	1	1	1
Occupancy (h/y)	8760	8760	8760
Fraction of time indoors	0.5	0.8	0.9
Breathing rate (m^3/h)	0.92	0.64	0.22
Ingestion of green veg. (kg/y) high rates	80	35	15
Ingestion of root veg. (kg/y) high rates	130	95	45
Ingestion of fruit (kg/y) high rates	75	50	35
Ingestion of sheep meat (kg/y) high rates	25	10	3
Ingestion of offal (kg/y) high rates	20	10	5.5
Ingestion of cow meat (kg/y) high rates	45	30	10
Ingestion of milk (kg/y) high rates	240	240	320

Data source: [Ref-15]

The input data for the Stage 3 assessment is presented in Appendix B of this document.

7. Annual Dose to the Most Exposed Members from Direct Radiation

This section reports the prospective dose assessment for the annual dose to the most exposed members of the public from direct radiation from the UK ABWR. Since the GDA Step 2 submission, a more detailed assessment of the direct dose has been undertaken. In the Step 2 submission the direct exposure of members of the public was based on a simple, large volume, model representation of the turbine building. In this submission more detailed modelling has been undertaken as described in section 6.3.2. Radioactive sources such as the turbine were modelled in more detail, which resulted in greater geometric attenuation, and therefore lower direct dose rates.

7.1 Results

The results of the calculated external dose rates are summarised in Table 7.1-1 below.

Table 7.1-1: Summary of External Dose Rates

	Total external dose rate (μSv/h)					
Distance from source building (m)	**Reactor Building**	**Turbine Building**	**Radioactive Waste Building**	**Condensate Storage Tank (CST)**	**Suppression Pool Water Surge Tank (SPT)**	**Total**
100	1.98E-05	1.93E-03	5.29E-05	7.68E-06	1.27E-04	2.14E-03
Site boundary*	2.69E-06	1.83E-04	5.20E-06	9.53E-07	3.61E-06	1.95E-04
300	1.97E-06	2.06E-04	2.47E-06	4.36E-07	6.71E-06	2.18E-04
500	4.58E-07	3.50E-05	2.52E-07	4.22E-08	6.21E-07	3.63E-05
1000	3.24E-08	1.67E-06	2.32E-09	4.44E-10	4.60E-09	1.71E-06
1500	3.68E-09	1.59E-07	3.89E-11	2.08E-11	9.62E-11	1.63E-07

*Site boundary distances vary with building: reactor building 265m; Turbine building 310m; Radioactive waste building 243m; CST 240m and SPT 350m [Ref-17].

For the purposes of this assessment the dose rate to members of the public is estimated by summing the dose rate for the contributing sources at each distance considered. It is recognised that this is not realistic but serves to give an upper bound to the dose rate at the site boundary.

7.1.1 Dose Rate

The calculated dose rates at the distances included in the model were:

- At the site boundary the external dose rate was found to be 1.95E-04 μSv/h;
- At 500m the external dose rate was found to be 3.63E-05 μSv/h;

- At 1000m the external dose rate was found to be 1.71E-06 µSv/h;
- At 1500m the external dose rate was found to be 1.63E-07 µSv/h;

7.1.2 Estimate of Annual Exposure from Direct Radiation

The annual exposure from direct radiation will depend upon: the dose rate at the location where the member of public is present; the distance that this location is from the source; the time spent at that location; and, whether the individual is indoors or outdoors.

For this assessment a number of exposure scenarios have been considered. These are described and quantified below.

i. **Exposure Scenario 1:**

Assuming fulltime occupancy by an Adult living at the site boundary, spending 50 % of their time outside (i.e. 12 of 24 hours) and the remaining 50 % inside, the estimated annual exposure is:

Annual exposure = 1.95E-04 x (12/24 x 8760 x 1 + 12/24 x 8760 x 0.1)

= 1.95E-04 x (4380+ 438)

= 1.95E-04 x 4818

= 9.40E-01 µSv/y

ii. **Exposure Scenario 2:**

Assuming fulltime occupancy by an Adult living at 500 m from the source buildings, spending 50 % of their time outside and the remaining 50 % inside, the estimated annual exposure is:

Annual exposure = 3.63E-05 x (12/24 x 8760 x 1 + 12/24 x 8760 x 0.1)

= 3.63E-05 x (4380+ 438)

= 3.63E-05 x 4818

= 1.75E-01 µSv/y

iii. **Exposure Scenario 3:**

Assuming fulltime occupancy by an Adult living at 1,000 m from the source buildings, spending 50 % of their time outside and the remaining 50 % inside, the estimated annual exposure is:

Annual exposure = 1.71E-06 x (12/24 × 8760 x 1 + 12/24 x 8760 x 0.1)

= 1.71E-06 x (4380+ 438)

= 1.71E-06 x 4818

= 8.24E-03 µSv/y

7.2 Discussion

The three different exposure scenarios above have been examined in order to capture the variation in dose that will arise from different behaviour patterns at different locations.

The maximum predicted exposure due to direct exposure is estimated to be 9.40E-01 μSv/y incurred by an Adult member of the public living at the site boundary (exposure scenario 1). This assumed occupancy pattern is consistent with the IRAT methodology and has been taken forward in the assessment of total exposure for the Stage 1 and Stage 2 assessments.

For comparison an Adult individual who resides at 500m (exposure scenario 2) or 1000 m (exposure scenario 3) from the source buildings the calculated annual direct exposure is 1.75E-01 μSv/y or 8.24E-03 μSv/y, respectively.

The above estimates of annual exposure are based on an Adult whose occupancy time is spent 50 % of their time outside and 50 % of the time inside. This will result in the highest estimate of exposure for a member of the public.

A Child is assumed to spend 20 % of their time outside and 80 % of their time inside and an Infant is assumed to spend 10 % of their time outside and 90 % of their time inside. A scaling factor can be derived to estimate of the Child and Infant exposure for scenarios where the exposure location is fixed. In these circumstances the Child and Infant exposure will be 50 % and 34 % of the Adult exposure, respectively.

8. Annual Dose to the Most Exposed Member of the Public

This section reports the results of the prospective dose assessment for the annual dose to the most exposed members of the public for liquid and gaseous discharges at the proposed annual discharge limits.

8.1 Stage 1 Assessment

8.1.1 Liquid Discharges

The dose to the most exposed member of the public (the Fisherman family) from seafood consumption and external irradiation and for each radionuclide is presented in Table A.1 in Appendix A for the proposed annual discharge limit for liquid discharges. The total predicted dose incurred by the Fisherman family was found to be 3.48E-03 μSv/y.

The total predicted dose of 3.48E-03 μSv/y is dominated by external irradiation. This exposure pathway contributes 2.34E-03 μSv/y (67%) to the overall predicted dose. The principal contributor to exposure due to external irradiation is Co-60 (94%).

8.1.2 Gaseous Discharges

The dose to the most exposed member of the public (the Local Resident Family) from each pathway considered and for each radionuclide discharged at the proposed annual discharge limit is presented in Table A.9 in Appendix A.

The overall dose incurred by the Local Resident family due to gaseous discharges at the proposed annual discharge limit was found to be 1.43E+02 μSv/y.

The total predicted dose to the Local Resident family due to the proposed annual gaseous discharge limit of 1.43E+02 μSv/y is dominated by the contributions from C-14 (81%). The contribution each exposure route makes to the total exposure is 6.01E+01 μSv/y (42%), 1.67E+01 μSv/y (12%) and 6.65E+01 μSv/y (46%) for ingestion of terrestrial foods, external irradiation and inhalation pathways, respectively.

8.1.3 Estimated Dose from All Sources

The initial assessment of the dose from each discharge route and direct radiation is given in Table 8.1-1 below:

Table 8.1-1: Summary of IRAT Stage 1 Results

Exposure pathway	Initial annual dose (μSv/y)	Most exposed age group
Liquid discharges*	3.48E-03	Adult
Gaseous discharges†	1.43E+02	Infant
Direct radiation∞	9.40E-01	Adult
Total	1.44E+02	--

Data sources: * Table A.1; † Table A.9; ∞Section 7.

The annual dose to members of the public from all discharges based on the simple and cautious Stage 1 assessment of the representative person is estimated to be 1.44E+02 μSv/y for the proposed annual discharge limit. This is in excess of 20 µSv/y (as defined by the Environment Agency's guidance [Ref-14]) therefore an IRAT Stage 2 assessment is required using more refined data (see section 8.2).

8.1.4 Discussion

The Stage 1 dose estimate presented above is based on the simple and cautious approach presented in the Environment Agency IRAT methodology.

The gaseous release is assumed to occur at ground level, leading to a bounding estimate of the airborne activity concentration at the receptor locations of interest. The Local Resident member of the public is assumed to reside at the site boundary whilst food production takes place at 500 m from the release location. These assumptions regarding ground level release and occupancy patterns results in conservative estimates for radiation exposure from the various pathways considered.

The liquid discharges are made into the local marine compartment where the member of the public is assumed to incur external exposure due to occupancy in areas of contaminated sediment. Internal exposure is incurred due to consumption of seafood, where 50% of the fish consumed and 100% of molluscs and crustacean consumed are caught in the local compartment. The exposures due to pathways associated with liquid discharges make a small contribution to the overall exposure.

The exposure pathways associated with gaseous discharges contribute 1.43E+02 µSv/y or about 99% of the overall exposure to members of the public.

8.2 Stage 2 Assessment

The dose to a member of the Fisherman family due to liquid discharges is estimated to be 3.48E-03 µSv/y using the default Stage 1 parameters. This dose rate is sufficiently low not to warrant further analysis. Nevertheless, for completeness, a Stage 2 assessment for liquid discharges based on more refined data has been undertaken. The results are discussed below.

8.2.1 Liquid Discharges

The dose to the Fisherman family from each pathway considered and for each radionuclide using a more realistic volumetric exchange rate is presented in Table A.2 of Appendix A for the proposed annual liquid discharge limit.

The total predicted dose incurred by the Fisherman family was found to be 2.68E-04 µSv/y.

The total predicted dose to the the Fisherman family is dominated by external irradiation. This exposure pathway contributes 1.80E-04 µSv/y (67%) to the overall predicted dose. As for the Stage 2 assessment, the principal contributors to exposure due to external irradiation is Co-60 (94%). The principal contributor to seafood ingestion is H-3 (61%)

8.2.2 Gaseous Discharges

Using a more realistic effective release height of 19m, the dose to the most exposed member of the public from each pathway, and for each radionuclide considered, is presented in Table A.10 in Appendix A at the proposed annual discharge limit.

The total predicted dose incurred by the Local Resident family due to the proposed annual gaseous discharge limit is estimated to be 2.36E+01 µSv/y.

The total predicted dose to the Local Resident family is dominated by the contributions from C-14 (90%). The contribution made by the ingestion, external irradiation and inhalation exposure pathways to the total exposure is 1.98E+01 µSv/y (84%), 7.51E-01 µSv/y (3%) and 2.99E+00 µSv/y (13%) , respectively.

8.2.3 Estimated Dose from All Sources

The initial assessment of the dose from each discharge route and direct radiation is given in Table 8.2-1 below:

Table 8.2-1: Summary of IRAT Stage 2 Results

Exposure pathway	Initial annual dose (µSv/y)	Most exposed age group
Liquid discharges*	2.68E-04	Adult
Gaseous discharges†	2.36E+01	Infant
Direct radiation∞	9.40E-01	Adult
Total	2.45E+01	-

Data sources: * Table A.2; † Table A.10; ∞Section 7.

The annual dose to members of the public, from all discharges based on the slightly more refined Stage 2 assessment of the representative person, is estimated to be 2.45E+01 µSv/y for the proposed annual discharge limit. The dose due to liquid discharges is very small at 2.68E-04 µSv/y. The dose due to gaseous discharges is predicted to be 2.36E+01 µSv/y. The IRAT Stage 2 dose is dominated by the ingestion pathway.

As the overall dose is above 20 µSv/y a Stage 3 assessment was undertaken using more realistic data (see section 8.3).

8.2.4 Discussion

The Stage 2 dose estimate presented above of 2.45E+01 µSv/y is based on the approach presented in the Environment Agency IRAT methodology.

The same assumptions are used as for the Stage 1 assessment but modification factors are applied to take account of the effective release height of the gaseous discharge (19m) and a more realistic local compartment volumetric exchange rate. An investigation on the sensitivity of the prospective dose on the marine parameters is presented in section 15.3; however, it should be noted that the exposures due to pathways associated with liquid discharges make a small contribution to the overall exposure.

The exposure pathways associated with gaseous discharges contribute about 2.36E+01 µSv/y or about 96% of the overall exposure to members of the public.

8.3 Stage 3 Assessment

The detailed results described in this sub-section are the result of the more refined Stage 3 assessment which was undertaken as the 20 µSv threshold was exceeded at Stage 2. The Stage 3 assessment also provides the input data for assessment of the build-up of radioactivity in the environment and for the assessment of the impact on NHS.

8.3.1 Liquid Discharges

Doses to Fisherman family Adult, Child and Infant consuming marine foodstuffs at high and mean consumption rates using more realistic site parameters are presented in Table A.3 to Table A.8 in Appendix A. The radionuclides between brackets indicate they are the precursor for that particular radionuclide.

The doses to Fisherman family Adult, Child and Infant due to liquid discharges and the consumption of foodstuffs at the high rate are found to be 2.29E-04, 6.17E-05 and 5.37E-06 µSv/y, respectively. The predicted offspring exposure due to liquid discharges is expected to be similar to that of the Adult.

The principal exposure pathway for all age groups is external exposure as a result of occupancy in areas of contaminated sediment. This exposure pathway contributes between 37% to 67% of the overall dose depending on the age group. The principal radionuclide that contributes to this exposure pathway is Co-60.

The ingestion of marine seafoods contribute 33%, 63% and 58% of the total dose for the Adult, Child and Infant age groups, respectively. The radionuclides that make the most significant contribution to the ingestion doses are H-3, Co-60, Zn-65 and Fe-55.

The doses to Adult, Child and Infant due to liquid discharges and the consumption of foodstuffs at the mean rate are found to be 1.61E-04, 3.22E-05 and 4.44E-06 µSv/y, respectively.

The principal exposure pathway for the groups that consumes seafood at the mean rate is dependent on the age group. For the Adult age group the ingestion of seafood contributes 5% to the overall dose and exposure to external dose pathways contribute 95%. For the Child and Infant age groups the ingestion of seafood becomes more important at 30% and 49% respectively. The balance of the dose is primarily due to the exposure incurred due to occupancy in areas of contaminated sediment.

As can be seen the predicted annual doses are very low as a result of small liquid discharges and the dispersive nature of the surrounding marine environment.

8.3.2 Gaseous Discharges

Doses to Local Resident family Adult, Child and Infant consuming terrestrial foodstuffs at the 'top two' and mean consumption rates using more specific site parameters are presented from Table A.11 to Table A.16 in Appendix A. The radionuclides between brackets indicate they are the precursor for that particular radionuclide.

The doses to Adult, Child and Infant due to gaseous discharges when residing at 270m from the point of discharge (i.e. at the site boundary) and the consumption of foodstuffs produced at 500m at the 'top two' rate are 1.27E+01, 1.40E+01 and 2.35E+01 µSv/y respectively. The predicted offspring exposure due to gaseous discharges is expected to be bounded by the above dose estimates.

The principal exposure pathway is due to ingestion which contributes between 80% and 92% of the overall dose depending on the age group. The remaining exposure is due mainly to the inhalation of radioactive materials in the plume and irradiation due to immersion in the plume.

The doses to Local Resident family Adult, Child and Infant due to gaseous discharges and the consumption of foodstuffs at the mean rate are found to be 8.53E+00, 9.04E+00 and 1.14E+01 µSv/y, respectively. Similarly to the 'top two' exposure pathways, the principal exposure pathway is due to ingestion which contributes between 70% and 83% of the overall dose depending on the age group. The remaining exposure is due mainly to the inhalation of radioactive materials in the plume and irradiation due to immersion in the plume.

The principal contributor to the overall annual exposure for both consumption patterns is C-14 which contributes over 90% to the total exposure.

8.3.3 Estimated Dose from All Sources

The assessment of the exposure from each discharge route for the 'top two' consumption rate and direct exposure for the age group that has the highest predicted exposure is given in Table 8.3-1.

Table 8.3-1: Summary of 'top two' Consumption Rate and Direct Exposure

Exposure pathway	Adult annual dose (µSv/y)	Child Annual dose (µSv/y)	Infant annual dose (µSv/y)
Liquid discharges*	2.29E-04	6.17E-05	5.37E-06
Gaseous discharges†	1.27E+01	1.40E+01	2.35E+01
Direct radiation∞	9.40E-01	4.70E-01	3.20E-01
Total	1.36E+01	1.45E+01	2.38E+01

Data sources: * Table A.3 to A.5; †Table A.11 to A.13; ∞Section 7.

The assessment of the exposure from each discharge route for the mean consumption rate and direct exposure is given in Table 8.3-2.

Table 8.3-2: Summary of Mean Consumption Rate and Direct Exposure

Exposure pathway	Adult annual dose (µSv/y)	Child annual dose (µSv/y)	Infant age group (µSv/y)
Liquid discharges*	1.61E-04	3.22E-05	4.44E-06
Gaseous discharges†	8.53E+00	9.04E+00	1.14E+01
Direct radiation∞	9.40E-01	4.70E-01	3.20E-01
Total	9.47E+00	9.51E+00	1.17E+01

Data sources: * Table A.6 to A.8; † Table A.14 to A.16; ∞Section 7.

8.3.4 Discussion

The highest Stage 3 dose estimate presented above of 2.38E+01 µSv/y is incurred by an Infant member of the Local Resident family and is based on the PC-CREAM 08® models and cautious assumptions and parameters.

The exposure pathway associated with gaseous discharges and consumption of foodstuffs at the 'top two' rate contribute 2.35E+01 µSv/y or about 99% of the overall exposure to Infant members of the public. The exposures due to pathways associated with liquid discharges make a small contribution to the overall exposure.

Figure 8.3-1 presents the contribution each terrestrial pathway makes to the Infant consuming terrestrial foodstuffs at the 'top two' rate dose due to gaseous discharges.

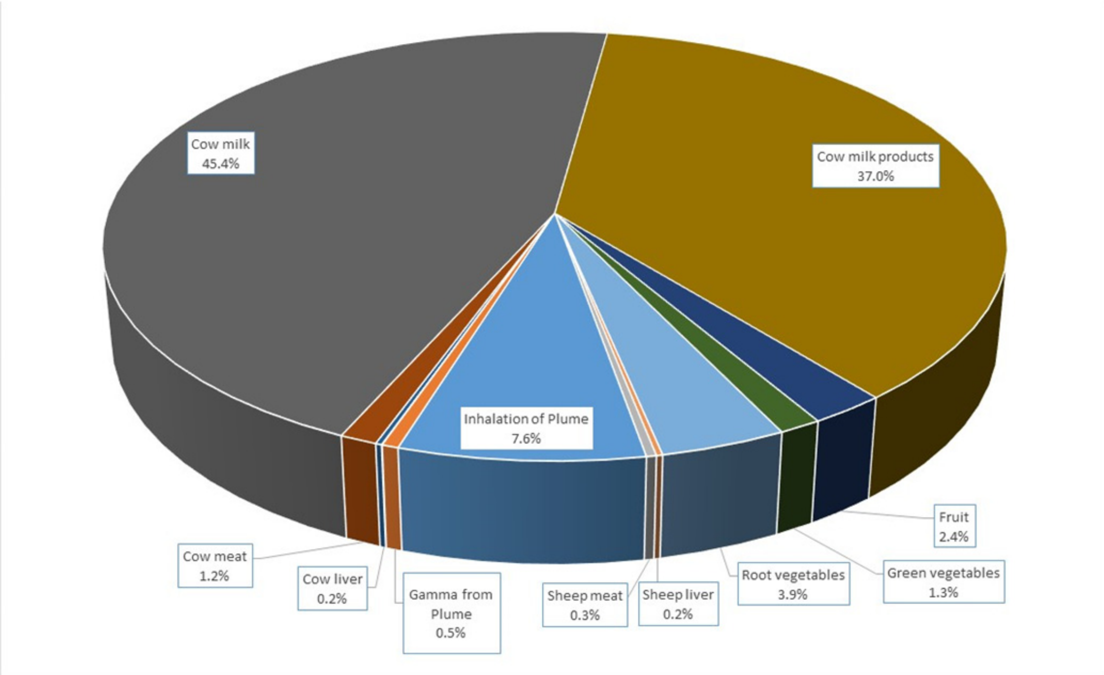

Figure 8.3-1: Contribution of Each Pathway to the Terrestrial Dose to an Infant due to Gaseous Discharge (Overall Dose 23.5 µSv/y)

The above estimates of exposure may be compared with the typical annual exposure of an individual member of the UK population of about 2,700 µSv/y due to natural sources (2,300 µSv/y) and manmade sources (400 µSv/y), the latter being principally from medical exposures [Ref-33].

9. Annual Dose to the Representative Person for the Facility

The annual dose to the representative person has been determined for the following population groups:

i. A Local Resident family for gaseous discharges who also consume locally sourced seafoods at average rate.

ii. A Fisherman family for liquid discharges who also consume locally sourced terrestrial foods at average rate.

The assessment of the annual dose to the representative person is based on the results of the Stage 3 assessments.

9.1 Results

The summary tables in this section make reference to the source location of the data within this document, where further background can be found. Table A.17, Table A.18 and Table A.19 present the doses to the Adult, Child and Infant members of the Fisherman family respectively. Table A.20, Table A.21 and Table A.22 present the doses to the Adult, Child and Infant members of the Local Resident family respectively (all in Appendix A).

The dose contribution from direct radiation from the source buildings is described in section 7. Assuming a full-time occupancy at the site boundary, the direct exposure of the Local Resident Adult is estimated to be 9.40E-01 μSv/y. A scaling factor is derived to estimate the Child and Infant exposure for scenarios where the exposure location is fixed. In these circumstances the Child and Infant exposure are 50% and 34% of the Adult exposure, respectively, due to differences in assumed outdoor and indoor occupancy. For the Fisherman family, although they may be located anywhere within the extent of the local compartment, a bounding assumption is made that they have the same exposure to direct radiation as the Local Resident family.

The assessment of the overall dose from each discharge route and direct radiation for each age group is given in Table 9.1-1 and Table 9.1-2.

Table 9.1-1: Overall Dose from Each Discharge Route and Direct Radiation for Each Age Group (Fisherman Family)

Age group	Liquid discharges (μSv/y)	Gaseous discharges (μSv/y)	Direct exposure (μSv/y)	Total (μSv/y)
Adult	2.29E-04*	5.95E+00*	9.40E-01◊	6.89E+00
Child	6.17E-05†	6.65E+00†	4.70E-01◊	7.12E+00
Infant	5.37E-06∞	9.45E+00∞	3.20E-01◊	9.77E+00

Data sources: * Table A.17; † Table A.18; ∞ Table A.19; ◊ Section 7

Table 9.1-2: Overall Dose from Each Discharge Route and Direct Radiation for Each Age Group (Local Resident Family)

Age group	Liquid discharges (μSv/y)	Gaseous discharges (μSv/y)	Direct exposure (μSv/y)	Total (μSv/y)
Adult	8.81E-06*	1.27E+01*	9.40E-01◊	1.36E+01
Child	9.54E-06†	1.40E+01†	4.70E-01◊	1.45E+01
Infant	2.18E-06∞	2.35E+01∞	3.20E-01◊	2.38E+01

Data sources: * Table A.20; † Table A.21; ∞ Table A.22; ◊ Section 7

9.2 Discussion

For the Fisherman family, the Infant receives the greatest overall dose from all discharges. This is dominated by the terrestrial dose which contributes to 97% of the overall dose. For the terrestrial dose, C-14 dominates through the ingestion of milk, milk products and root vegetables, contributing 41%, 28% and 9% of the total terrestrial dose respectively within these categories. It should also be noted that, as can be seen from the estimates of annual exposure from direct radiation presented in section 7, there is a rapid reduction in direct exposure with distance from the source. Therefore the effect of direct exposure will be limited to the local environs around the site.

For the Local Resident family, the most exposed individual is the Infant. This is dominated by the ingestion pathway which contributes about 92% of the gaseous dose. The principal route of exposure from this source is due to C-14 which dominates through the ingestion of milk and milk products, contributing 40% and 34% of the total terrestrial dose respectively within these categories.

10. Potential Doses due to Short-term Discharges

The assessment of the radiological consequences of short-term discharges is reported in this section. The only event whose dose effects are considered is that of a fuel pin failure, see section 6.1 and 6.3.4.1 for further detail.

As discussed in these previous sections, the assessment of the potential dose due to short-term discharges considers gaseous discharges only.

Potential doses due to short-term releases were calculated for members of the public using parameters applicable for the detailed generic assessment as described in section 6.3.4. Potential doses due to short-term discharges were calculated for a local representative person based on the methods described in [Ref-29] and [Ref-30]. The assessment of short-term discharges considers the following exposure pathways: The methodology and data used for the assessment of short-term discharges are presented in sections 5.2.5 and 6.3.4, respectively.

- Inhalation;
- Cloud shine;
- Ground shine; and,
- Ingestion.

In the case of the UK ABWR, only noble gas releases occur as a result of the short-term discharge for the scenario considered. As noble gases do not deposit nor are absorbed by the body upon inhalation, only the cloud shine exposure pathway needs be considered in this assessment.

10.1 Results

A summary of the effective dose due to the short-term discharge is given in Table 10.1-1.

Table 10.1-1: The Effective Dose due to the Short-term Discharge

Age group	Cloud Effective Dose (µSv)
Adult*	1.86E-02
Child†	1.68E-02
Infant∞	1.62E-02

Data sources: *Table A.25; †Table A.26; ∞Table A.27

The detailed breakdown of the contributions that each isotope and pathway make to these doses are presented in Table A.25, Table A.26 and Table A.27 in Appendix A for Adult, Child and Infant members of the public respectively.

Skin doses due to immersion in the plume were calculated based upon the calculated time integrated activity concentration and the dose conversion factor for beta cloud submersion as given in [Ref-34]. The dose conversion factors give the equivalent dose to the organ (in this case, skin). The organ dose equivalents were calculated for the isotopes shown in Table A.23 in Appendix A. No benefit is claimed for shielding provided by clothing. The predicted organ equivalent dose due to cloud immersion is 2.52E-02 µSv. To determine the dose to a 1cm^2 area of skin, the resulting dose was divided by the skin surface area to give the dose per cm^2. The skin areas for an Adult, Child and Infant are 1.9 m^2, 1.12 m^2 and 0.48 m^2, respectively [Ref-35]. Therefore the dose per unit area is 1.33E-06, 2.25E-06 and 5.25E-06 μSv/cm^2 for Adult, Child and Infant age groups, respectively.

10.2 Discussion

For the purposes of this assessment the maximum gaseous discharge associated with the expected event is conservatively assumed to occur over a period of 24 hours to give a bounding case. In practice the same activity could be discharged over a period of up to 14 days.

The predicted effective doses of 1.86E-02, 1.68E-02 and 1.62E-02 μSv for the Adult Child and Infant age groups, respectively, are substantially below any dose limit and annual dose constraints. There is significant margin between the predicted dose and the dose constraint of 20 μSv/y, above which it is recommended that further assessment is undertaken. It is therefore considered that the short-term doses due to expected events are sufficiently small that the dose assessment need not be refined further.

The predicted exposure of the skin from beta emissions in the plume is much less than 0.001 μSv/cm^2 of exposed skin for all age groups. This is significantly below the annual equivalent dose limit for skin for "other persons" of 50,000 μSv/y averaged over any 1 cm^2 area regardless of the area exposed [Ref-7].

11. Comparison of the Calculated Doses with the Relevant Dose Constraints

11.1 Dose Limits and Dose Constraints

Dose limits apply when *retrospective* assessments of doses from past discharges are made. For *prospective* assessments the relevant dose criteria are dose constraints. However a complete prospective assessment may include additional elements such as an assessment of doses from past discharges and doses from other sites nearby as an additional check on the prospective dose assessment outcome. The total outcome may then be compared with the dose limit.

EPR16 [Ref-2] states that a maximum constraint of 0.3 mSv/y should be used when determining applications for discharge permits or authorisations from a single new source, defined as "a facility, or group of facilities, which can be optimised as an integral whole in terms of radioactive waste disposals". This constraint is referred to as a source constraint.

In exercising those relevant functions in relation to the planning stage of radiation protection, the Environment Agencies of England and Wales are required to have regard to maximum doses to members of the public, which may result from a defined source arising from discharges of radioactive waste first made on or after 13th May 2000 (1st May 2003 in Northern Ireland) [Ref-2], [Ref-8] and [Ref-9]. Taking the legislation and advice from the HPA (now PHE), on the dose constraints together, unless there are exceptional circumstances that make compliance with these constraints impracticable, no option for the management of radioactive substances or radioactive wastes should be pursued if, in normal operation, its associated discharges would lead to doses above them. PHE has also advised the UK Government (including the Devolved Administrations) that a lower dose constraint not exceeding 0.15 mSv/y should be applied at the design stage of new nuclear power stations and waste disposal facilities [Ref-10]. This advice will be taken into account where relevant.

The International Atomic Energy Agency (IAEA) has presented dose criteria which are considered sufficiently low that doses arising from sources or practices that meet these criteria may be exempted from regulatory control. One of the criteria is that the dose should be less than about 10 μSv/y (0.01 mSv/y) per practice [Ref-36][Ref-37]. The statutory guidance to the Environment Agency [Ref-38] states that where the prospective dose to the most exposed group of members of the public resulting from discharges from a site at its current discharge limits is below 10 μSv/y (0.01 mSv/y), the Environment Agency should not seek to reduce further the discharge limits that are in place, provided that the holder of the permit or authorisation applies and continues to apply Best Available Techniques (BAT) to limit discharges. Taking the internationally accepted assumption (for the purpose of radiation protection) that any dose, no matter how small, has the potential to cause harm, an annual dose of 10 to 20 μSv/y (0.01 to 0.02 mSv/y) can be broadly equated to an annual risk of death of about one in a million per year. In their 'Principles' document [Ref-11] the UK Environment Agencies state that *"0.01 mSv/y and 0.02 mSv/y can be considered to be broadly equivalent for the purposes of this principle and so 0.02 mSv/y has been retained to ensure consistency of this guidance across the UK and with the approach adopted previously"*.

The following Table 11.1-1 from [Ref-11] summarises the dose criteria and how they apply to prospective dose assessments:

Table 11.1-1: Dose Criteria and Their Application to Prospective Dose Assessments

Effective dose criteria	Dose quantity	Application to prospective dose	Purpose of assessment	Applicable to GDA
Dose limit	1 mSv/y	One or more future discharges are planned and the radioactivity will combine with the residues of past discharges from one or more sources and direct radiation.	To show that total doses from one or more past and present and future sources will not exceed dose limit.	Yes Although strictly applicable this public dose limit considers contributions from other sources which do not form part of the GDA assessment.
Site constraint	0.5 mSv/y	Future discharges from the planned operation of more than one source where the sources are on sites that are adjacent. Direct radiation is not included.	To assist optimisation of the planned operation of sources where the sources are under separate control but located close together.	No This constraint considers multiple sources that may be present on one site.
Source constraint	0.3 mSv/y	Upper constraint on future discharges and direct radiation from the planned operation of a single source. Dose assessment should be refined until it is considered to be sufficiently realistic or falls below 0.02 mSv/y.	To assist constrained optimisation of the planned operation of a single source. Provide a realistic assessment of doses to act as an input to the optimisation process.	Yes This constraint considers a single source as assessed in the GDA process.
Between dose threshold and source constraint	0.02 to 0.3 mSv/y	Future discharges and direct radiation from the planned operation of a single source. Dose assessment should be refined until it is considered to be sufficiently realistic or the assessed dose falls below 0.02 mSv/y.	To assist constrained optimisation of the planned operation of a single source. Provide a realistic assessment of doses to act as an input to the optimisation process.	Yes This constraint considers a single source as assessed in the GDA process.
New nuclear power stations	0.15 mSv/y	PHE recommendation for design of new nuclear power stations and waste disposal facilities.	To take into account possibility that judgments on risks from radiation may change during the planning and construction of new plant.	Yes It should be noted that this value is not part of the UK legislative regime and is a recommendation from PHE in response to an ICRP consultation in 2008.

Effective dose criteria	Dose quantity	Application to prospective dose	Purpose of assessment	Applicable to GDA
Level of dose below which the dose assessment requires no further work.	0.02 mSv/y	Future discharges and direct radiation from the planned operation of a single source. If doses are below this threshold, the dose assessment need not be refined further.	To assist constrained optimisation of the planned operation of a single source. Doses sufficiently low to be used as an input to the optimisation process without further refinement.	Yes This criterion considers a single source as assessed in the GDA process.

11.2 Discussion

The prospective dose assessment of the annual dose to the representative person for the UK ABWR is presented in section 9.1 of this document. The prospective doses to two representative groups (the Fisherman family and Local Resident family) have been assessed and are presented in Table 9.1-1 and Table 9.1-2 for the Fisherman family and Local Resident family, respectively.

The estimates of the total prospective dose including that due to direct exposure are below 20 μSv/y for all age groups in the Fisherman family group and for the Adult and Child age in the Local Resident family group. However, the annual dose for the Infant member of the Local Resident group of 2.38E+01 μSv/y exceeds 20 μSv/y. This would normally indicate that further refinement of the dose modelling assessment is recommended. However, it should be noted that the assessment of doses due to radioactive discharges from the UK ABWR presented in this document include a number of conservatisms, including:

- the assessment is based on the proposed annual discharge limits and the actual discharges are expected to be lower;
- the release and resulting atmospheric dispersion of the gaseous discharge, the dominant exposure route, is based on an effective discharge height of 19m and assumption of full entrainment in the building wake whereas the actual discharge would be made via the main stack at a height of 75m, resulting in greater dispersion and consequently lower annual dose;
- the inhalation dose coefficient for C-14 is based on the default value in PC-CREAM 08® whereas it will be discharged primarily as CO_2 resulting in a lower estimate of inhalation dose.

Taking these factors into account would result in a reduction in the annual dose across all age groups. Furthermore, it is considered there is limited value in doing more detailed modelling as many of the inputs that would be used in a more detailed model, for example precise building layouts, local topography, more detailed site specific meteorological data, etc, are not available or applicable at the GDA stage. Therefore as the threshold is exceeded by only a small margin, the current dose assessment is considered to be sufficiently realistic and it is concluded that further refinement is not warranted.

12. Assessment of the Build-Up of Radionuclides in the Local Environment

The continuous discharge of radioactive material into the environment may lead to accumulation of radioactivity in local environmental media. This section reports the assessment of the build-up of radioactivity in the local environment around the generic site due to the liquid and gaseous discharges made during normal operations of the UK ABWR.

12.1 Results

12.1.1 Liquid Discharges

The results of the assessment of the build-up of activity due to liquid discharges, based on Stage 1 parameters and a 60 year discharge duration at the proposed annual discharge limit, are presented in Table A.28 in Appendix A.

Radionuclides that have been separate identified as being an individual component of the discharge but also are a daughter product of a parent radionuclides have been summed, i.e. La-140 includes contribution from decay of Ba-140, Nb-95 from decay of Zr-95, Pu-238 from decay of Cm-242, Pu-239 from decay of Cm-243 and Pu-240 from decay of Cm-244. The separate contributions have been summed and have been identified with an asterisk in Table A.28.

The results of the assessment are summarised as follows:

- The total activity concentration in unfiltered seawater is estimated to be 2.38E-01 Bq/l. The main contributor to this activity is H-3.

- The total activity predicted to accumulate in seabed sediment is 4.37E-01 Bq/ kg of which 94% is due to H-3.

12.1.2 Gaseous Discharges

The results of assessment of the build-up of activity due to gaseous discharges, based on stage 1 parameters and a 60 year discharge duration at the proposed annual discharge limit, are presented in Table A.29 in Appendix A.

PC-CREAM 08® enables separate quantification when a radionuclide is present due to ingrowth during atmospheric dispersion (FD) and ingrowth in the food-chain (SD). However in Table A.29 all contributions to a particular radionuclide concentration have been summed for clarity. These have been identified with an asterisk in Table A.29.

The results of the assessment are summarised as follows:

- The total activity in soil after 60 years of continuous discharge is estimated to be 2.70E+02 Bq/kg due to H-3 (44%) and C-14 (56%).

12.2 Discussion on the Potential Impact on the Future Use of Sea or Land

The predicted concentrations presented above are based on IRAT Stage 1 parameters and so will bound the concentrations that may be predicted at the majority of UK coastal sites that could host a new UK ABWR unit.

The concentrations in seawater and seabed sediments are based on a local compartment exchange rate of $100m^3/s$, which is lower that the local compartment exchange rate found in locations that could host a nuclear power plant in the UK. Similarly for gaseous discharges the soil concentrations have been determined at 100m from a ground level release which is a conservative approach for normal operational gaseous releases from UK nuclear power plant. In reality, gaseous releases to the environment will be discharged to atmosphere via a tall stack which will aid dispersion and result in lower activity concentrations and deposition rates.

Despite the conservatism in the assessment, it is concluded that the build-up of radionuclides in the local environment of the facility, based on the anticipated lifetime discharges, will not compromise legitimate use or users or uses of the land or sea. Further detail is provided in the following sections.

12.2.1 Future Use of Sea

The predicted total activity concentrations in marine media reach a total of 2.38E-01 Bq/l in unfiltered sea water and 4.37E-01 Bq/kg in seabed sediment after 60 years of continuous discharge. The radiological consequences due to activities in the sea, occupancy in areas of contaminated sediment and consumption of marine foodstuffs are based on the Stage 1 assessment presented in section 8.1. The predicted doses due to the build-up of activity are 2.34E-03 and 1.11E-03 µSv/y due to external exposure and consumption of seafood, respectively. It is noted that the doses presented in section 8.1 are based on a 50 year discharge duration but as explained in section 6.2 a discharge duration of 50 or 60 years has little impact on the predicted dose.

Minor pathways that may result in public exposure due to leisure pursuits in the aquatic environment are described in section 15. For the aquatic pathway annual doses were found to be 4.5E-08 µSv/y for immersion in seawater to an Adult; 2.7E-06 µSv/y for the inadvertent ingestion of seawater by a Child and 2.9E-07 µSv/y for the inadvertent ingestion of sand by an Adult.

It is concluded that the presence of residual contamination at the predicted levels will not compromise future users of the sea.

12.2.2 Future Use of Land

The predicted total activities in soil at 100m from the point of release are presented in Table A.29 in Appendix A and are predicted to reach a total of 2.70E+02 Bq/kg after 60 years of continuous discharge at ground level due principally to H-3 and C-14. The predicted annual doses due to the build-up of activity, based in the Stage 1 assessment methodology, is 6.01E+01 µSv/y due to ingestion of locally grown foodstuffs. It should be noted that the Stage 1 assessment is based on the conservative assumption that it is based on a ground level release.

Minor pathways in the terrestrial environment are described in section 15. The minor pathways considered are the inadvertent ingestion of soil and the inadvertent ingestion of house dust. The highest predicted annual doses were 1.09E-02 µSv/y incurred by an Infant ingesting soil and 9.05E-03 µSv/y incurred by an Infant ingesting contaminated house dust.

It is concluded that the presence of residual contamination at the predicted levels will not compromise future users of the land.

13. Collective Dose

To enable assessment of the impact of the proposed discharges due to normal operations on national, European and World populations an estimate of the collective dose per year of discharge to these populations was determined as described in sections 5.2.7 and 6.3.6.

13.1 Results

Table 13.1-1 summarises the collective dose per year of discharge to UK, EU12 and World populations due to liquid discharges truncated to 500 years:

Table 13.1-1: Collective Dose per Year of Discharge due to Liquid Discharges

Population	First pass (man Sv)	Global circulation (man Sv)	Total (man Sv)
UK*	2.32E-07	1.53E-07	3.84E-07
EU12†	5.95E-07	9.24E-07	1.52E-06
World∞	8.89E-07	2.57E-05	2.66E-05

Data sources: * Table A.37; † Table A.38; ∞ Table A.39

The first pass collective dose is the collective dose due to the initial discharge; the global circulation collective dose is the dose due to circulation of mobile, longer-lived radionuclides in the oceans and atmosphere, i.e. C-14, H-3 and Kr-85. The first pass collective dose was estimated by summation of fish, crustacean, mollusc and beach sediment gamma contributions.

Table 13.1-2 summarises the collective dose per year of discharge to UK, EU12, EU25 and World populations due to gaseous discharges truncated to 500 years.

Table 13.1-2: Collective Dose per Year of Discharge due to Gaseous Discharges

Population	First pass (man Sv)	Global circulation (man Sv)	Total (man Sv)
UK	2.53E-01*	1.78E-01∞	4.31E-01
EU	1.52E+00†	-	-
EU12	-	1.08E+00∞	2.60E+00§
EU25	-	1.37E+00∞	2.89E+00¤
World	-	2.99E+01∞	2.99E+01

Data sources: * Table A.40; † Table A.41; ∞ Table A.42; §Sum of first pass EU and EU12 global circulation; ¤Sum of first pass EU and EU25 global circulation

13.2 Discussion

A detailed breakdown of the contributions each radionuclide makes to the predicted collective doses are presented in Tables A.37 to A.42 in Appendix A. The radionuclides between brackets indicate they are the parent for that particular radionuclide whilst radionuclides marked with an asterisk indicate that the contribution for progeny of parent radionuclides is included, as is the contribution from ingrowth during transport in air and in the food chain.

From the detailed breakdown for liquid discharges presented in Table A.37 in Appendix A it can be seen that for the UK population H-3 (88%) is the major contributor to the total collective dose. The principal pathway is the consumption of fish (39%). Dose contribution from the global circulation represents 40% of the total collective dose due to liquid discharges.

As shown in Table A.38 and Table A.39 in Appendix A, similar patterns emerge for the EU12 and world populations. H-3 is the dominant radionuclide contributing 92% and over 99% to the total collective dose, respectively.

From the detailed breakdown of the collective dose due to gaseous discharges presented in Table A.40 in Appendix A, It can be seen that for the UK population first pass collective dose C-14 (97%) is the dominant radionuclide. The dominant pathways for the first pass dose are the ingestion of grain (51%) and milk (23%).

The first pass dose from gaseous discharges for the EU population presented in Table A.41 in Appendix A is dominated by C-14 which contributes 99% to the total collective dose. The dominant pathways for the first pass dose are the ingestion of grain (59%) and milk products (20%).

For the world population presented in Table A.42 in Appendix A, C-14 is the dominant radionuclide for dose from gaseous discharges. C-14 contributes over 99% of the global circulation collective dose for all population groups.

The International Atomic Energy Agency (IAEA) considers practices giving rise to collective doses below 1 man Sv per year of operation may be exempted from regulatory control [Ref-39]. As can be seen from the results presented above, the predicted collective dose from the single UK ABWR is within the 1 man Sv threshold for liquid discharges for all population groups. For gaseous discharges the 1 man Sv threshold is predicted to be exceeded for EU and World populations. The collective dose for these population groups is dominated by C-14.

It is possible to obtain an estimation of individual per-caput dose from the collective dose. The population data for UK, EU12. EU25 and World are assumed in PC-CREAM 08® to be 59.6 million, 360 million, 456 million and 10 billion respectively and therefore any per-caput doses must be based on these populations.

The per-caput doses from marine discharges from a single UK ABWR unit are equal to 6.44E-06, 4.22E-06 and 2.66E-06 nSv for populations of the UK, Europe (assumed to be EU12) and World, respectively. The per-caput doses from atmospheric discharges from a single UK ABWR unit are equal to 7.23E+00, 7.22E+00, 6.34E+00 and 2.99E+00 nSv for populations of the UK, EU12, EU25 and World respectively.

The European Commission has published a guidance document on the calculation, presentation and use of collective doses for routine discharges [Ref-40]. In this document guidance is given on the use of per-caput doses, with the point made that the group doses and associated per-caput doses could form a useful input to optimisation and option comparison decision-making. The UK Environment Agencies state that discharges giving rise to calculated average annual individual doses for a population group in the nanosievert (nSv/y) range or below should be ignored in the decision making process as the associated risks are minuscule [Ref-11]. The risks presented by the per-caput doses presented in this section are therefore minuscule and can be ignored.

14. Potential Dose Rate to Non-Human Species

14.1 Methodology

Section 12 describes the assessment of the build-up of radionuclides in environmental media due to the discharge of radioactivity at the proposed annual discharge limit over a period of 60 years. The results of that assessment have been used to assess the impact on NHS.

Specifically, the activity concentrations in the plume due to the continuous discharge of noble gases have been calculated based on the proposed annual discharge limit presented in Table 6.3-4. The activity concentration of the discharged noble gases and daughter products have been calculated at 100m from a ground level release with the PC-CREAM 08® PLUME module using the proposed annual discharge limit and the site parameters given in Table 6.3-1. The predicted air concentrations of the gaseous discharges and their associated daughter products are presented in Table A.30 in Appendix A for the Stage 1 assessment parameters.

The ERICA tool [Ref-21] was used to determine the dose to NHS in the marine and terrestrial environments. The parameters used for the assessment of the impact on NHS as a result of liquid discharges are given in Table A.31 and Table A.32 in Appendix A. The parameters used for the assessment of the impact on NHS due to gaseous discharges are given in Table A.33 in Appendix A.

One of the functions provided within ERICA is the ability to determine the risk quotient (RQ). The RQ is the calculated dose rate divided by the dose rate screening value. Therefore, an RQ value less than one means the predicted dose is lower than the threshold posed by the dose rate screening value. The screening value has default values of 10µGy/h (the ERICA value) or 40µGy/h for terrestrial animals and 400µGy/h for terrestrial plants and aquatic biota as proposed by the Environment Agency, IAEA and the US DOE [Ref-23] [Ref-41] [Ref-42]. For the purposes of this assessment a dose rate screening value of 10µGy/h has been selected for all NHS species as this screening value has been proposed by the EA for assessment of a single source.

Following the calculation of the expected value of the RQ, ERICA has the capability to estimate the 95th or 99th percentile value for the RQ, to give an indication of the likelihood of exceeding the dose rate screening value. This can be achieved by selecting a value of 3 or 5 for the Uncertainty Factor (UF), both of which are default available options in the ERICA tool. In this assessment, a UF of 5 has been used to estimate the 99th percentile value and test for 1% probability of exceeding the dose screening value, assuming that the RQ distribution is exponential.

The use of the default UF values (of either 3 or 5) is appropriate if there is good evidence that the uncertainties in the assessed dose rates exhibit an exponential distribution. It is noted in [Ref-43] that for log-normal distributions it would generally be appropriate to use an UF in the range of 7 to 28. Avila et al has issued a response to this note [Ref-44] in which they suggest that the range in UF of 7 to 28 proposed in [Ref-43] is not appropriate though, for a one-sided distribution, a UF of 5 more correctly represents the 97.5th percentile value rather than the 99th percentile value originally stated in [Ref-21]. Therefore, for the purposes of this assessment a UF value of 5 was retained.

The assessment of the impact of noble gas releases on NHS has been undertaken using the Environment Agency R&D 128 methodology [Ref-23]. The airborne activity concentrations of noble gases at 100m due to a ground level discharge are presented in Table A.30 in Appendix A. The R&D 128 methodology includes the isotopes Ar-41, Kr-85, Kr-88, Xe-131m and Xe-133. For the purposes of this assessment, Kr-88 was used as a surrogate isotope for all noble gas releases other than Ar-41, Kr-85, Xe-131m and Xe-133. It is considered that the use of Kr-88 as a surrogate will result in a conservative estimate of the radiation exposure of NHS from the noble gases because its dose per unit concentration [Ref-23] bounds that of the noble gases considered.

14.2 Results

The dose rates to marine biota and the corresponding RQs calculated using the ERICA tool are presented in Table A.34 in Appendix A.

The dose rates to terrestrial biota and the corresponding RQs calculated using the ERICA tool are presented in Table A.35 in Appendix A.

The dose rates to terrestrial biota and the corresponding RQs due to the discharge of radioactive noble gases to the atmosphere calculated using the modified R&D 128 tool are presented in Table A.36 in Appendix A.

14.3 Discussion

Following a Stage 1 assessment of the impact of liquid releases to the marine environment, all the reference species are predicted to have an RQ orders of magnitude less than 1. The risk to marine biota due to the liquid radioactive discharges is found to be very low. Therefore it is concluded that there is no requirement to proceed to a Stage 2 assessment for marine biota.

Since the modified R&D 128 methodology now includes the same reference animal and plants as those assessed with the ERICA tool then the predicted doses presented in Tables A.35 and A.36 can be summed for comparison against the dose rate screening value, though it can be noted that the contribution to the risk to terrestrial species from exposure to noble gases is very low. It is found that the maximum dose rate to terrestrial organisms from aerial discharges is received by Birds, Mammal (Large), Mammal (Small - burrowing) and Reptiles each incurring a dose rate of 6.09µGy/h. This is below the screening value of 10µGy/h whilst the corresponding RQ is 0.61. However, the more conservative RQ based on a UF of 5 is a maximum of about 3. Since the conservative value of the RQ is greater than 1, a further refined assessment was undertaken.

The assessment of the impact on terrestrial organisms from aerial discharges presented above is based on Stage 1 default parameters. The key assumption for this assessment is that the gaseous release is at ground level. For the Stage 2 assessment it is assumed that the effective release height is 19m. As described in section 8, a release at this height will reduce the airborne concentration of radioactive contaminants, and hence deposition rates and subsequently soil concentration, by a scaling factor of 0.045. As the dose rate to terrestrial species will scale linearly with soil concentration then the corresponding maximum dose rate to terrestrial species will be 0.27µGy/h. The corresponding expected RQ is 0.027 with the conservative RQ being 0.14.

For terrestrial species these refined RQs are significantly less than 1 therefore indicating that the risk of exceeding the environmental media concentration limit is very low. For this reason it is considered that no further assessment is required for this exposure pathway.

15. Emerging Issues

A number of topics that do not conveniently fall in to the above sections of this document are considered in this section. This section includes a commentary on some dose modelling topics that are currently undergoing development, and which are presented here to acknowledge their current status, as well as an examination of the sensitivity of some parameters used in the assessments.

The topic areas considered are:

- Consideration of minor exposure pathways (e.g. seaweed consumption, ingestion of soil);
- Issues affecting the NHS assessment (e.g. the screening value and the Uncertainty Factor used);
- Sensitivity to parameters assumed in modelling dispersion in the local marine compartment; and,
- Inhalation dose from noble gases.

15.1 Consideration of Minor Exposure Pathways

There are a number of minor exposure pathways that were not considered in the dose assessments presented earlier in this document. The assessment of the radiological impact to members of the public from a number of pathways that have accumulated activity due to the continuous discharge of radioactive materials over a period of 60 years is presented below. Generic site conditions and parameters have been assumed, i.e. the local compartment volumetric exchange rate was 100m^3/s and the gaseous discharge was at ground level and the receptor location is at 100m from the discharge point.

The minor exposure pathways considered were:

Aquatic pathways:

- The exposure due to swimming in seawater;
- The inadvertent ingestion of seawater; and,
- The inadvertent ingestion of sand.

Terrestrial pathways:

- The inadvertent consumption of soil; and,
- The inadvertent ingestion of house dust.

Based on the activity concentrations presented in Table A.28 in Appendix A, the hourly external dose rate due to immersion in water is found to be 1.5E-10 µSv/h. The annual occupancy in seawater is recommended to be 300 hours per year for generic assessments [Ref-45]. The predicted annual dose from this pathway is therefore 4.5E-08 µSv/y. This exposure is insignificant when compared with the Stage 1 assessment's predicted external exposure from contaminated sediments reported in section 8.1.1 of 2.34E-03 µSv/y. For comparison, the exposure due to the presence of naturally occurring K-40 in seawater is estimated to be of the order of 0.2 µSv/y for an annual occupancy of 300 hours per year.

Inadvertent ingestion of seawater may arise during swimming. The volume of seawater ingested per year is estimated to be 0.2, 0.5 and 0.5 l/y for Infant, Child and Adult members of the public. The corresponding effective doses are predicted to be 2.3E-06 μSv/y, 2.7E-06 μSv/y and 2.1E-06 μSv/y for Infant, Child and Adult members of the public respectively. These effective doses are insignificant when compared with the Stage 1 assessment's predicted effective doses due to ingestion of seafoods of 1.11E-03 μSv/y reported in section 8.1.1.

The inadvertent ingestion of sand may also occur when occupying beaches consisting of contaminated sediment. To predict the annual effective dose it is assumed that sand with the same activity concentration as seabed sediment is ingested at the hourly rate given in [Ref-45], i.e. 50, 10 and 5mg/h for Infant, Child and Adult members of the public. The duration of ingestion is that assumed for the Stage 3 assessment of liquid discharges, i.e. beach occupancy of 2000, 300 and 30h/y for Adult, Child and Infant members of the public as defined in Appendix B of this document. The annual effective dose from this pathway is predicted to be 2.9E-07 μSv/y, 2.2E-07 μSv/y and 2.7E-07 μSv/y, for Adult, Child and Infant members of the public respectively.

Another potential terrestrial minor exposure pathway is the inadvertent consumption of soil. To predict the annual effective dose it is assumed that soil with the same activity concentration as that presented in Table A.29 in Appendix A is ingested at the hourly rate given in [Ref-45], i.e. 50, 10 and 5 mg/h for Infant, Child and Adult members of the public. The duration of ingestion is assumed to be the same as the time spent outdoors, i.e. 4380, 1750 and 880 hours per year for Adult, Child and Infant age group. The corresponding predicted annual effective dose from this pathway is predicted to be 1.96E-03, 2.16E-03 and 1.09E-02 μSv/y, for Adult, Child and Infant members of the public, respectively.

An estimate of the annual dose due to the inadvertent ingestion of house dust has also been made. The annual dose to an Infant is estimated to be about 9.0E-03 μSv/y. Corresponding ingestion doses for Child and Adult age groups are 4.5E-04 and 3.3E-04 μSv/y, respectively.

These effective doses are insignificant when compared with the Stage 1 assessment's predicted effective doses due to ingestion of terrestrial foods of 6.01E+01 μSv/y reported in section 8.1.2.

Based on the assessments made and outlined above, it is considered that the minor pathways listed here do not make a significant additional contribution to the effective annual doses presented elsewhere in this document.

15.2 Issues Affecting the Non-Human Species Assessment

The screening value used in the assessment of the impact of discharges of radioactive material into the environment (reported in section 14 and used as a basis for the dose assessment for NHS) was 10 μGy/h. Other default options for this value in ERICA are a screening dose rate of 40 μGy/h for terrestrial animal populations and 400 μGy/h for all other organisms. These values are based on current and historical international recommendations [Ref-23] [Ref-41] [Ref-42], [Ref-46].

The screening value of 10 μGy/h was selected as it is the most appropriate value to use for GDA. This section presents a discussion of the reasons why this judgement was made.

The ERICA screening level of 10 μGy/h is intended to be protective of the structure and function of generic ecosystems and organism groups. It is derived from a statistical analysis of radiation effects data dominated by acute, external gamma exposures to terrestrial organisms. The screening level represents the dose rate at which a 10% change in an observed effect may be expected to occur, relative to a control group, in 5% of species. This analysis was based on reproduction, morbidity and mortality from acute and chronic exposures.

Recent research (specifically, that carried out by the PROTECT project) investigated the possibility of deriving screening values for different groups of reference organisms, as well as options for defining additional benchmarks which might form the basis for regulatory action levels. It was acknowledged it would be desirable to have screening values for as many reference organisms as justifiable, but that there were insufficient data currently available with which to derive such levels on the basis of a rigorous statistical analysis [Ref-46]. The suggested initial screening level values for broad groups of organisms [Ref-47] were 200 μGy/h for invertebrates, 70 μGy/h for plants, and 2 μGy/h for vertebrates [Ref-48]. However, it was concluded that the supporting data were insufficient to be able to place any confidence in these values. It was also noted that these dose rates are within the range of natural background levels [Ref-46].

The principal difference in the application of the organism group-specific screening levels is that they should protect 95% of species within each organism group, rather than 95% of all species, as would be the case with the generic screening value of 10 μGy/h.

In a similar vein, ICRP [Ref-49] has introduced the concept of reference animals and plants (RAP) and provides preliminary numerical benchmarks for each RAP in the form of a range of dose rates or Derived Consideration Reference Levels (DCRL), which span an order of magnitude.

The DCRLs were derived following review of effects data for the families of plants and animals on which RAPs are based. The value of using natural background rates experienced by animals and plants is acknowledged [Ref-49]. The DCRLs provide a pragmatic judgement of the orders of magnitude in differences in radiosensitivity between different organism types, and a range of reference levels for each RAP. These values are based primarily on expert judgement, rather than the statistical analysis used to derive the ERICA and PROTECT screening values. The detailed application of the DCRLs and their regulatory interpretation are still evolving. It will be necessary to develop more detailed structured guidance on undertaking assessments in the event that screening levels are exceeded.

Table 15.2-1, based on [Ref-50], presents a summary of the alternative screening values proposed by various organisations.

Table 15.2-1: Summary of Screening Values

	IAEA 1992	UNSCEAR 1996	Environment Canada 2003	ERICA	ICRP 2008
	µGy/h				
Terrestrial					
Plants	400	400	100	10	
Reference Pine tree					4 to 40
Reference wild grass					40 to 400
Animals	40	40 to 100		10	
Invertebrates			200		
Reference Bee					400 to 4,000
Reference Earthworm					400 to 4,000
Birds					
Reference duck					4 to 40
Mammals			100		
Reference deer					4 to 40
Reference Rat					4 to 40
Aquatic					
Freshwater Organisms	400	400		10	
Algae			100		
Macrophytes			100		
Benthic invertebrates			200		
Reference frog					40 to 400
Fish			20		
Reference trout					40 to 400
Marine organisms		400		10	
Reference Crab					400 to 4,000
Reference Flatfish					40 to 400
Reference Brown seaweed					400 to 4,000
Deep Ocean Organisms	1000			10	

Table 15.2-1 indicates that there is a high level of agreement between the various screening levels, but that the ERICA screening levels are among the lowest currently used, reflecting their generic nature. It should be noted, however, that the ICRP DCRLs for mammals and birds (duck, deer, rat etc) are lower than the

generic 10 μGy/h screening level. ICRP comments that there is a very low probability of certain effects occurring for the band 100 to 1000 μGy/d that could result in reduced reproductive success or morbidity; however, at the band below (10 to 100 μGy/d) such effects have not been observed.

There are concerns that, by having a single low screening value, such as the 10 μGy/h screening value derived during the ERICA and PROTECT projects that NHS assessments could become the limiting factor in assessments. It should be noted that in the event of screening values being exceeded then a more detailed assessment should be undertaken prior to any conclusion being reached. However, the results presented in section 14 show that, despite using the single low screening value of 10 μGy/h, the risk of exceeding the environmental media concentration limit is very low. It is for these reasons that the generic screening value is deemed appropriate for use in GDA.

15.3 Sensitivity to Parameters Assumed in Modelling Dispersion in the Local Marine Compartment

The methods used for the calculation of radiation exposure used in the PC-CREAM 08® software package are described in [Ref-19]. The parameters that govern the activity in marine biota and the activity on seabed sediment in the local and regional compartments and hence exposure of the marine representative persons include element-dependent parameters and local compartment details.

Element-dependent parameters used include:
- Sediment to water distribution coefficients; and,
- Concentration factors for marine biota.

Local compartment parameters used include:
- Local compartment volume;
- Local compartment sediment density;
- Local compartment diffusion rate;
- Local compartment depth;
- Local compartment coastline length;
- Local compartment suspended sediment load;
- Local compartment sediment rate; and,
- Local compartment volumetric exchange rate.

The sensitivity of marine biota and seabed sediment concentrations, and hence dose to the representative persons, to changes in the values assigned to the element-dependent parameters will be proportional to the values assigned to these parameters. Conversely, the sensitivity of marine biota and seabed sediment concentrations, and hence dose to the representative persons, to changes in the values assigned to individual local compartment parameters is not immediately obvious due to the complexity of the inter-relationships between these parameters. For example, the rate of accumulation of activity into the top layer of sediment is dependent on the rate constant for the transfer of activity from the water column to the sediment top layer, as well as the rate of transfer from the top layer to the underlying layer of sediment. The activity in the water column is dependent on the discharge rate of radionuclides into that compartment, the compartment volume, the volumetric exchange rate, radioactive decay and the interactions of radionuclides with suspended and seabed sediment.

The Environment Agency has published a report on the analysis of parameter uncertainty, arising from the consultation on the Hinkley Point C permit application [Ref-51]. This report examined the effect on the key radionuclides (Ag-110m, C-14, H-3, Co-60 and Cs-137) variations in the suspended sediment load and the volumetric exchange rate. It also examined the effect of changes in the H-3 sediment-water distribution coefficient (Kd).

The report concluded that:

- When the suspended sediment load was increased the amount of activity associated with water itself (dissolved phase) is reduced for all nuclides except H-3.
- When the volumetric exchange rate is reduced the concentrations of radionuclides increase.
- When the Kd for H-3 was increased the concentration in suspended sediment was increased and the concentration in filtered and unfiltered seawater decreased.

The report was based on the parameters appropriate for Hinkley Point, i.e. a local volumetric exchange rate of 1×10^{11} m^3/y (corresponding to an exchange rate of 3,000 m^3/s) and a suspended sediment load of 0.2g/l (corresponding to 2×10^{-4} t/m^3). The Stage 3 parameters used for the assessment of the liquid discharges from the UK ABWR were a local volumetric exchange rate of 4×10^{10} m^3/y (corresponding to an exchange rate of 1,300 m^3/s) and a suspended sediment load of 0.01g/l (corresponding to 1×10^{-5} t/m^3).

The volumetric exchange rate used in the UK ABWR Stage 3 dose assessment is similar to that used as a baseline value in the Hinkley C permit and Environment Agency report and it is expected that similar conclusions can be drawn. However the suspended sediment load is significantly lower for the UK ABWR Stage 3 dose assessment. An assessment of the effect of increasing the suspended sediment load, starting from a baseline value of 0.01 g/l, demonstrated that the Environment Agency's conclusions regarding the effect of increasing the suspended sediment load are unaffected by the lower suspended sediment load used for the UK ABWR Stage 3 assessment.

In summary it is concluded that:

- An increased sediment load will reduce the concentration in marine biota and consequently reduce the dose due to ingestion of marine foodstuffs.
- An increase in Kd will tend to increase the concentration in seabed sediment and reduce the concentration in marine biota and consequently reduce the dose due to ingestion of marine foodstuffs.
- Concentration in biota is directly proportional to concentration factors and increasing the concentration factor will result in an increase in dose due to the consumption of marine foodstuffs.

It is concluded in [Ref-51] that the sensitivity studies showed that, even with a big range in the parameters used in the marine modelling (including adoption of cautious values), the representative person and the dose received are not changed. A similar conclusion can be made in the assessments presented in section 11 of this document, where the predicted dose due to liquid discharges contribute a minor proportion to the overall annual prospective dose.

15.4 Inhalation Dose from Noble Gases

The exposure pathway considered in the assessment of the inhalation dose received from noble gases is external exposure due to immersion in the plume of radioactive noble gases released to the environment at the proposed annual limit. This section considers ongoing research which may affect this assessment for the UK ABWR.

The ICRP [Ref-52] considered exposure due to internal irradiation by absorbed gas and irradiation of tissues of the lung due to gas contained within the lung. The ICRP concluded that the dose equivalent rate to any tissue due to external exposure was more than 200 times greater than the internal irradiation by absorbed gas, and more than 130 times greater than the irradiation of the lung due to gas contained within the lung. The ICRP has therefore concluded that exposure to noble gas need only consider external irradiation.

A recent paper by Leggett et al [Ref-53] presents a generic biokinetic model for noble gases with application to radon. This paper states that the ICRP plans to provide biokinetic models or dose coefficients for intakes of noble gases in a forthcoming series of reports on occupational intakes of radonuclides. Currently the ICRP has published three reports for public consultation on their contents. The radionuclides considered in these consultation reports include radon but no other radioactive noble gases. It is expected that other radioactive noble gases will be included in later publications. Any future dose assessment undertaken by prospective operators will have to consider these publications when they are available.

16. Uncertainty and Validation

As with all models, there is a degree of uncertainty present in the majority of the assumptions used in the assessments presented in this document, specifically:

- The estimate of the radioactive discharge to the environment.
- The atmospheric and marine dispersion of radioactivity following its discharge to the environment.
- The transfer of radioactivity in the environment.
- Dose coefficients for the inhalation or ingestion of radioactive species.

The degree of uncertainty of each of the above areas is discussed in the following sections.

16.1 Radioactive Discharges

The proposed annual limits for the UK ABWR are quantified for both liquid and gaseous discharges in Hitachi-GE's Quantification of Discharges and Limits document [Ref-3] which provides a detailed breakdown of the radioisotopes that may be discharged as a result of normal operations, including any expected events. The quantification of the discharges is based on a combination of theoretical assessment (calculation) and operator experience.

[Ref-3] includes a comparison of the expected annual discharge from the UK ABWR with the actual discharges reported for a number of similar operating power plants based in Europe and the US. This comparison shows that the expected liquid and gaseous discharges from the UK ABWR are broadly similar to the reported annual discharge when weighted to annual power generation (GWeh per year).

Examined in further detail, this comparison indicate that the UK ABWR's expected annual gaseous discharge of C-14, the most radiologically significant radioisotope, is within about 5% of the average reported annual discharge of C-14 from comparable plant. The proposed annual limit of liquid discharges for the UK ABWR are found to be lower than the reported discharges from comparable plant, though it is subject to greater variability. Therefore it is considered that the uncertainty associated with the gaseous discharges is about a factor of 10%. Higher uncertainty is associated with the liquid discharge. However the predicted doses due to this source are very low and so can tolerate higher uncertainty.

It should be noted that dose assessments described in this document are based upon discharges at the proposed discharge limit values, which are higher than the actual expected discharges. [Ref-3] describes the relationship between the expected discharges and the proposed discharge limits (a multiplication factor termed the Headroom Factor); therefore it can be expected that the predicted doses will be higher than the actual doses by a similar degree.

16.2 Atmospheric Dispersion Modelling Methodology

The dispersion of gaseous discharges in the atmosphere depends on number of factors. This section examines the influence of effective release height and meteorological conditions on the dispersion of gaseous discharges into the atmosphere and the effect of recent research and discussion in this topic area.

16.2.1 Effective Release Height

The assessments of the dose to the representative person for the more refined and further detailed assessments are presented in section 8.2.2 and 8.3.2, respectively. At this stage the precise detailed design of the discharge stack and surrounding buildings for the UK ABWR is not known. The main stack heights of the 4 existing Japanese ABWRs are 57m, 75m, 98m and 100m. Therefore, for the purposes of this assessment, a proposed design stack height of 57m will be used. It should be noted that the actual main stack height will be determined during detailed site specific studies. These assessments are based on an effective release height of 19m. This effective release height is derived from the physical stack height of 57m (the shortest stack at the existing ABWR stations operating in Japan given above) and a general rule of thumb that, for a release that is fully entrained into the building wake, the effective release height is 1/3rd of the stack height. At the time of writing of the previous version of this document during GDA Step 2, information on the UK ABWR building dimensions were not available. However, the dose assessment work can now incorporate information on the height of the reactor building (specifically that it is 42.6m [Ref-54]. Knowledge of the building height enables two further models to be used to determine the impact, if any, on the predicted dose to the representative person. The two additional models used are described in NRPB-157 [Ref-55] and the Department for Environment, Food & Rural Affairs and Environment Agency’s guidance [Ref-56]. The effective release height for each of these two models is found to be 14m and 24m for the R-157 and Annex F models, respectively. No benefit has been claimed for plume rise due to temperature or momentum effects and it is assumed that the gaseous discharge is fully entrained into the building wake.

The effect of these different effective release heights can be estimated by using the IRAT Stage 2 methodology as described in section 8.2.2 and substituting these effective release heights. It is found that the predicted annual dose due to discharges at these release heights are 3.84E+01 µSv/y and 1.71E+01 µSv/y for an effective release height of 14m or 24m respectively. By comparing these annual doses due to gaseous discharges with the predicted dose of 2.36E+01 µSv/y for the initial effective release height of 19m, it is concluded that the use of an effective release height of 19m, a mid-point value between 14m and 24m, does not introduce a significant error to the dose results and an effective release eight of 19m may be retained for future assessments.

16.2.2 Meteorological Conditions

The dispersion of gaseous discharges into the atmosphere is influenced by the meteorological conditions during the release. The effect of variation in the annual average meteorological conditions can be examined with reference to NRPB–R91 [Ref-32].

NRPB–R91 describes the Gaussian plume model for short and medium range dispersion. The Gaussian plume model uses a number of variables that are dependent on the stability of the atmosphere, usually classified as Pasquil stability categories. Pasquil stability categories are classified in the range A to G with category A being the most unstable, corresponding to a hot summers afternoon, and category G the most stable, corresponding to a cold winter’s night. Category D is the most common Pasquil category in the UK representing neutral weather conditions. NRPB-R91 also presents data showing the typical annual average frequency of each Pasquil stability category, ranging from 50% D (appropriate for inland locations) to 80% D (appropriate for coastal locations). The effect of different meteorological conditions on continuous dispersion from a point source for a uniform wind rose can be seen by comparing Figures 34 (50% D) and 40 (80% D) of [Ref-32]. If the ground level concentrations are compared it can be seen that the concentration for 50% D is about a factor of 2 higher than for 80% D. This is likely to be primarily due to an increase in the average windspeed and decrease in the proportion of stable meteorological conditions as one goes from 50% D to 80% D. This comparison gives an indication of the variability in ground level concentrations with meteorological conditions that can be expected to arise over locations on the UK mainland.

16.2.3 Receptor Point Distance

The effect of receptor point distance from the release depends on the release height of the discharge. For a ground level release the ground level air concentration always reduces with distance. However, for an elevated release height the ground level concentration tends to increase, reach a maximum and then reduce with increasing distance from the discharge location. This is illustrated in Figure 16.2-1 below.

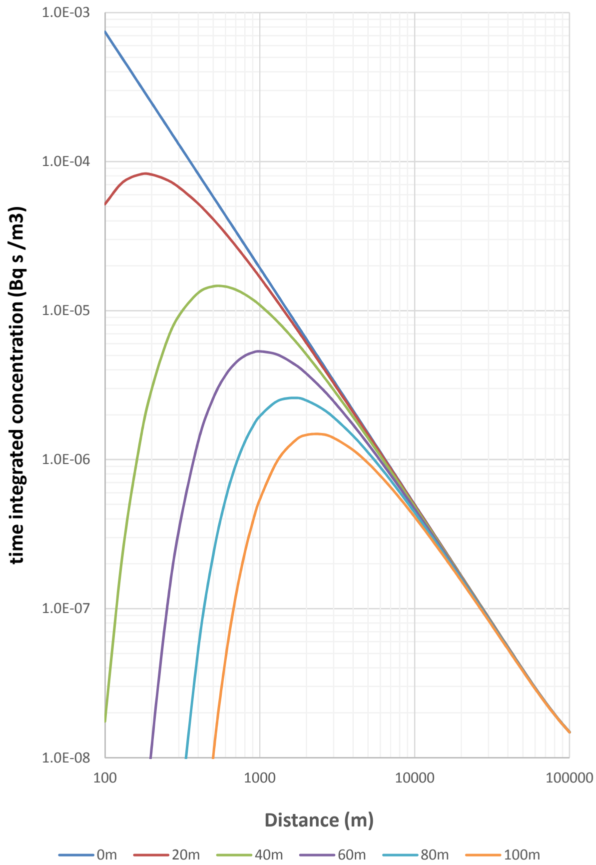

Figure 16.2-1: Dispersion vs Distance from Release for a Range of Release Heights for Cat D Stability Category

Figure 16.2-1 illustrates the variation in ground level concentrations with release height and distance from the point of discharge. As the discharge height increases then substantial reductions in ground level concentrations are observed at locations closer than about 1 km when compared with a ground level discharge. The magnitude of the reduction is also dependent on the discharge height.

The dispersion of gaseous radioactive species in the atmosphere has been calculated using either the PLUME model with in PC-CREAM 08® for the assessment of the radiological consequences of a continuous discharge or ADMS of the assessment of a short-term discharge. Both PLUME and ADMS encode the Gaussian plume model.

PC-CREAM 08® is based on a standard Gaussian plume model. [Ref-19] includes a commentary on the validation of the Gaussian plume model which states that annual average concentrations within a few kilometres of the site are likely to be predicted within a factor of 2. This report goes on further to state that a comparison of predictions from a Gaussian plume model and the UK Met Office's Lagrangian particle model, NAME, for a long term release found differences between the two models were small compared with the expected precision of the models.

[Ref-19] also outlines limitations with the Gaussian plume models. These limitations include: inapplicability in calm or near calm conditions; conditions at the point of release remaining constant through the travel time of the plume; and, that surface roughness is constant and terrain is flat.

ADMS is a "new generation" Gaussian plume air dispersion model which uses the boundary layer depth and the Monin-Obukhov length to characterise the atmospheric boundary layer properties rather than using the single parameter Pasquill-Gifford class. It is continually validated against available measured pollutant concentration data obtained from real world situations, field campaigns and wind tunnel experiments by the model developers, CERC, and is shown to have good agreement with observed values. A list of recent model validation for buildings, complex terrain and flat terrain can be found on the CERC website [Ref-58].

16.3 Marine Dispersion Modelling Methodology

The marine dispersion model in PC-CREAM 08® is based on a simplified 55 compartment version of the MARINAII model [Ref-19]. Dispersion on a local scale is modelled by a single well-mixed water compartment together with associated sediment compartments. The local model is linked with the corresponding regional marine compartment. The limited understanding of the movement of water bodies, the demarcation of hypothetical compartments and use of simplifying parameters (Kd, volumetric exchange rates, etc) are key sources of uncertainty.

The PC-CREAM 08® marine model has been tested extensively by comparing predictions with environmental measurements for a number of different cases. Most predictions made by the model for filtered water were within a factor of two of the measured values. For sediments, predictions from the model were within a factor of two to five of the measured values. The Environment Agency has also investigated the sensitivity of parameter values on the predicted concentrations. The findings are summarised in section 17.3 of this document. The sensitivity studies showed that even with a large range in the parameters used in the marine modelling (including adoption of cautious values) the dose received are not significantly changed, therefore demonstrating the marine modelling is not unduly sensitive to uncertainties in parameter values.

16.4 The Transfer of Radioactivity in the Environment

The separate models in PC-CREAM 08® have been subject to varying degrees of validation and verification; these studies are summarised in [Ref-19].

It is noted that the estimation of the radiological impact of a continuous release is dependent on a number of factors, which are in turn variable to a greater or lesser degree. These include agricultural practises assumed in the local area, such as time of planting and harvesting, and whether and what animal husbandry is practiced. Much use is made of annual averages for parameters, both for those parameters identified above as well as the rate of consumption of different foods. This is considered adequate when assessing the radiological consequences of routine discharges integrated over long periods of time. Consequently, the results generated by PC-CREAM08® are not deemed to have significant levels of uncertainty.

16.5 Inhalation and Ingestion Dose Coefficients

The HPA (now PHE) has recently published a report assessing the reliability of dose coefficients for ingestion and inhalation of radionuclides by members of the public [Ref-57]. In this report the HPA reported the results of a parametric study to quantify uncertainties resulting from internal exposure to representative number of radionuclides. The radionuclides studied were U-238, Ra-226, Pu-239, Am-241, C-137, Sr-90, I-131, I-129 and H-3. The central value and range of the distributions of the effective dose coefficients were described by a UF. The UF indicates that the risk coefficient has a 95% probability of being within a factor (the UF) of the nominal risk associated with the dose coefficient. A Monte Carlo approach is described where distributions of various biokinetic parameters were tested, e.g. f1 values (fraction of the intake transferred to blood from the alimentary tract) and regional deposition in the lung.

It was found that the inferred UF values were around 2–3 for ingestion and 2-6 for inhalation of the radionuclides considered for all age groups. The report conclude that the derived UF values for the radionuclides considered seem acceptable when considered alongside the likely levels of exposure expected from them (the sub-microsievert to microsievert range) with the dose limit for planned exposures for members of the public at 1000 μSv.

17. Summary of the Prospective Dose Assessments

This document presents the methods and data used to determine the prospective dose assessment requirements identified in the Environment Agency's P&ID [Ref-1]. The results of the prospective dose assessments are presented in the relevant sections throughout this document and are summarised below. The prospective dose assessments were undertaken for discharges at the proposed annual discharge limits for liquid and gaseous discharges from a single UK ABWR unit.

17.1 Annual Dose to the Most Exposed Members of the Public for Liquid Discharges

A staged approach, consistent with industry relevant good practice, was undertaken in the assessment of the radiological impact of liquid discharges.

The Stage 1 assessment, based on the Environment Agency's IRAT methodology, predicted that the overall dose incurred by the Fisherman family due to liquid discharges at the proposed annual discharge limit of 3.48E-03 μSv/y. Although this is less than the 20 μSv/y threshold, a Stage 2 assessment was nevertheless undertaken using more refined data. The Stage 2 dose to the Fisherman family, using more refined data, is an annual dose of 2.68E-04 μSv/y.

A detailed Stage 3 assessment was also undertaken for completeness. The predicted overall dose to Adult, Child and Infant members of the Fisherman family due to liquid discharges and the consumption of marine foodstuffs at the high rate are found to be 2.29E-04, 6.17E-05 and 5.37E-06 μSv/y, respectively.

It can be seen that the predicted doses to members of the Fisherman family are very low and do not approach any dose constraint or limit. It is considered not essential to undertake further assessments using site-specific data to further refine the dose assessment. Nevertheless a site-specific assessment may be undertaken to underpin the any site-specific permit and so further refine the dose assessment.

17.2 Annual Dose to the Most Exposed Members of the Public for Gaseous Discharges

In the same manner as the liquid discharges assessment, a staged approach, consistent with industry relevant good practice, was undertaken in the assessment of the radiological impact of gaseous discharges.

The Stage 1 assessment, based on the Environment Agency's IRAT methodology, predicted that the overall dose incurred by the Local Resident family due to gaseous discharges at the proposed annual discharge limit of 1.43E+02 μSv/y. As this exceeds the 20 μSv/y threshold, a Stage 2 assessment was undertaken using more refined data. The Stage 2 assessment of the Local Resident family, using more refined data, results in an estimated annual dose of 2.36E+01 μSv/y.

As this exceeds the 20μSv/y threshold a Stage 3 assessment was undertaken using more detailed data and this study predicted doses to Adult, Child and Infant due to gaseous discharges and the consumption of foodstuffs at the 'top two' rate of 1.27E+01, 1.40E+01 and 2.35E+01 μSv/y, respectively. The doses to Adult, Child and Infant due to gaseous discharges and the consumption of foodstuffs at the mean rate are found to be 8.53E+00, 9.04E+00 and 1.14E+01μSv/y, respectively.

It can be seen that the predicted dose to members of the Local Resident family are below the 20 μSv/y threshold for all age groups except for Infants consuming locally produced food at the 'top two' rate. The annual dose for an Infant consuming locally produced food at the 'top two' rate is predicted to be slightly higher than the 20 μSv/y with a predicted annual dose of 2.35E+01 μSv/y. However, the dose assessment is considered to be sufficiently realistic and, as the threshold is exceeded by a small margin, it is considered that further refinement is not warranted at the GDA. Nevertheless a site-specific assessment may be undertaken to underpin the any site-specific permit and so further refine the dose assessment.

17.3 Annual Dose to the Most Exposed Members of the Public for All Discharges from the Facility

The initial assessment of the overall dose to the most exposed members of the public is made by summing the initial assessment doses for liquid discharges, gaseous discharges and direct exposure.

For the Stage 1 assessment using conservative and simple bounding assumptions, the predicted annual dose to the most exposed members of the public is shown in Table 8.1-1.

The predicted annual dose due to discharges at the proposed annual limit and for permanent occupancy at 100m from the source results in an estimated annual dose of 1.44E+02 µSv/y. This is in excess of the source threshold of 20 µSv/y and so a further more refined assessment was undertaken.

The Stage 2 assessment used more refined data including an effective release height of 19 m for the gaseous discharge and a local compartment volumetric exchange rate of 4.0E+10 m^3/y. the predicted annual dose for the Stage 2 assessment is presented in Table 8.2-1.

The predicted annual dose due to discharges at the proposed annual limit and for permanent occupancy at 100m from the source results in an estimated annual dose of 2.45E+01 µSv/y. As this is greater than 20 µSv/y, a further more refined assessment was undertaken.

The Stage 3 assessment used more detailed data including a release height of 19m and the permanent habitation at 270m from the source; the results of this assessment are presented in Table 17.3-1 below.

Table 17.3-1: Predicted Annual Dose to the Most Exposed Member of the Public (Stage 3)

Exposure pathway	Initial annual dose (µSv/y)	Most exposed age group
Liquid discharges	2.29E-04*	Adult*
Gaseous discharges	2.35E+01†	Infant†
Direct radiation	9.40E-01∞	Adult∞
Total	2.44E+01	--

Data sources: * Table A.3; † TableA.13; ∞ Section 7

The Stage 3 predicted annual dose due to discharges at the proposed annual limit and for permanent occupancy at 270m from the source results in an estimated annual dose of 2.44E+01 µSv/y. This estimate of the annual dose from all discharges, irrespective of the age of the member of the public in the exposed population, includes the contribution from Infant members of the Local Resident family consuming foodstuffs consuming at the 'top two' rate and direct exposure of an Adult member of the public. This is above 20 µSv/y. However the dose assessment is considered to be sufficiently realistic and, as the threshold is exceeded by a small margin, it is considered that further refinement is not warranted at the GDA. Further assessment using site-specific information may result in a reduction in this estimate due to more refined occupancy patterns and refined consumption rates. This may be undertaken to underpin the any site-specific permit.

17.4 Annual Dose from Direct Radiation to the Most Exposed Member of the Public

Section 7 presents the estimated external exposure due to direct radiation from the operation of an individual ABWR unit. In GDA Step 3 a more detailed assessment of the direct dose due to all potential sources present on site has been undertaken [Ref-27]. Of the sources assessed, the principal source of direct exposure is due to sources within the turbine building. The calculations are based on full-time occupancy at the given distances from the source. An occupancy pattern of 50% of the time indoors and 50% of the time outdoors for an Adult has been assumed.

The estimated annual exposure from direct radiation are:

- At the site boundary the annual external dose was found to be 9.40E-01 μSv/y;
- At 500 m the annual external dose was found to be 1.75E-01 μSv/y;
- At 1000 m the annual gamma dose was found to be 8.24E-03 μSv/y.

The annual exposure from direct radiation will depend on the dose rate at the location where the member of public is present, the distance that this location is from the source, the time spent at that location and whether the individual is indoors or outdoors. The assessments in this document assume a static location close to the source. The resulting annual exposure to direct radiation can therefore be regarded as a conservative assessment. In practise it is reasonable to expect an individual would not reside as close to the source as assumed and that they would move between at least two locations. It is expected that a more realistic occupancy pattern would be assessed in a site-specific study that would underpin any future permit application.

17.5 Annual Dose to the Representative Person for the Facility

The annual dose to the representative person has been determined for the following population groups:

i. A Local Resident family for gaseous discharges who also consume locally sourced seafoods at average rate;

ii. A Fisherman family for liquid discharges who also consume locally sourced terrestrial foods at average rate.

The assessment of the annual dose to the representative person is based on the results of the Stage 3 assessments.

The assessment of the overall dose from each discharge route and direct radiation for each age group is presented in Table 9.1-1 and Table 9.1-2 for the Fisherman family and the Local Resident family respectively.

It can be seen from the results for the Local Resident family presented in Table 9.1-2 that the predicted annual dose is between 1.36E+01 and 2.38E+01 μSv/y. The doses due to liquid discharges make a minor contribution to the overall predicted annual exposure. As the age group decreases then the importance of the terrestrial exposure pathways due to gaseous discharges increase. For the Infant age group the dose due to gaseous discharges contributes about 99% of the overall dose. For this age group, the principal route of exposure from this source is due to C-14 which dominates through the ingestion of milk and milk products, providing 40% and 34% of the total terrestrial dose respectively.

17.6 Potential Short-term Doses

The assessment of the potential short-term dose is presented in section 10 of this document. A summary of the predicted radiological impact to an Adult, Child and Infant is presented in Table 10.1-1. The predicted effective dose to members of the public is below 2.00E-02 μSv for all age groups.

The predicted skin dose per cm^2 to Adult, Child and Infant age groups are 1.33E-06, 2.25E-06 and 5.25E-06 $\mu Sv/cm^2$ respectively.

The predicted effective doses are substantially below any dose limit and annual dose constraints. There is significant margin between the predicted dose and the 20 μSv/y value above which further, more refined assessment is generally recommended. It is therefore considered that the short-term doses due to planned and expect events are sufficiently small that the dose assessment need not be refined further.

The predicted exposure of the skin from beta emissions in the plume and deposited activity is significantly less than 0.001 $\mu Sv/cm^2$ for all age groups. This is significantly below the annual equivalent dose limit of 50,000 μSv/y averaged over any area of $1cm^2$, regardless of the area exposed.

17.7 A Comparison of the Calculated Doses with the Relevant Dose Constraints

Section 11 of this document presents a comparison of the calculated doses with the relevant dose constraints.

The predicted prospective annual dose to the Adult, Child and Infant age groups due to discharges at the proposed annual limits are substantially below the source constraints of 0.3 mSv/y and well below the HPA recommended value of 0.15 mSv/y.

The estimates of the total prospective dose including that due to direct exposure are below 20 μSv/y for Adult and Child age groups, therefore no refinement of the dose assessments is required. The Infant member of the Local Resident family is predicted to incur an annual exposure of 2.38E+01 μSv/y which is above 20 μSv/y. However the dose assessment is considered to be sufficiently realistic and, as the threshold is exceeded by a small margin, it is considered that in this case further refinement is not warranted. The principal route of exposure is due to the ingestion of contaminated foodstuffs at the 'top two' rate resulting from the discharge of gaseous radioactive material to the atmosphere.

A site-specific study for the UK ABWR is likely to be based on more realistic metrological conditions, whilst food production may take place at locations greater than 500m from the point of release. This will result in a further reduction in the estimated annual dose due to discharges of gaseous radioactive substances at the proposed discharge limit.

The predicted doses to members of the Local Resident family are based on future discharges and direct radiation from the planned operation of a single UK ABWR unit. The dose assessment has been refined to be reasonably realistic for a generic assessment.

17.8 Assessment of the Build-up of Radioactivity in the Local Environment

The build-up of activity in the local marine and terrestrial environment has been presented in Section 12 of this document.

It is predicted that the total activity concentration in seawater and seabed sediment due to liquid discharges at the proposed annual discharge limit is 2.38E-01 Bq/l in unfiltered sea water and 4.37E-01 Bq/kg in seabed sediment after 60 years of continuous discharge. The predicted activity concentration in sediment after 60 years of continuous discharge at the proposed annual discharge limit are all less than 1/2000th of the 'out of scope' activity concentrations [Ref-2].

The predicted total activities in soil are predicted to reach a total of 2.70E+02 Bq/kg after 60 years of continuous discharge due principally to the accumulation of H-3 and C-14. It can be seen that all of the radionuclides predicted to accumulate in soil after 60 years of continuous discharge at the proposed annual discharge limit are less than 1/1,000th of the 'out of scope' activity concentrations with the exception of C-14, where the predicted concentration is 1/75th of the 'out of scope' values.

It should be noted that the above estimates of build-up in marine and terrestrial environments are based on the conservative and bounding parameters used for the Stage 1 assessments. Despite the conservatism in the assessment, it is concluded that impact of residual activity in the environment due to operation of a single UK ABWR is negligible and will not restrict future use of the land and sea.

17.9 Collective Dose

Section 13 of this report describes the collective dose assessment for the gaseous and liquid discharges at the proposed annual limit from one UK ABWR unit. The results of the calculation of collective dose are orders of magnitude below 1 man Sv for liquid discharges and range between 0.4 and 30 man Sv for gaseous discharges depending upon the exposure population.

The IAEA considers practices giving rise to collective doses below 1 man Sv may be exempted from regulatory control. As can be seen in section 13 of this document, the predicted collective dose from the single UK ABWR is within the 1 man Sv threshold for liquid discharges for all population groups. For gaseous discharges the 1 man Sv threshold is predicted to be exceeded for EU and World populations. The collective dose for these population groups is dominated by C-14.

The per-caput doses from marine discharges from an individual UK ABWR unit are equal to 6.44E-06, 4.22E-06 and 2.66E-06 nSv for populations of the UK, Europe (assumed to be EU12) and World, respectively. The per-caput doses from atmospheric discharges from an individual UK ABWR unit are equal to 7.23E+00, 7.22E+00, 6.34E+00 and 2.99E+00 nSv for populations of the UK, EU12, EU25 and World respectively. The risks presented by the above per-caput doses are therefore minuscule and are not considered further.

17.10 Dose Rate to NHS

The assessment of the predicted dose rate to NHS is presented in section 14. This assessment is based on discharges at the proposed annual discharge limit and is based on Stage 1 parameters. The ERICA risk assessment system was used for the assessment of the impact on NHS for liquid and gaseous discharges. The assessment of the impact due to noble gas discharges was made using the Environment Agency's R&D128 method, as revised [Ref-23].

The assessment of the impact on marine organisms from liquid releases to the marine environment shows all the reference species are calculated to a maximum predicted expected RQ of 3.06E-05 with the conservative RQ being 1.53E-04.

The assessment of the impact on terrestrial organisms from gaseous discharges based on Stage 2 parameters result in a maximum predicted expected RQ of 0.027 with the conservative RQ being 0.14.

All the RQs are less than 1 therefore indicating that the risk of exceeding the environmental media concentration limit is very low.

18. Conclusions

This document presents the input data used, the methodologies applied and the results of the prospective dose assessment in support of the GDA submission for an individual UK ABWR unit.

The principal conclusions of the assessment are as follows:

- It is concluded the prospective annual dose for an individual UK ABWR unit due to discharges at the proposed annual discharge limit will not result in any source constraint or dose limit to be exceeded.

- The assessments presented in this document demonstrate that the principal sources of exposure from the UK ABWR are due to gaseous discharges.

- The predicted annual dose from all discharges and direct radiations from the UK ABWR for the Local Resident family is between 1.36E+01 and 2.38E+01 μSv/y. The predicted doses for the Adult and Child age groups are below 20 μSv/y (the value above which it is generally recommended that further, more refined, assessment is undertaken). The contribution from Infant members of the local resident family consuming foodstuffs consuming at the ‘top two’ rate is above 20 μSv/y. However, it should be noted that the assessment of doses due to radioactive discharges presented in this document is based on a number of conservative assumptions. It is considered that there is limited value in doing more detailed modelling at the GDA stage; furthermore, many of the inputs that would be used in a more detailed model for example precise building layouts, local topography, more detailed site specific meteorological data, are not available are applicable at the GDA stage. Considering the in-built conservatisms and the fact that the 20 μSv/y threshold is exceeded by only a small margin, the current dose assessment is considered to be sufficiently realistic and it is concluded that further refinement is not warranted.

- The build-up of radioactivity in the local environment as a result of the liquid and gaseous discharges is considered not to prejudice legitimate users or uses of the land or sea.

- The collective dose to the UK, European and world populations has been calculated, truncated to 500 years and is dominated by C-14 in the gaseous discharges.

- All doses to NHS are predicted to result in RQs of less than 1 indicating that the risk of exceeding the environmental media concentration limit and hence causing harm to NHS is very low.

- Doses due to a short-term release are substantially below any dose limit and annual dose constraints. There is significant margin between the predicted dose and the 20 μSv/y above which further, more refined, assessment is normally recommended, and it is therefore considered that the short-term doses due to expected events are sufficiently small that the dose assessment for short-term discharges need not be refined further.

Appendix A – Results of the Initial Radiological Assessment and Detailed Assessments

This Appendix presents the detailed results of the calculations of:

- The initial and detailed radiological prospective dose assessment to member of the public, input parameters and predicted dose for the short-term release
- Input parameters and resulting build-up of radioactivity in the environment
- Input parameters and calculated exposure and risk to non-human species
- The collective dose to UK, EU and world populations

The following table are presented in this Appendix:

Table A.1: IRAT Stage 1 Assessment for Liquid Discharges at the Proposed Annual Discharge Limit

				DPUR			Annual Dose (µSv/y)			
Radio-nuclide	**Bq/y**	**$T_{1/2}$ Day**	**DPUR Isotope**	**External Irradiation**	**Seafood Consumption**	**Total**	**External Irradiation**	**Seafood Consumption**	**Total**	**Age Group**
Ag-110m	5.7E+00	2.50E+02	Ag-110m	1.20E-10	3.90E-09	4.00E-09	6.84E-10	2.22E-08	2.28E-08	Adult
Am-241	1.1E-01	1.58E+05	Am-241	2.50E-11	4.60E-11	7.10E-11	2.75E-12	5.06E-12	7.81E-12	Adult
Ba-140	6.2E+03	1.28E+01	Ba-140	4.60E-12	3.50E-13	5.00E-12	2.85E-08	2.17E-09	3.10E-08	Adult
Ce-141	4.5E+04	3.25E+01	Ce-141	1.60E-12	1.60E-13	1.70E-12	7.20E-08	7.20E-09	7.65E-08	Adult
Ce-144	2.4E+05	2.84E+02	Ce-144	1.40E-11	1.30E-12	1.50E-11	3.36E-06	3.12E-07	3.60E-06	Adult
Cm-242	2.1E+00	1.63E+02	Cm-242	3.90E-15	2.90E-12	2.90E-12	8.19E-15	6.09E-12	6.09E-12	Adult
Cm-243	4.9E-03	1.04E+04	Cm-243	2.60E-10	3.40E-11	3.00E-10	1.27E-12	1.67E-13	1.47E-12	Adult
Cm-244	4.5E-01	6.61E+03	Cm-244	4.00E-14	2.70E-11	2.70E-11	1.80E-14	1.22E-11	1.22E-11	Adult
Co-58	8.2E+04	7.08E+01	Co-58	5.40E-11	1.50E-11	6.90E-11	4.43E-06	1.23E-06	5.66E-06	Adult
Co-60	8.2E+05	1.92E+03	Co-60	2.70E-09	7.50E-11	2.80E-09	2.21E-03	6.15E-05	2.30E-03	Adult
Cr-51	3.7E+04	2.77E+01	Cr-51	3.70E-13	2.30E-13	6.00E-13	1.37E-08	8.51E-09	2.22E-08	Adult
Cs-134	5.7E+03	7.53E+02	Cs-134	8.40E-11	4.00E-11	1.20E-10	4.79E-07	2.28E-07	6.84E-07	Adult
Cs-137	6.6E+03	1.10E+04	Cs-137	1.20E-10	2.80E-11	1.50E-10	7.92E-07	1.85E-07	9.90E-07	Adult
Fe-55	9.4E+06	9.86E+02	Fe-55	0.00E+00	3.00E-13	3.00E-13	0.00E+00	2.82E-06	2.82E-06	Adult
Fe-59	2.1E+04	4.46E+01	Fe-59	4.70E-11	1.50E-12	4.90E-11	9.87E-07	3.15E-08	1.03E-06	Adult
H-3	7.6E+11	4.48E+03	H-3	0.00E+00	8.90E-16	8.90E-16	0.00E+00	6.76E-04	6.76E-04	Offspring
I-131	6.0E+04	8.04E+00	I-131	2.50E-15	2.50E-12	2.50E-12	1.50E-10	1.50E-07	1.50E-07	Adult
La-140	7.0E+03	1.68E+00	La-140	1.30E-12	1.80E-13	1.50E-12	9.10E-09	1.26E-09	1.05E-08	Adult
Mn-54	4.0E+05	3.13E+02	Mn-54	2.20E-10	5.00E-12	2.30E-10	8.80E-05	2.00E-06	9.20E-05	Adult
Nb-95	1.8E+05	3.51E+01	Nb-95	2.20E-11	2.00E-13	2.20E-11	3.96E-06	3.60E-08	3.96E-06	Adult
Ni-63	8.6E+05	3.66E+04	Ni-63	0.00E+00	3.60E-12	3.60E-12	0.00E+00	3.10E-06	3.10E-06	Adult
Pu-238	3.6E+00	3.20E+04	Pu-238	5.00E-14	1.60E-09	1.60E-09	1.80E-13	5.76E-09	5.76E-09	Adult
Pu-239	5.7E-01	8.81E+06	Pu-239	1.20E-13	1.70E-09	1.70E-09	6.84E-14	9.69E-10	9.69E-10	Adult
Pu-240	9.0E-01	2.40E+06	Pu-240	5.30E-14	1.70E-09	1.70E-09	4.77E-14	1.53E-09	1.53E-09	Adult
Ru-103	2.7E+04	3.93E+01	Ru-103	7.60E-12	1.20E-12	8.80E-12	2.05E-07	3.24E-08	2.38E-07	Adult
Ru-106	1.9E+04	3.68E+02	Ru-106	3.50E-11	1.30E-11	4.80E-11	6.65E-07	2.47E-07	9.12E-07	Adult
Sb-122	1.2E+02	2.70E+00	Cs-137	1.20E-10	2.80E-11	1.50E-10	1.44E-08	3.36E-09	1.80E-08	Adult
Sb-124	5.3E+04	6.02E+01	Cs-137	1.20E-10	2.80E-11	1.50E-10	6.36E-06	1.48E-06	7.95E-06	Adult
Sb-125	8.2E+04	1.01E+03	Sb-125	1.50E-11	1.50E-11	2.90E-11	1.23E-06	1.23E-06	2.38E-06	Adult
Sr-89	9.0E+03	5.05E+01	Sr-89	4.00E-17	1.50E-12	1.50E-12	3.60E-13	1.35E-08	1.35E-08	Offspring
Sr-90	4.5E+03	1.04E+04	Sr-90	1.00E-15	6.10E-12	6.10E-12	4.50E-12	2.75E-08	2.75E-08	Offspring
Te-123m	6.2E+01	1.20E+02	Cs-137	1.20E-10	2.80E-11	1.50E-10	7.44E-09	1.74E-09	9.30E-09	Adult
Zn-65	1.1E+05	2.44E+02	Zn-65	8.00E-11	3.30E-09	3.40E-09	8.80E-06	3.63E-04	3.74E-04	Adult
Zr-95	8.2E+04	6.40E+01	Zr-95	8.60E-11	6.50E-13	8.70E-11	7.05E-06	5.33E-08	7.13E-06	Adult
						Total	**2.34E-03**	**1.11E-03**	**3.48E-03**	

Table A.2: IRAT Stage 2 Assessment for Liquid Discharges at the Proposed Annual Discharge Limit

				DPUR				Annual dose (µSv/y)			
Radio-nuclide	**Bq/y**	**$T_{1/2}$ day**	**DPUR Isotope**	**External Irradiation**	**Seafood Consumption**	**Total**	**Scaling Factor**	**External Irradiation**	**Seafood Consumption**	**Total**	**Age Group**
Ag-110m	5.7E+00	2.50E+02	Ag-110m	1.20E-10	3.90E-09	4.00E-09	7.7E-02	5.27E-11	1.71E-09	1.76E-09	Adult
Am-241	1.1E-01	1.58E+05	Am-241	2.50E-11	4.60E-11	7.10E-11	7.7E-02	2.12E-13	3.90E-13	6.01E-13	Adult
Ba-140	6.2E+03	1.28E+01	Ba-140	4.60E-12	3.50E-13	5.00E-12	7.7E-02	2.20E-09	1.67E-10	2.39E-09	Adult
Ce-141	4.5E+04	3.25E+01	Ce-141	1.60E-12	1.60E-13	1.70E-12	7.7E-02	5.54E-09	5.54E-10	5.89E-09	Adult
Ce-144	2.4E+05	2.84E+02	Ce-144	1.40E-11	1.30E-12	1.50E-11	7.7E-02	2.59E-07	2.40E-08	2.77E-07	Adult
Cm-242	2.1E+00	1.63E+02	Cm-242	3.90E-15	2.90E-12	2.90E-12	7.7E-02	6.31E-16	4.69E-13	4.69E-13	Adult
Cm-243	4.9E-03	1.04E+04	Cm-243	2.60E-10	3.40E-11	3.00E-10	7.7E-02	9.81E-14	1.28E-14	1.13E-13	Adult
Cm-244	4.5E-01	6.61E+03	Cm-244	4.00E-14	2.70E-11	2.70E-11	7.7E-02	1.39E-15	9.36E-13	9.36E-13	Adult
Co-58	8.2E+04	7.08E+01	Co-58	5.40E-11	1.50E-11	6.90E-11	7.7E-02	3.41E-07	9.47E-08	4.36E-07	Adult
Co-60	8.2E+05	1.92E+03	Co-60	2.70E-09	7.50E-11	2.80E-09	7.7E-02	1.70E-04	4.74E-06	1.77E-04	Adult
Cr-51	3.7E+04	2.77E+01	Cr-51	3.70E-13	2.30E-13	6.00E-13	7.7E-02	1.05E-09	6.55E-10	1.71E-09	Adult
Cs-134	5.7E+03	7.53E+02	Cs-134	8.40E-11	4.00E-11	1.20E-10	7.7E-02	3.69E-08	1.76E-08	5.27E-08	Adult
Cs-137	6.6E+03	1.10E+04	Cs-137	1.20E-10	2.80E-11	1.50E-10	7.7E-02	6.10E-08	1.42E-08	7.62E-08	Adult
Fe-55	9.4E+06	9.86E+02	Fe-55	0.00E+00	3.00E-13	3.00E-13	7.7E-02	0.00E+00	2.17E-07	2.17E-07	Adult
Fe-59	2.1E+04	4.46E+01	Fe-59	4.70E-11	1.50E-12	4.90E-11	7.7E-02	7.60E-08	2.43E-09	7.92E-08	Adult
H-3	7.6E+11	4.48E+03	H-3	0.00E+00	8.90E-16	8.90E-16	7.7E-02	0.00E+00	5.21E-05	5.21E-05	Offspring
I-131	6.0E+04	8.04E+00	I-131	2.50E-15	2.50E-12	2.50E-12	7.7E-02	1.16E-11	1.16E-08	1.16E-08	Adult
La-140	7.0E+03	1.68E+00	La-140	1.30E-12	1.80E-13	1.50E-12	7.7E-02	7.01E-10	9.70E-11	8.09E-10	Adult
Mn-54	4.0E+05	3.13E+02	Mn-54	2.20E-10	5.00E-12	2.30E-10	7.7E-02	6.78E-06	1.54E-07	7.08E-06	Adult
Nb-95	1.8E+05	3.51E+01	Nb-95	2.20E-11	2.00E-13	2.20E-11	7.7E-02	3.05E-07	2.77E-09	3.05E-07	Adult
Ni-63	8.6E+05	3.66E+04	Ni-63	0.00E+00	3.60E-12	3.60E-12	7.7E-02	0.00E+00	2.38E-07	2.38E-07	Adult
Pu-238	3.6E+00	3.20E+04	Pu-238	5.00E-14	1.60E-09	1.60E-09	7.7E-02	1.39E-14	4.44E-10	4.44E-10	Adult
Pu-239	5.7E-01	8.81E+06	Pu-239	1.20E-13	1.70E-09	1.70E-09	7.7E-02	5.27E-15	7.46E-11	7.46E-11	Adult
Pu-240	9.0E-01	2.40E+06	Pu-240	5.30E-14	1.70E-09	1.70E-09	7.7E-02	3.67E-15	1.18E-10	1.18E-10	Adult
Ru-103	2.7E+04	3.93E+01	Ru-103	7.60E-12	1.20E-12	8.80E-12	7.7E-02	1.58E-08	2.49E-09	1.83E-08	Adult
Ru-106	1.9E+04	3.68E+02	Ru-106	3.50E-11	1.30E-11	4.80E-11	7.7E-02	5.12E-08	1.90E-08	7.02E-08	Adult
Sb-122	1.2E+02	2.70E+00	Cs-137	1.20E-10	2.80E-11	1.50E-10	7.7E-02	1.11E-09	2.59E-10	1.39E-09	Adult
Sb-124	5.3E+04	6.02E+01	Cs-137	1.20E-10	2.80E-11	1.50E-10	7.7E-02	4.90E-07	1.14E-07	6.12E-07	Adult
Sb-125	8.2E+04	1.01E+03	Sb-125	1.50E-11	1.50E-11	2.90E-11	7.7E-02	9.47E-08	9.47E-08	1.83E-07	Adult
Sr-89	9.0E+03	5.05E+01	Sr-89	4.00E-17	1.50E-12	1.50E-12	7.7E-02	2.77E-14	1.04E-09	1.04E-09	Offspring
Sr-90	4.5E+03	1.04E+04	Sr-90	1.00E-15	6.10E-12	6.10E-12	7.7E-02	3.47E-13	2.11E-09	2.11E-09	Offspring
Te-123m	6.2E+01	1.20E+02	Cs-137	1.20E-10	2.80E-11	1.50E-10	7.7E-02	5.73E-10	1.34E-10	7.16E-10	Adult
Zn-65	1.1E+05	2.44E+02	Zn-65	8.00E-11	3.30E-09	3.40E-09	7.7E-02	6.78E-07	2.80E-05	2.88E-05	Adult
Zr-95	8.2E+04	6.40E+01	Zr-95	8.60E-11	6.50E-13	8.70E-11	7.7E-02	5.43E-07	4.10E-09	5.49E-07	Adult
							Total	**1.80E-04**	**8.58E-05**	**2.68E-04**	

Table A.3: Stage 3 Assessment (μSv/y) for an Adult (High Consumption Rate) due to Liquid Discharges

	Annual dose (μSv/y)									
Radionuclide	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**External beta from beaches**	**External beta from fishing equipment**	**External gamma from beaches**	**External gamma from fishing equipment**	**Sea spray inhalation**	**Total**
Ag-110m	3.77E-11	9.59E-12	7.50E-11	1.73E-12	1.13E-13	1.12E-14	7.70E-12	7.70E-14	1.25E-17	1.32E-10
Am-241	1.19E-13	6.08E-14	4.75E-12	2.20E-13	7.13E-18	1.06E-14	4.49E-13	4.49E-15	3.04E-15	5.62E-12
Np-237 (Am-241)	6.46E-19	1.85E-19	2.59E-18	3.73E-20	2.25E-19	1.29E-19	1.21E-17	1.21E-19	9.74E-21	1.60E-17
Ba-140	3.68E-12	9.21E-11	7.35E-11	4.23E-11	5.00E-12	1.22E-12	7.38E-11	7.38E-13	4.60E-15	2.92E-10
La-140 (Ba-140)	1.01E-10	2.56E-11	1.01E-10	5.85E-11	2.85E-11	2.00E-12	2.69E-09	2.69E-11	7.10E-16	3.04E-09
Ce-141	2.28E-10	2.86E-11	4.56E-10	1.31E-10	4.35E-10	1.51E-10	6.99E-09	6.99E-11	1.31E-14	8.49E-09
Ce-144	1.02E-08	1.29E-09	2.04E-08	5.88E-09	1.76E-07	1.83E-08	2.30E-07	2.30E-09	9.01E-13	4.65E-07
Cm-242	1.01E-13	2.54E-14	6.05E-12	1.85E-13	2.74E-18	0.00E+00	4.15E-14	4.15E-16	5.29E-15	6.41E-12
Pu-238 (Cm-242)	1.91E-14	2.51E-14	2.87E-13	2.20E-14	1.57E-19	0.00E+00	3.49E-17	3.49E-19	2.73E-16	3.53E-13
Cm-243	3.79E-15	9.62E-16	2.28E-13	6.97E-15	1.52E-15	1.00E-15	1.02E-13	1.02E-15	9.48E-17	3.45E-13
Pu-239 (Cm-243)	2.50E-18	3.42E-18	3.75E-17	2.87E-18	8.25E-23	0.00E+00	1.11E-20	1.11E-22	3.56E-20	4.63E-17
Cm-244	2.72E-13	6.90E-14	1.63E-11	4.99E-13	0.00E+00	0.00E+00	1.17E-14	1.17E-16	7.44E-15	1.72E-11
Pu-240 (Cm-244)	7.54E-16	1.02E-15	1.13E-14	8.67E-16	1.80E-21	0.00E+00	1.12E-16	1.12E-18	1.07E-17	1.41E-14
Co-58	3.99E-08	1.01E-08	2.00E-08	4.59E-09	3.71E-10	1.09E-10	3.24E-07	3.24E-09	1.57E-14	4.02E-07
Co-60	2.20E-06	5.57E-07	1.10E-06	2.53E-07	1.11E-07	5.31E-08	1.42E-04	1.42E-06	1.18E-12	1.48E-04
Cr-51	1.10E-10	1.10E-10	1.75E-10	5.04E-11	8.58E-14	0.00E+00	1.16E-09	1.16E-11	1.94E-16	1.61E-09
Cs-134	1.51E-09	1.29E-08	1.51E-09	2.89E-10	1.25E-10	3.10E-11	3.05E-08	3.05E-10	1.09E-14	4.72E-08
Cs-137	1.24E-09	1.07E-08	1.24E-09	2.39E-10	7.15E-10	1.75E-10	4.29E-08	4.29E-10	9.13E-15	5.77E-08
Fe-55	3.23E-06	8.20E-07	1.94E-05	2.23E-06	0.00E+00	0.00E+00	4.90E-07	4.90E-09	6.76E-13	2.62E-05
Fe-59	3.21E-08	8.09E-09	1.93E-07	2.22E-08	1.10E-10	6.86E-11	4.28E-08	4.28E-10	1.20E-14	2.99E-07
H-3	7.09E-06	1.84E-05	7.09E-06	8.15E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.44E-09	3.34E-05
I-131	2.57E-09	6.43E-09	2.57E-09	2.95E-08	1.98E-13	5.10E-14	1.06E-11	1.06E-13	5.23E-14	4.11E-08
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-13	4.30E-14	6.19E-13	6.19E-15	0.00E+00	7.73E-13
La-140	3.16E-11	7.92E-12	3.16E-11	1.83E-11	5.85E-12	4.11E-13	5.53E-10	5.53E-12	2.22E-16	6.55E-10
Mn-54	1.01E-08	2.05E-08	1.01E-06	1.40E-08	6.60E-11	0.00E+00	5.79E-06	5.79E-08	7.78E-14	6.91E-06
Nb-95	5.68E-10	2.14E-10	2.84E-09	9.80E-10	4.51E-11	1.63E-10	2.91E-07	2.91E-09	2.67E-14	2.99E-07
Ni-63	1.97E-08	5.04E-08	3.95E-08	4.54E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.66E-14	1.14E-07

	Annual dose (µSv/y)									
Radionuclide	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**External beta from beaches**	**External beta from fishing equipment**	**External gamma from beaches**	**External gamma from fishing equipment**	**Sea spray inhalation**	**Total**
Pu-238	2.53E-11	3.23E-11	3.79E-10	2.91E-11	4.33E-17	0.00E+00	9.63E-15	9.63E-17	3.61E-13	4.66E-10
U-234 (Pu-238)	5.89E-18	1.75E-18	1.77E-17	6.78E-18	5.24E-21	0.00E+00	1.70E-17	1.70E-19	3.04E-19	4.96E-17
Pu-239	4.42E-12	5.66E-12	6.64E-11	5.08E-12	3.04E-17	0.00E+00	4.10E-15	4.10E-17	6.30E-14	8.16E-11
U-235 (Pu-239)	3.40E-22	1.02E-22	1.02E-21	3.91E-22	7.84E-22	1.19E-21	1.05E-19	1.05E-21	1.61E-23	1.10E-19
Pu-240	6.97E-12	8.93E-12	1.05E-10	8.02E-12	3.46E-18	0.00E+00	2.16E-13	2.16E-15	9.94E-14	1.29E-10
U-236 (Pu-240)	1.61E-20	4.83E-21	4.83E-20	1.85E-20	1.87E-24	0.00E+00	4.33E-20	4.33E-22	7.88E-22	1.32E-19
Ru-103	7.41E-10	3.74E-11	1.49E-08	1.71E-09	7.72E-13	6.61E-13	2.86E-10	2.86E-12	2.13E-13	1.76E-08
Ru-106	6.52E-09	3.33E-10	1.30E-07	1.50E-08	1.79E-10	1.99E-11	8.76E-10	8.76E-12	2.26E-12	1.53E-07
Sb-122	4.41E-13	1.78E-11	3.54E-13	4.07E-14	3.30E-15	2.40E-16	5.82E-14	5.82E-16	6.37E-18	1.87E-11
Sb-124	1.34E-09	5.41E-08	1.07E-09	1.23E-10	8.84E-11	7.28E-12	1.06E-08	1.06E-10	8.43E-14	6.75E-08
Sb-125	1.11E-09	4.59E-08	8.91E-10	1.02E-10	2.90E-10	1.20E-10	5.37E-08	5.37E-10	1.19E-13	1.03E-07
Te-125m (Sb-125)	6.96E-09	1.95E-08	6.96E-09	8.01E-09	1.40E-12	1.29E-10	4.37E-09	4.37E-11	1.67E-14	4.60E-08
Sr-89	1.84E-11	4.62E-11	9.17E-12	5.27E-12	2.14E-11	1.53E-12	6.89E-14	6.89E-16	1.32E-14	1.02E-10
Sr-90	1.27E-10	3.31E-10	6.38E-11	3.68E-11	7.11E-10	6.16E-11	2.86E-14	2.86E-16	5.03E-14	1.33E-09
Te-123m	3.85E-11	9.76E-11	3.85E-11	4.43E-11	5.83E-15	1.39E-14	2.15E-12	2.15E-14	6.76E-17	2.21E-10
Te-123 (Te-123m)	5.67E-25	1.73E-24	5.67E-25	6.52E-25	0.00E+00	0.00E+00	1.70E-25	1.70E-27	1.50E-31	3.69E-24
Zn-65	6.53E-06	3.31E-07	3.92E-06	3.00E-08	3.89E-11	0.00E+00	3.83E-07	3.83E-09	3.91E-14	1.12E-05
Zr-95	2.32E-10	5.84E-11	5.81E-09	4.01E-10	1.02E-09	3.81E-10	2.52E-07	2.52E-09	3.92E-14	2.62E-07
Nb-95 (Zr-95)	3.25E-11	1.25E-11	1.63E-10	5.61E-11	4.23E-11	1.53E-10	2.73E-07	2.73E-09	1.54E-15	2.77E-07
Total	**1.92E-05**	**2.03E-05**	**3.30E-05**	**3.44E-06**	**2.91E-07**	**7.30E-08**	**1.51E-04**	**1.51E-06**	**6.45E-09**	**2.29E-04**

Table A.4: Stage 3 Assessment (µSv/y) for a Child (High Consumption Rate) due to Liquid Discharges

	Annual dose (µSv/y)									
Radionuclide	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**External beta from beaches**	**External beta from fishing equipment**	**External gamma from beaches**	**External gamma from fishing equipment**	**Sea spray inhalation**	**Total**
Ag-110m	1.75E-11	3.56E-12	3.48E-11	6.98E-13	1.69E-14	0.00E+00	1.15E-12	0.00E+00	1.02E-18	5.78E-11
Am-241	3.28E-14	1.34E-14	1.31E-12	5.25E-14	1.07E-18	0.00E+00	6.74E-14	0.00E+00	1.50E-16	1.47E-12
Np-237 (Am-241)	1.61E-19	3.70E-20	6.47E-19	8.11E-21	3.38E-20	0.00E+00	1.81E-18	0.00E+00	4.83E-22	2.70E-18
Ba-140	2.05E-12	4.11E-11	4.10E-11	2.05E-11	7.51E-13	0.00E+00	1.11E-11	0.00E+00	3.55E-16	1.16E-10
La-140 (Ba-140)	5.32E-11	1.08E-11	5.32E-11	2.67E-11	4.28E-12	0.00E+00	4.04E-10	0.00E+00	6.70E-17	5.52E-10
Ce-141	1.20E-10	1.21E-11	2.41E-10	6.01E-11	6.53E-11	0.00E+00	1.05E-09	0.00E+00	9.75E-16	1.55E-09
Ce-144	5.40E-09	5.46E-10	1.08E-08	2.71E-09	2.64E-08	0.00E+00	3.45E-08	0.00E+00	7.14E-14	8.04E-08
Cm-242	5.04E-14	1.02E-14	3.02E-12	8.06E-14	4.11E-19	0.00E+00	6.23E-15	0.00E+00	3.85E-16	3.17E-12
Pu-238 (Cm-242)	4.99E-15	5.23E-15	7.48E-14	4.99E-15	2.36E-20	0.00E+00	5.24E-18	0.00E+00	1.35E-17	9.01E-14
Cm-243	1.01E-15	2.05E-16	6.08E-14	1.62E-15	2.28E-16	0.00E+00	1.52E-14	0.00E+00	4.91E-18	7.91E-14
Pu-239 (Cm-243)	6.75E-19	7.38E-19	1.01E-17	6.75E-19	1.24E-23	0.00E+00	1.67E-21	0.00E+00	1.77E-21	1.22E-17
Cm-244	7.94E-14	1.61E-14	4.76E-12	1.27E-13	0.00E+00	0.00E+00	1.75E-15	0.00E+00	3.86E-16	4.98E-12
Pu-240 (Cm-244)	2.04E-16	2.21E-16	3.05E-15	2.04E-16	2.71E-22	0.00E+00	1.69E-17	0.00E+00	5.35E-19	3.70E-15
Co-58	2.29E-08	4.62E-09	1.15E-08	2.29E-09	5.57E-11	0.00E+00	4.86E-08	0.00E+00	1.22E-15	9.00E-08
Co-60	1.78E-06	3.61E-07	8.93E-07	1.78E-07	1.66E-08	0.00E+00	2.14E-05	0.00E+00	9.20E-14	2.46E-05
Cr-51	5.63E-11	4.53E-11	9.00E-11	2.25E-11	1.29E-14	0.00E+00	1.73E-10	0.00E+00	1.80E-17	3.88E-10
Cs-134	2.78E-10	1.90E-09	2.78E-10	4.63E-11	1.88E-11	0.00E+00	4.58E-09	0.00E+00	4.54E-16	7.10E-09
Cs-137	2.39E-10	1.65E-09	2.39E-10	3.99E-11	1.07E-10	0.00E+00	6.44E-09	0.00E+00	3.81E-16	8.71E-09
Fe-55	2.69E-06	5.47E-07	1.62E-05	1.62E-06	0.00E+00	0.00E+00	7.34E-08	0.00E+00	5.72E-14	2.11E-05
Fe-59	2.10E-08	4.22E-09	1.26E-07	1.26E-08	1.65E-11	0.00E+00	6.42E-09	0.00E+00	9.22E-16	1.70E-07
H-3	2.26E-06	4.69E-06	2.26E-06	2.26E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.27E-10	9.45E-06
I-131	1.52E-09	3.04E-09	1.52E-09	1.52E-08	2.97E-14	0.00E+00	1.59E-12	0.00E+00	6.97E-15	2.12E-08
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-14	0.00E+00	9.29E-14	0.00E+00	0.00E+00	1.09E-13
La-140	1.66E-11	3.33E-12	1.66E-11	8.33E-12	8.78E-13	0.00E+00	8.30E-11	0.00E+00	2.10E-17	1.29E-10
Mn-54	4.63E-09	7.51E-09	4.63E-07	5.56E-09	9.90E-12	0.00E+00	8.69E-07	0.00E+00	6.46E-15	1.35E-06
Nb-95	2.69E-10	8.13E-11	1.35E-09	4.04E-10	6.76E-12	0.00E+00	4.37E-08	0.00E+00	2.03E-15	4.58E-08
Ni-63	9.21E-09	1.88E-08	1.84E-08	1.84E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.79E-15	4.83E-08

	Annual dose (µSv/y)									
Radionuclide	Crustaceans	Fish	Molluscs	Seaweed	External beta from beaches	External beta from fishing equipment	External gamma from beaches	External gamma from fishing equipment	Sea spray inhalation	Total
Pu-238	6.61E-12	6.74E-12	9.89E-11	6.61E-12	6.50E-18	0.00E+00	1.45E-15	0.00E+00	1.79E-14	1.19E-10
U-234 (Pu-238)	2.22E-18	5.29E-19	6.69E-18	2.22E-18	7.86E-22	0.00E+00	2.54E-18	0.00E+00	2.16E-20	1.42E-17
Pu-239	1.19E-12	1.22E-12	1.79E-11	1.19E-12	4.57E-18	0.00E+00	6.15E-16	0.00E+00	3.13E-15	2.15E-11
U-235 (Pu-239)	1.28E-22	3.08E-23	3.84E-22	1.28E-22	1.18E-22	0.00E+00	1.57E-20	0.00E+00	1.16E-24	1.65E-20
Pu-240	1.88E-12	1.93E-12	2.83E-11	1.88E-12	5.20E-19	0.00E+00	3.24E-14	0.00E+00	4.95E-15	3.40E-11
U-236 (Pu-240)	5.98E-21	1.44E-21	1.80E-20	5.98E-21	2.80E-25	0.00E+00	6.49E-21	0.00E+00	5.75E-23	3.79E-20
Ru-103	3.81E-10	1.54E-11	7.63E-09	7.63E-10	1.16E-13	0.00E+00	4.29E-11	0.00E+00	1.61E-14	8.84E-09
Ru-106	3.49E-09	1.43E-10	6.98E-08	6.98E-09	2.68E-11	0.00E+00	1.31E-10	0.00E+00	1.72E-13	8.06E-08
Sb-122	2.40E-13	7.73E-12	1.93E-13	1.93E-14	4.95E-16	0.00E+00	8.73E-15	0.00E+00	5.95E-19	8.19E-12
Sb-124	6.97E-10	2.25E-08	5.58E-10	5.58E-11	1.33E-11	0.00E+00	1.59E-09	0.00E+00	6.56E-15	2.54E-08
Sb-125	5.32E-10	1.75E-08	4.25E-10	4.25E-11	4.34E-11	0.00E+00	8.05E-09	0.00E+00	8.76E-15	2.66E-08
Te-125m (Sb-125)	3.80E-09	8.51E-09	3.80E-09	3.80E-09	2.10E-13	0.00E+00	6.55E-10	0.00E+00	1.22E-15	2.06E-08
Sr-89	1.02E-11	2.06E-11	5.12E-12	2.55E-12	3.20E-12	0.00E+00	1.03E-14	0.00E+00	1.02E-15	4.17E-11
Sr-90	6.83E-11	1.42E-10	3.41E-11	1.71E-11	1.07E-10	0.00E+00	4.29E-15	0.00E+00	3.69E-15	3.68E-10
Te-123m	1.93E-11	3.90E-11	1.93E-11	1.93E-11	8.75E-16	0.00E+00	3.23E-13	0.00E+00	5.00E-18	9.72E-11
Te-123 (Te-123m)	1.74E-25	4.24E-25	1.74E-25	1.74E-25	0.00E+00	0.00E+00	2.55E-26	0.00E+00	9.41E-33	9.72E-25
Zn-65	2.68E-06	1.08E-07	1.61E-06	1.07E-08	5.84E-12	0.00E+00	5.75E-08	0.00E+00	3.04E-15	4.46E-06
Zr-95	1.16E-10	2.34E-11	2.91E-09	1.74E-10	1.53E-10	0.00E+00	3.78E-08	0.00E+00	2.88E-15	4.12E-08
Nb-95 (Zr-95)	1.54E-11	4.73E-12	7.71E-11	2.31E-11	6.34E-12	0.00E+00	4.10E-08	0.00E+00	1.17E-16	4.11E-08
Total	**9.49E-06**	**5.80E-06**	**2.17E-05**	**2.09E-06**	**4.36E-08**	**0.00E+00**	**2.26E-05**	**0.00E+00**	**4.27E-10**	**6.17E-05**

Table A.5: Stage 3 Assessment (μSv/y) for an Infant (High Consumption Rate) due to Liquid Discharges

	Annual dose (μSv/y)									
Radionuclide	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**External beta from beaches**	**External beta from fishing equipment**	**External gamma from beaches**	**External gamma from fishing equipment**	**Sea spray inhalation**	**Total**
Ag-110m	0.00E+00	2.40E-12	0.00E+00	0.00E+00	1.69E-15	0.00E+00	1.15E-13	0.00E+00	8.23E-20	2.52E-12
Am-241	0.00E+00	5.62E-15	0.00E+00	0.00E+00	1.07E-19	0.00E+00	6.74E-15	0.00E+00	8.93E-18	1.24E-14
Np-237 (Am-241)	0.00E+00	1.77E-20	0.00E+00	0.00E+00	3.38E-21	0.00E+00	1.81E-19	0.00E+00	3.03E-23	2.02E-19
Ba-140	0.00E+00	3.19E-11	0.00E+00	0.00E+00	7.51E-14	0.00E+00	1.11E-12	0.00E+00	3.22E-17	3.31E-11
La-140 (Ba-140)	0.00E+00	8.33E-12	0.00E+00	0.00E+00	4.27E-13	0.00E+00	4.04E-11	0.00E+00	7.27E-18	4.92E-11
Ce-141	0.00E+00	1.03E-11	0.00E+00	0.00E+00	6.53E-12	0.00E+00	1.05E-10	0.00E+00	8.03E-17	1.22E-10
Ce-144	0.00E+00	4.84E-10	0.00E+00	0.00E+00	2.64E-09	0.00E+00	3.45E-09	0.00E+00	7.16E-15	6.58E-09
Cm-242	0.00E+00	8.04E-15	0.00E+00	0.00E+00	4.11E-20	0.00E+00	6.23E-16	0.00E+00	3.27E-17	8.70E-15
Pu-238 (Cm-242)	0.00E+00	2.18E-15	0.00E+00	0.00E+00	2.36E-21	0.00E+00	5.24E-19	0.00E+00	7.84E-19	2.18E-15
Cm-243	0.00E+00	1.06E-16	0.00E+00	0.00E+00	2.28E-17	0.00E+00	1.52E-15	0.00E+00	3.33E-19	1.65E-15
Pu-239 (Cm-243)	0.00E+00	2.87E-19	0.00E+00	0.00E+00	1.24E-24	0.00E+00	1.67E-22	0.00E+00	9.80E-23	2.87E-19
Cm-244	0.00E+00	8.33E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-16	0.00E+00	2.81E-17	8.54E-15
Pu-240 (Cm-244)	0.00E+00	8.60E-17	0.00E+00	0.00E+00	2.71E-23	0.00E+00	1.69E-18	0.00E+00	2.96E-20	8.78E-17
Co-58	0.00E+00	2.99E-09	0.00E+00	0.00E+00	5.57E-12	0.00E+00	4.86E-09	0.00E+00	1.14E-16	7.85E-09
Co-60	0.00E+00	2.21E-07	0.00E+00	0.00E+00	1.66E-09	0.00E+00	2.14E-06	0.00E+00	7.19E-15	2.36E-06
Cr-51	0.00E+00	3.34E-11	0.00E+00	0.00E+00	1.29E-15	0.00E+00	1.73E-11	0.00E+00	1.97E-18	5.07E-11
Cs-134	0.00E+00	5.42E-10	0.00E+00	0.00E+00	1.88E-12	0.00E+00	4.58E-10	0.00E+00	2.16E-17	1.00E-09
Cs-137	0.00E+00	4.94E-10	0.00E+00	0.00E+00	1.07E-11	0.00E+00	6.44E-10	0.00E+00	1.92E-17	1.15E-09
Fe-55	0.00E+00	2.98E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.34E-09	0.00E+00	4.45E-15	3.06E-07
Fe-59	0.00E+00	2.92E-09	0.00E+00	0.00E+00	1.65E-12	0.00E+00	6.42E-10	0.00E+00	7.51E-17	3.56E-09
H-3	0.00E+00	2.45E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.07E-11	2.45E-06
I-131	0.00E+00	2.63E-09	0.00E+00	0.00E+00	2.97E-15	0.00E+00	1.59E-13	0.00E+00	9.10E-16	2.63E-09
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-15	0.00E+00	9.29E-15	0.00E+00	0.00E+00	1.09E-14
La-140	0.00E+00	2.57E-12	0.00E+00	0.00E+00	8.78E-14	0.00E+00	8.30E-12	0.00E+00	2.27E-18	1.10E-11
Mn-54	0.00E+00	4.48E-09	0.00E+00	0.00E+00	9.90E-13	0.00E+00	8.69E-08	0.00E+00	5.75E-16	9.14E-08
Nb-95	0.00E+00	5.91E-11	0.00E+00	0.00E+00	6.76E-13	0.00E+00	4.37E-09	0.00E+00	1.66E-16	4.43E-09
Ni-63	0.00E+00	1.41E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.42E-16	1.41E-08

Radionuclide	Annual dose (µSv/y)									
	Crustaceans	Fish	Molluscs	Seaweed	External beta from beaches	External beta from fishing equipment	External gamma from beaches	External gamma from fishing equipment	Sea spray inhalation	Total
Pu-238	0.00E+00	2.81E-12	0.00E+00	0.00E+00	6.50E-19	0.00E+00	1.45E-16	0.00E+00	1.04E-15	2.81E-12
U-234 (Pu-238)	0.00E+00	2.33E-19	0.00E+00	0.00E+00	7.86E-23	0.00E+00	2.54E-19	0.00E+00	1.70E-21	4.89E-19
Pu-239	0.00E+00	4.75E-13	0.00E+00	0.00E+00	4.57E-19	0.00E+00	6.15E-17	0.00E+00	1.73E-16	4.76E-13
U-235 (Pu-239)	0.00E+00	1.41E-23	0.00E+00	0.00E+00	1.18E-23	0.00E+00	1.57E-21	0.00E+00	9.29E-26	1.60E-21
Pu-240	0.00E+00	7.50E-13	0.00E+00	0.00E+00	5.19E-20	0.00E+00	3.24E-15	0.00E+00	2.74E-16	7.54E-13
U-236 (Pu-240)	0.00E+00	6.68E-22	0.00E+00	0.00E+00	2.80E-26	0.00E+00	6.49E-22	0.00E+00	4.40E-24	1.32E-21
Ru-103	0.00E+00	1.18E-11	0.00E+00	0.00E+00	1.16E-14	0.00E+00	4.29E-12	0.00E+00	1.33E-15	1.61E-11
Ru-106	0.00E+00	1.17E-10	0.00E+00	0.00E+00	2.68E-12	0.00E+00	1.31E-11	0.00E+00	1.59E-14	1.32E-10
Sb-122	0.00E+00	6.27E-12	0.00E+00	0.00E+00	4.95E-17	0.00E+00	8.73E-16	0.00E+00	6.49E-20	6.27E-12
Sb-124	0.00E+00	1.73E-08	0.00E+00	0.00E+00	1.33E-12	0.00E+00	1.59E-10	0.00E+00	5.65E-16	1.75E-08
Sb-125	0.00E+00	1.27E-08	0.00E+00	0.00E+00	4.34E-12	0.00E+00	8.05E-10	0.00E+00	7.11E-16	1.35E-08
Te-125m (Sb-125)	0.00E+00	7.06E-09	0.00E+00	0.00E+00	2.10E-14	0.00E+00	6.55E-11	0.00E+00	9.63E-17	7.12E-09
Sr-89	0.00E+00	1.60E-11	0.00E+00	0.00E+00	3.20E-13	0.00E+00	1.03E-15	0.00E+00	9.27E-17	1.63E-11
Sr-90	0.00E+00	4.31E-11	0.00E+00	0.00E+00	1.07E-11	0.00E+00	4.29E-16	0.00E+00	2.75E-16	5.38E-11
Te-123m	0.00E+00	3.07E-11	0.00E+00	0.00E+00	8.75E-17	0.00E+00	3.23E-14	0.00E+00	3.93E-19	3.07E-11
Te-123 (Te-123m)	0.00E+00	1.83E-25	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.55E-27	0.00E+00	6.21E-34	1.85E-25
Zn-65	0.00E+00	6.78E-08	0.00E+00	0.00E+00	5.84E-13	0.00E+00	5.75E-09	0.00E+00	2.84E-16	7.36E-08
Zr-95	0.00E+00	1.72E-11	0.00E+00	0.00E+00	1.53E-11	0.00E+00	3.78E-09	0.00E+00	2.33E-16	3.81E-09
Nb-95 (Zr-95)	0.00E+00	3.44E-12	0.00E+00	0.00E+00	6.34E-13	0.00E+00	4.10E-09	0.00E+00	9.52E-18	4.11E-09
Total	**0.00E+00**	**3.10E-06**	**0.00E+00**	**0.00E+00**	**4.36E-09**	**0.00E+00**	**2.26E-06**	**0.00E+00**	**3.07E-11**	**5.37E-06**

Table A.6: Stage 3 Assessment (μSv/y) for an Adult (Mean Consumption Rate) due to Liquid Discharges

	Annual dose (μSv/y)									
Radionuclide	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**External beta from beaches**	**External beta from fishing equipment**	**External gamma from beaches**	**External gamma from fishing equipment**	**Sea spray inhalation**	**Total**
Ag-110m	3.30E-12	1.44E-12	6.56E-12	6.01E-13	1.13E-13	1.12E-14	7.70E-12	7.70E-14	1.25E-17	1.98E-11
Am-241	1.04E-14	9.11E-15	4.16E-13	7.64E-14	7.13E-18	1.06E-14	4.49E-13	4.49E-15	3.04E-15	9.79E-13
Np-237 (Am-241)	5.65E-20	2.78E-20	2.27E-19	1.30E-20	2.25E-19	1.29E-19	1.21E-17	1.21E-19	9.74E-21	1.29E-17
Ba-140	3.22E-13	1.38E-11	6.43E-12	1.47E-11	5.00E-12	1.22E-12	7.38E-11	7.38E-13	4.60E-15	1.16E-10
La-140 (Ba-140)	8.88E-12	3.84E-12	8.88E-12	2.03E-11	2.85E-11	2.00E-12	2.69E-09	2.69E-11	7.10E-16	2.79E-09
Ce-141	2.00E-11	4.29E-12	3.99E-11	4.55E-11	4.35E-10	1.51E-10	6.99E-09	6.99E-11	1.31E-14	7.76E-09
Ce-144	8.93E-10	1.93E-10	1.79E-09	2.05E-09	1.76E-07	1.83E-08	2.30E-07	2.30E-09	9.01E-13	4.32E-07
Cm-242	8.82E-15	3.81E-15	5.29E-13	6.45E-14	2.74E-18	0.00E+00	4.15E-14	4.15E-16	5.29E-15	6.54E-13
Pu-238 (Cm-242)	1.67E-15	3.76E-15	2.51E-14	7.65E-15	1.57E-19	0.00E+00	3.49E-17	3.49E-19	2.73E-16	3.85E-14
Cm-243	3.32E-16	1.44E-16	1.99E-14	2.42E-15	1.52E-15	1.00E-15	1.02E-13	1.02E-15	9.48E-17	1.28E-13
Pu-239 (Cm-243)	2.19E-19	5.13E-19	3.28E-18	1.00E-18	8.25E-23	0.00E+00	1.11E-20	1.11E-22	3.56E-20	5.06E-18
Cm-244	2.38E-14	1.03E-14	1.43E-12	1.74E-13	0.00E+00	0.00E+00	1.17E-14	1.17E-16	7.44E-15	1.65E-12
Pu-240 (Cm-244)	6.60E-17	1.54E-16	9.88E-16	3.02E-16	1.80E-21	0.00E+00	1.12E-16	1.12E-18	1.07E-17	1.63E-15
Co-58	3.49E-09	1.51E-09	1.75E-09	1.60E-09	3.71E-10	1.09E-10	3.24E-07	3.24E-09	1.57E-14	3.36E-07
Co-60	1.93E-07	8.36E-08	9.66E-08	8.81E-08	1.11E-07	5.31E-08	1.42E-04	1.42E-06	1.18E-12	1.45E-04
Cr-51	9.60E-12	1.65E-11	1.54E-11	1.76E-11	8.58E-14	0.00E+00	1.16E-09	1.16E-11	1.94E-16	1.23E-09
Cs-134	1.32E-10	1.93E-09	1.32E-10	1.01E-10	1.25E-10	3.10E-11	3.05E-08	3.05E-10	1.09E-14	3.33E-08
Cs-137	1.09E-10	1.60E-09	1.09E-10	8.31E-11	7.15E-10	1.75E-10	4.29E-08	4.29E-10	9.13E-15	4.61E-08
Fe-55	2.83E-07	1.23E-07	1.70E-06	7.77E-07	0.00E+00	0.00E+00	4.90E-07	4.90E-09	6.76E-13	3.38E-06
Fe-59	2.81E-09	1.21E-09	1.69E-08	7.71E-09	1.10E-10	6.86E-11	4.28E-08	4.28E-10	1.20E-14	7.20E-08
H-3	6.20E-07	2.76E-06	6.20E-07	2.83E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.44E-09	4.29E-06
I-131	2.25E-10	9.64E-10	2.25E-10	1.03E-08	1.98E-13	5.10E-14	1.06E-11	1.06E-13	5.23E-14	1.17E-08
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-13	4.30E-14	6.19E-13	6.19E-15	0.00E+00	7.73E-13
La-140	2.77E-12	1.19E-12	2.77E-12	6.35E-12	5.85E-12	4.11E-13	5.53E-10	5.53E-12	2.22E-16	5.78E-10
Mn-54	8.85E-10	3.07E-09	8.85E-08	4.86E-09	6.60E-11	0.00E+00	5.79E-06	5.79E-08	7.78E-14	5.95E-06
Nb-95	4.97E-11	3.21E-11	2.49E-10	3.41E-10	4.51E-11	1.63E-10	2.91E-07	2.91E-09	2.67E-14	2.95E-07
Ni-63	1.73E-09	7.56E-09	3.45E-09	1.58E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.66E-14	1.43E-08

	Annual dose (µSv/y)									
Radionuclide	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**External beta from beaches**	**External beta from fishing equipment**	**External gamma from beaches**	**External gamma from fishing equipment**	**Sea spray inhalation**	**Total**
Pu-238	2.22E-12	4.85E-12	3.32E-11	1.01E-11	4.33E-17	0.00E+00	9.63E-15	9.63E-17	3.61E-13	5.07E-11
U-234 (Pu-238)	5.15E-19	2.63E-19	1.55E-18	2.36E-18	5.24E-21	0.00E+00	1.70E-17	1.70E-19	3.04E-19	2.21E-17
Pu-239	3.87E-13	8.49E-13	5.81E-12	1.77E-12	3.04E-17	0.00E+00	4.10E-15	4.10E-17	6.30E-14	8.88E-12
U-235 (Pu-239)	2.97E-23	1.53E-23	8.91E-23	1.36E-22	7.84E-22	1.19E-21	1.05E-19	1.05E-21	1.61E-23	1.08E-19
Pu-240	6.10E-13	1.34E-12	9.17E-12	2.79E-12	3.46E-18	0.00E+00	2.16E-13	2.16E-15	9.94E-14	1.42E-11
U-236 (Pu-240)	1.41E-21	7.24E-22	4.23E-21	6.43E-21	1.87E-24	0.00E+00	4.33E-20	4.33E-22	7.88E-22	5.73E-20
Ru-103	6.49E-11	5.61E-12	1.30E-09	5.94E-10	7.72E-13	6.61E-13	2.86E-10	2.86E-12	2.13E-13	2.26E-09
Ru-106	5.70E-10	5.00E-11	1.14E-08	5.21E-09	1.79E-10	1.99E-11	8.76E-10	8.76E-12	2.26E-12	1.83E-08
Sb-122	3.86E-14	2.66E-12	3.10E-14	1.42E-14	3.30E-15	2.40E-16	5.82E-14	5.82E-16	6.37E-18	2.81E-12
Sb-124	1.17E-10	8.12E-09	9.39E-11	4.29E-11	8.84E-11	7.28E-12	1.06E-08	1.06E-10	8.43E-14	1.92E-08
Sb-125	9.76E-11	6.88E-09	7.80E-11	3.57E-11	2.90E-10	1.20E-10	5.37E-08	5.37E-10	1.19E-13	6.17E-08
Te-125m (Sb-125)	6.09E-10	2.92E-09	6.09E-10	2.79E-09	1.40E-12	1.29E-10	4.37E-09	4.37E-11	1.67E-14	1.15E-08
Sr-89	1.60E-12	6.93E-12	8.03E-13	1.83E-12	2.14E-11	1.53E-12	6.89E-14	6.89E-16	1.32E-14	3.41E-11
Sr-90	1.12E-11	4.96E-11	5.58E-12	1.28E-11	7.11E-10	6.16E-11	2.86E-14	2.86E-16	5.03E-14	8.52E-10
Te-123m	3.37E-12	1.46E-11	3.37E-12	1.54E-11	5.83E-15	1.39E-14	2.15E-12	2.15E-14	6.76E-17	3.90E-11
Te-123 (Te-123m)	4.96E-26	2.59E-25	4.96E-26	2.27E-25	0.00E+00	0.00E+00	1.70E-25	1.70E-27	1.50E-31	7.57E-25
Zn-65	5.71E-07	4.96E-08	3.43E-07	1.04E-08	3.89E-11	0.00E+00	3.83E-07	3.83E-09	3.91E-14	1.36E-06
Zr-95	2.03E-11	8.77E-12	5.08E-10	1.40E-10	1.02E-09	3.81E-10	2.52E-07	2.52E-09	3.92E-14	2.56E-07
Nb-95 (Zr-95)	2.85E-12	1.87E-12	1.42E-11	1.95E-11	4.23E-11	1.53E-10	2.73E-07	2.73E-09	1.54E-15	2.76E-07
Total	**1.68E-06**	**3.05E-06**	**2.89E-06**	**1.20E-06**	**2.91E-07**	**7.30E-08**	**1.51E-04**	**1.51E-06**	**6.45E-09**	**1.61E-04**

Table A.7: Stage 3 Assessment (µSv/y) for a Child (Mean Consumption Rate) due to Liquid Discharges

	Annual dose (µSv/y)									
Radionuclide	Crustaceans	Fish	Molluscs	Seaweed	External beta from beaches	External beta from fishing equipment	External gamma from beaches	External gamma from fishing equipment	Sea spray inhalation	Total
Ag-110m	4.37E-12	1.07E-12	8.71E-12	0.00E+00	1.69E-14	0.00E+00	1.15E-12	0.00E+00	1.02E-18	1.53E-11
Am-241	8.20E-15	4.01E-15	3.27E-13	0.00E+00	1.07E-18	0.00E+00	6.74E-14	0.00E+00	1.50E-16	4.06E-13
Np-237 (Am-241)	4.04E-20	1.11E-20	1.62E-19	0.00E+00	3.38E-20	0.00E+00	1.81E-18	0.00E+00	4.83E-22	2.06E-18
Ba-140	5.12E-13	1.23E-11	1.03E-11	0.00E+00	7.51E-13	0.00E+00	1.11E-11	0.00E+00	3.55E-16	3.49E-11
La-140 (Ba-140)	1.33E-11	3.23E-12	1.33E-11	0.00E+00	4.28E-12	0.00E+00	4.04E-10	0.00E+00	6.70E-17	4.38E-10
Ce-141	3.01E-11	3.63E-12	6.02E-11	0.00E+00	6.53E-11	0.00E+00	1.05E-09	0.00E+00	9.75E-16	1.21E-09
Ce-144	1.35E-09	1.64E-10	2.70E-09	0.00E+00	2.64E-08	0.00E+00	3.45E-08	0.00E+00	7.14E-14	6.52E-08
Cm-242	1.26E-14	3.05E-15	7.56E-13	0.00E+00	4.11E-19	0.00E+00	6.23E-15	0.00E+00	3.85E-16	7.78E-13
Pu-238 (Cm-242)	1.25E-15	1.57E-15	1.87E-14	0.00E+00	2.36E-20	0.00E+00	5.24E-18	0.00E+00	1.35E-17	2.15E-14
Cm-243	2.53E-16	6.16E-17	1.52E-14	0.00E+00	2.28E-16	0.00E+00	1.52E-14	0.00E+00	4.91E-18	3.10E-14
Pu-239 (Cm-243)	1.69E-19	2.21E-19	2.53E-18	0.00E+00	1.24E-23	0.00E+00	1.67E-21	0.00E+00	1.77E-21	2.92E-18
Cm-244	1.98E-14	4.83E-15	1.19E-12	0.00E+00	0.00E+00	0.00E+00	1.75E-15	0.00E+00	3.86E-16	1.22E-12
Pu-240 (Cm-244)	5.09E-17	6.64E-17	7.62E-16	0.00E+00	2.71E-22	0.00E+00	1.69E-17	0.00E+00	5.35E-19	8.97E-16
Co-58	5.73E-09	1.39E-09	2.88E-09	0.00E+00	5.57E-11	0.00E+00	4.86E-08	0.00E+00	1.22E-15	5.86E-08
Co-60	4.45E-07	1.08E-07	2.23E-07	0.00E+00	1.66E-08	0.00E+00	2.14E-05	0.00E+00	9.20E-14	2.22E-05
Cr-51	1.41E-11	1.36E-11	2.25E-11	0.00E+00	1.29E-14	0.00E+00	1.73E-10	0.00E+00	1.80E-17	2.24E-10
Cs-134	6.94E-11	5.70E-10	6.94E-11	0.00E+00	1.88E-11	0.00E+00	4.58E-09	0.00E+00	4.54E-16	5.31E-09
Cs-137	5.96E-11	4.94E-10	5.96E-11	0.00E+00	1.07E-10	0.00E+00	6.44E-09	0.00E+00	3.81E-16	7.16E-09
Fe-55	6.73E-07	1.64E-07	4.05E-06	0.00E+00	0.00E+00	0.00E+00	7.34E-08	0.00E+00	5.72E-14	4.96E-06
Fe-59	5.24E-09	1.27E-09	3.15E-08	0.00E+00	1.65E-11	0.00E+00	6.42E-09	0.00E+00	9.22E-16	4.44E-08
H-3	5.66E-07	1.41E-06	5.66E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.27E-10	2.54E-06
I-131	3.79E-10	9.11E-10	3.79E-10	0.00E+00	2.97E-14	0.00E+00	1.59E-12	0.00E+00	6.97E-15	1.67E-09
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-14	0.00E+00	9.29E-14	0.00E+00	0.00E+00	1.09E-13
La-140	4.15E-12	9.98E-13	4.15E-12	0.00E+00	8.78E-13	0.00E+00	8.30E-11	0.00E+00	2.10E-17	9.32E-11
Mn-54	1.16E-09	2.25E-09	1.16E-07	0.00E+00	9.90E-12	0.00E+00	8.69E-07	0.00E+00	6.46E-15	9.88E-07
Nb-95	6.73E-11	2.44E-11	3.37E-10	0.00E+00	6.76E-12	0.00E+00	4.37E-08	0.00E+00	2.03E-15	4.42E-08
Ni-63	2.30E-09	5.65E-09	4.60E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.79E-15	1.26E-08

	Annual dose (µSv/y)									
Radionuclide	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**External beta from beaches**	**External beta from fishing equipment**	**External gamma from beaches**	**External gamma from fishing equipment**	**Sea spray inhalation**	**Total**
Pu-238	1.65E-12	2.02E-12	2.47E-11	0.00E+00	6.50E-18	0.00E+00	1.45E-15	0.00E+00	1.79E-14	2.84E-11
U-234 (Pu-238)	5.56E-19	1.59E-19	1.67E-18	0.00E+00	7.86E-22	0.00E+00	2.54E-18	0.00E+00	2.16E-20	4.95E-18
Pu-239	2.98E-13	3.67E-13	4.48E-12	0.00E+00	4.57E-18	0.00E+00	6.15E-16	0.00E+00	3.13E-15	5.15E-12
U-235 (Pu-239)	3.21E-23	9.25E-24	9.61E-23	0.00E+00	1.18E-22	0.00E+00	1.57E-20	0.00E+00	1.16E-24	1.60E-20
Pu-240	4.71E-13	5.79E-13	7.08E-12	0.00E+00	5.20E-19	0.00E+00	3.24E-14	0.00E+00	4.95E-15	8.16E-12
U-236 (Pu-240)	1.50E-21	4.32E-22	4.50E-21	0.00E+00	2.80E-25	0.00E+00	6.49E-21	0.00E+00	5.75E-23	1.30E-20
Ru-103	9.52E-11	4.61E-12	1.91E-09	0.00E+00	1.16E-13	0.00E+00	4.29E-11	0.00E+00	1.61E-14	2.05E-09
Ru-106	8.73E-10	4.28E-11	1.75E-08	0.00E+00	2.68E-11	0.00E+00	1.31E-10	0.00E+00	1.72E-13	1.85E-08
Sb-122	5.99E-14	2.32E-12	4.82E-14	0.00E+00	4.95E-16	0.00E+00	8.73E-15	0.00E+00	5.95E-19	2.44E-12
Sb-124	1.74E-10	6.75E-09	1.40E-10	0.00E+00	1.33E-11	0.00E+00	1.59E-09	0.00E+00	6.56E-15	8.67E-09
Sb-125	1.33E-10	5.25E-09	1.06E-10	0.00E+00	4.34E-11	0.00E+00	8.05E-09	0.00E+00	8.76E-15	1.36E-08
Te-125m (Sb-125)	9.50E-10	2.55E-09	9.50E-10	0.00E+00	2.10E-13	0.00E+00	6.55E-10	0.00E+00	1.22E-15	5.11E-09
Sr-89	2.56E-12	6.19E-12	1.28E-12	0.00E+00	3.20E-12	0.00E+00	1.03E-14	0.00E+00	1.02E-15	1.32E-11
Sr-90	1.71E-11	4.25E-11	8.54E-12	0.00E+00	1.07E-10	0.00E+00	4.29E-15	0.00E+00	3.69E-15	1.75E-10
Te-123m	4.82E-12	1.17E-11	4.82E-12	0.00E+00	8.75E-16	0.00E+00	3.23E-13	0.00E+00	5.00E-18	2.17E-11
Te-123 (Te-123m)	4.35E-26	1.27E-25	4.35E-26	0.00E+00	0.00E+00	0.00E+00	2.55E-26	0.00E+00	9.41E-33	2.40E-25
Zn-65	6.70E-07	3.26E-08	4.02E-07	0.00E+00	5.84E-12	0.00E+00	5.75E-08	0.00E+00	3.04E-15	1.16E-06
Zr-95	2.90E-11	7.01E-12	7.26E-10	0.00E+00	1.53E-10	0.00E+00	3.78E-08	0.00E+00	2.88E-15	3.87E-08
Nb-95 (Zr-95)	3.86E-12	1.42E-12	1.93E-11	0.00E+00	6.34E-12	0.00E+00	4.10E-08	0.00E+00	1.17E-16	4.11E-08
Total	**2.37E-06**	**1.74E-06**	**5.42E-06**	**0.00E+00**	**4.36E-08**	**0.00E+00**	**2.26E-05**	**0.00E+00**	**4.27E-10**	**3.22E-05**

Table A.8: Stage 3 Assessment (µSv/y) for an Infant (Mean Consumption Rate) due to Liquid Discharges

	Annual dose (µSv/y)									
Radionuclide	Crustaceans	Fish	Molluscs	Seaweed	External beta from beaches	External beta from fishing equipment	External gamma from beaches	External gamma from fishing equipment	Sea spray inhalation	Total
Ag-110m	0.00E+00	1.68E-12	0.00E+00	0.00E+00	1.69E-15	0.00E+00	1.15E-13	0.00E+00	8.23E-20	1.80E-12
Am-241	0.00E+00	3.93E-15	0.00E+00	0.00E+00	1.07E-19	0.00E+00	6.74E-15	0.00E+00	8.93E-18	1.07E-14
Np-237 (Am-241)	0.00E+00	1.24E-20	0.00E+00	0.00E+00	3.38E-21	0.00E+00	1.81E-19	0.00E+00	3.03E-23	1.97E-19
Ba-140	0.00E+00	2.23E-11	0.00E+00	0.00E+00	7.51E-14	0.00E+00	1.11E-12	0.00E+00	3.22E-17	2.35E-11
La-140 (Ba-140)	0.00E+00	5.83E-12	0.00E+00	0.00E+00	4.27E-13	0.00E+00	4.04E-11	0.00E+00	7.27E-18	4.67E-11
Ce-141	0.00E+00	7.19E-12	0.00E+00	0.00E+00	6.53E-12	0.00E+00	1.05E-10	0.00E+00	8.03E-17	1.19E-10
Ce-144	0.00E+00	3.39E-10	0.00E+00	0.00E+00	2.64E-09	0.00E+00	3.45E-09	0.00E+00	7.16E-15	6.43E-09
Cm-242	0.00E+00	5.63E-15	0.00E+00	0.00E+00	4.11E-20	0.00E+00	6.23E-16	0.00E+00	3.27E-17	6.28E-15
Pu-238 (Cm-242)	0.00E+00	1.52E-15	0.00E+00	0.00E+00	2.36E-21	0.00E+00	5.24E-19	0.00E+00	7.84E-19	1.53E-15
Cm-243	0.00E+00	7.41E-17	0.00E+00	0.00E+00	2.28E-17	0.00E+00	1.52E-15	0.00E+00	3.33E-19	1.62E-15
Pu-239 (Cm-243)	0.00E+00	2.01E-19	0.00E+00	0.00E+00	1.24E-24	0.00E+00	1.67E-22	0.00E+00	9.80E-23	2.01E-19
Cm-244	0.00E+00	5.83E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-16	0.00E+00	2.81E-17	6.04E-15
Pu-240 (Cm-244)	0.00E+00	6.02E-17	0.00E+00	0.00E+00	2.71E-23	0.00E+00	1.69E-18	0.00E+00	2.96E-20	6.19E-17
Co-58	0.00E+00	2.09E-09	0.00E+00	0.00E+00	5.57E-12	0.00E+00	4.86E-09	0.00E+00	1.14E-16	6.95E-09
Co-60	0.00E+00	1.55E-07	0.00E+00	0.00E+00	1.66E-09	0.00E+00	2.14E-06	0.00E+00	7.19E-15	2.29E-06
Cr-51	0.00E+00	2.33E-11	0.00E+00	0.00E+00	1.29E-15	0.00E+00	1.73E-11	0.00E+00	1.97E-18	4.07E-11
Cs-134	0.00E+00	3.80E-10	0.00E+00	0.00E+00	1.88E-12	0.00E+00	4.58E-10	0.00E+00	2.16E-17	8.40E-10
Cs-137	0.00E+00	3.46E-10	0.00E+00	0.00E+00	1.07E-11	0.00E+00	6.44E-10	0.00E+00	1.92E-17	1.00E-09
Fe-55	0.00E+00	2.09E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.34E-09	0.00E+00	4.45E-15	2.16E-07
Fe-59	0.00E+00	2.04E-09	0.00E+00	0.00E+00	1.65E-12	0.00E+00	6.42E-10	0.00E+00	7.51E-17	2.69E-09
H-3	0.00E+00	1.72E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.07E-11	1.72E-06
I-131	0.00E+00	1.84E-09	0.00E+00	0.00E+00	2.97E-15	0.00E+00	1.59E-13	0.00E+00	9.10E-16	1.84E-09
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-15	0.00E+00	9.29E-15	0.00E+00	0.00E+00	1.09E-14
La-140	0.00E+00	1.80E-12	0.00E+00	0.00E+00	8.78E-14	0.00E+00	8.30E-12	0.00E+00	2.27E-18	1.02E-11
Mn-54	0.00E+00	3.13E-09	0.00E+00	0.00E+00	9.90E-13	0.00E+00	8.69E-08	0.00E+00	5.75E-16	9.00E-08
Nb-95	0.00E+00	4.14E-11	0.00E+00	0.00E+00	6.76E-13	0.00E+00	4.37E-09	0.00E+00	1.66E-16	4.41E-09
Ni-63	0.00E+00	9.88E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.42E-16	9.88E-09

	Annual dose (µSv/y)									
Radionuclide	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**External beta from beaches**	**External beta from fishing equipment**	**External gamma from beaches**	**External gamma from fishing equipment**	**Sea spray inhalation**	**Total**
Pu-238	0.00E+00	1.97E-12	0.00E+00	0.00E+00	6.50E-19	0.00E+00	1.45E-16	0.00E+00	1.04E-15	1.97E-12
U-234 (Pu-238)	0.00E+00	1.63E-19	0.00E+00	0.00E+00	7.86E-23	0.00E+00	2.54E-19	0.00E+00	1.70E-21	4.19E-19
Pu-239	0.00E+00	3.33E-13	0.00E+00	0.00E+00	4.57E-19	0.00E+00	6.15E-17	0.00E+00	1.73E-16	3.33E-13
U-235 (Pu-239)	0.00E+00	9.88E-24	0.00E+00	0.00E+00	1.18E-23	0.00E+00	1.57E-21	0.00E+00	9.29E-26	1.59E-21
Pu-240	0.00E+00	5.25E-13	0.00E+00	0.00E+00	5.19E-20	0.00E+00	3.24E-15	0.00E+00	2.74E-16	5.29E-13
U-236 (Pu-240)	0.00E+00	4.67E-22	0.00E+00	0.00E+00	2.80E-26	0.00E+00	6.49E-22	0.00E+00	4.40E-24	1.12E-21
Ru-103	0.00E+00	8.25E-12	0.00E+00	0.00E+00	1.16E-14	0.00E+00	4.29E-12	0.00E+00	1.33E-15	1.26E-11
Ru-106	0.00E+00	8.16E-11	0.00E+00	0.00E+00	2.68E-12	0.00E+00	1.31E-11	0.00E+00	1.59E-14	9.75E-11
Sb-122	0.00E+00	4.39E-12	0.00E+00	0.00E+00	4.95E-17	0.00E+00	8.73E-16	0.00E+00	6.49E-20	4.39E-12
Sb-124	0.00E+00	1.21E-08	0.00E+00	0.00E+00	1.33E-12	0.00E+00	1.59E-10	0.00E+00	5.65E-16	1.23E-08
Sb-125	0.00E+00	8.90E-09	0.00E+00	0.00E+00	4.34E-12	0.00E+00	8.05E-10	0.00E+00	7.11E-16	9.71E-09
Te-125m (Sb-125)	0.00E+00	4.94E-09	0.00E+00	0.00E+00	2.10E-14	0.00E+00	6.55E-11	0.00E+00	9.63E-17	5.01E-09
Sr-89	0.00E+00	1.12E-11	0.00E+00	0.00E+00	3.20E-13	0.00E+00	1.03E-15	0.00E+00	9.27E-17	1.15E-11
Sr-90	0.00E+00	3.02E-11	0.00E+00	0.00E+00	1.07E-11	0.00E+00	4.29E-16	0.00E+00	2.75E-16	4.08E-11
Te-123m	0.00E+00	2.15E-11	0.00E+00	0.00E+00	8.75E-17	0.00E+00	3.23E-14	0.00E+00	3.93E-19	2.15E-11
Te-123 (Te-123m)	0.00E+00	1.28E-25	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.55E-27	0.00E+00	6.21E-34	1.30E-25
Zn-65	0.00E+00	4.75E-08	0.00E+00	0.00E+00	5.84E-13	0.00E+00	5.75E-09	0.00E+00	2.84E-16	5.32E-08
Zr-95	0.00E+00	1.21E-11	0.00E+00	0.00E+00	1.53E-11	0.00E+00	3.78E-09	0.00E+00	2.33E-16	3.81E-09
Nb-95 (Zr-95)	0.00E+00	2.41E-12	0.00E+00	0.00E+00	6.34E-13	0.00E+00	4.10E-09	0.00E+00	9.52E-18	4.11E-09
Total	**0.00E+00**	**2.17E-06**	**0.00E+00**	**0.00E+00**	**4.36E-09**	**0.00E+00**	**2.26E-06**	**0.00E+00**	**3.07E-11**	**4.44E-06**

Table A.9: IRAT Stage 1 Assessment for the Gaseous Discharges at the Proposed Annual Discharge Limit

				DPUR				Annual dose (µSv/y)				
Radionuclide	**Bq/y**	**$T_{1/2}$ (days)**	**DPUR used**	**Food consumption**	**External irradiation**	**Inhalation**	**Total**	**Food consumption**	**External irradiation**	**Inhalation**	**Total**	**Age group**
Ag-110m	3.9E+01	2.50E+02	Ag-110m	3.10E-10	2.40E-09	1.70E-10	2.88E-09	1.21E-08	9.36E-08	6.63E-09	1.12E-07	Adult
Am-241	6.6E-04	1.58E+05	Am-241	5.70E-10	1.30E-10	9.40E-07	9.41E-07	3.76E-13	8.58E-14	6.20E-10	6.21E-10	Adult
Ar-41	5.2E+12	7.61E-02	Ar-41	0.00E+00	3.20E-12	0.00E+00	3.20E-12	0.00E+00	1.66E+01	0.00E+00	1.66E+01	Adult
Ba-140	3.5E+04	1.28E+01	Ba-140	2.80E-12	1.20E-10	1.10E-10	2.33E-10	9.80E-08	4.20E-06	3.85E-06	8.15E-06	Adult
C-14	1.7E+12	2.09E+06	C-14	3.30E-11	6.40E-17	3.50E-11	6.80E-11	5.61E+01	1.09E-04	5.95E+01	1.16E+02	Infant
Ce-141	4.9E+04	3.25E+01	Ce-141	8.00E-13	8.90E-12	7.20E-11	8.17E-11	3.92E-08	4.36E-07	3.53E-06	4.00E-06	Adult
Ce-144	4.5E+04	2.84E+02	Ce-144	2.40E-11	1.60E-11	8.60E-10	9.00E-10	1.08E-06	7.20E-07	3.87E-05	4.05E-05	Infant
Cm-242	4.9E-01	1.63E+02	Cm-242	1.80E-11	6.70E-14	1.20E-07	1.20E-07	8.82E-12	3.28E-14	5.88E-08	5.88E-08	Adult
Cm-243	4.9E-05	1.04E+04	Cm-243	3.80E-10	1.10E-09	7.00E-07	7.01E-07	1.86E-14	5.39E-14	3.43E-11	3.44E-11	Adult
Cm-244	6.2E-03	6.61E+03	Cm-244	3.00E-10	1.90E-12	6.10E-07	6.10E-07	1.86E-12	1.18E-14	3.78E-09	3.78E-09	Adult
Co-58	1.5E+05	7.08E+01	Co-58	4.40E-12	2.70E-10	3.60E-11	3.10E-10	6.60E-07	4.05E-05	5.40E-06	4.66E-05	Adult
Co-60	1.5E+05	1.92E+03	Co-60	5.30E-11	1.10E-08	2.20E-10	1.13E-08	7.95E-06	1.65E-03	3.30E-05	1.69E-03	Adult
Cr-51	1.3E+05	2.77E+01	Cr-51	1.30E-13	3.50E-12	8.30E-13	4.46E-12	1.69E-08	4.55E-07	1.08E-07	5.80E-07	Adult
Cs-134	9.4E+03	7.53E+02	Cs-134	4.70E-10	3.60E-09	1.50E-10	4.22E-09	4.42E-06	3.38E-05	1.41E-06	3.97E-05	Adult
Cs-137	5.7E+03	1.10E+04	Cs-137	3.80E-10	6.50E-09	1.00E-10	6.98E-09	2.17E-06	3.71E-05	5.70E-07	3.98E-05	Adult
Fe-59	2.4E+04	4.46E+01	Fe-59	1.60E-11	2.00E-10	8.30E-11	2.99E-10	3.84E-07	4.80E-06	1.99E-06	7.18E-06	Adult
H-3	1.0E+13	4.48E+03	H-3	2.70E-13	0.00E+00	6.90E-13	9.60E-13	2.70E+00	0.00E+00	6.90E+00	9.60E+00	Offspring
I-131	3.2E+08	8.04E+00	I-131	4.10E-09	3.80E-11	3.90E-10	4.53E-09	1.31E+00	1.22E-02	1.25E-01	1.45E+00	Infant
I-132	1.1E+08	9.58E-02	I-132	0.00E+00	1.30E-11	2.10E-12	1.51E-11	0.00E+00	1.43E-03	2.31E-04	1.66E-03	Adult
I-133	7.3E+07	8.66E-01	I-133	7.20E-11	7.60E-12	9.70E-11	1.77E-10	5.26E-03	5.55E-04	7.08E-03	1.29E-02	Infant
I-135	4.3E+07	2.75E-01	I-135	1.90E-12	7.80E-12	2.00E-11	2.97E-11	8.17E-05	3.35E-04	8.60E-04	1.28E-03	Infant
Kr-85	1.3E+09	3.91E+03	Kr-85	0.00E+00	1.30E-14	0.00E+00	1.30E-14	0.00E+00	1.69E-05	0.00E+00	1.69E-05	Adult
Kr-85m	1.0E+10	1.87E-01	Kr-85m	0.00E+00	3.60E-13	0.00E+00	3.60E-13	0.00E+00	3.60E-03	0.00E+00	3.60E-03	Adult
Kr-87	9.8E+03	5.30E-02	Kr-87	0.00E+00	2.10E-12	0.00E+00	2.10E-12	0.00E+00	2.06E-08	0.00E+00	2.06E-08	adult
Kr-88	9.3E+08	1.18E-01	Kr-88	0.00E+00	5.14E-12	0.00E+00	5.14E-12	0.00E+00	4.78E-03	0.00E+00	4.78E-03	adult
La-140	4.1E+04	1.68E+00	La-140	3.30E-13	2.10E-11	2.50E-11	4.63E-11	1.35E-08	8.61E-07	1.03E-06	1.90E-06	Adult
Mn-54	9.0E+04	3.13E+02	Mn-54	2.80E-11	9.10E-10	3.40E-11	9.72E-10	2.52E-06	8.19E-05	3.06E-06	8.75E-05	Adult
Nb-95	1.1E+05	3.51E+01	Nb-95	6.30E-13	1.10E-10	3.40E-11	1.45E-10	6.93E-08	1.21E-05	3.74E-06	1.59E-05	Adult
Pu-238	9.4E-03	3.20E+04	Pu-238	6.00E-10	4.40E-13	1.00E-06	1.00E-06	5.64E-12	4.14E-15	9.40E-09	9.41E-09	Adult
Pu-239	1.2E-03	8.81E+06	Pu-239	6.60E-10	7.00E-13	1.10E-06	1.10E-06	7.92E-13	8.40E-16	1.32E-09	1.32E-09	Adult
Pu-240	1.9E-03	2.40E+06	Pu-240	6.60E-10	5.60E-13	1.10E-06	1.10E-06	1.25E-12	1.06E-15	2.09E-09	2.09E-09	Adult
Sb-122	4.9E+02	2.70E+00	Cs-137	3.80E-10	6.50E-09	1.00E-10	6.98E-09	1.86E-07	3.19E-06	4.90E-08	3.42E-06	Adult
Sb-124	4.9E+04	6.02E+01	Cs-137	3.80E-10	6.50E-09	1.00E-10	6.98E-09	1.86E-05	3.19E-04	4.90E-06	3.42E-04	Adult
Sb-125	9.8E+03	1.01E+03	Sb-125	1.90E-11	1.20E-09	1.10E-10	1.33E-09	1.86E-07	1.18E-05	1.08E-06	1.30E-05	Adult
Sr-89	4.1E+04	5.05E+01	Sr-89	2.20E-11	1.60E-14	1.30E-10	1.52E-10	9.02E-07	6.56E-10	5.33E-06	6.23E-06	Infant
Sr-90	2.6E+03	1.04E+04	Sr-90	6.40E-10	3.20E-15	8.00E-10	1.44E-09	1.66E-06	8.32E-12	2.08E-06	3.74E-06	Child
Xe-131m	2.9E+09	1.18E+01	Xe-131m	0.00E+00	1.85E-14	0.00E+00	1.85E-14	0.00E+00	5.36E-05	0.00E+00	5.36E-05	adult
Xe-133	2.0E+11	5.24E+00	Xe-133	0.00E+00	7.00E-14	0.00E+00	7.00E-14	0.00E+00	1.40E-02	0.00E+00	1.40E-02	Adult
Xe-133m	1.8E+07	2.19E+00	Xe-133m	0.00E+00	6.78E-14	0.00E+00	6.78E-14	0.00E+00	1.22E-06	0.00E+00	1.22E-06	adult
Zn-65	4.1E+04	2.44E+02	Zn-65	1.00E-09	1.70E-10	3.50E-11	1.21E-09	4.10E-05	6.97E-06	1.44E-06	4.94E-05	Infant
Zr-95	5.3E+04	6.40E+01	Zr-95	1.20E-12	3.70E-10	1.10E-10	4.81E-10	6.36E-08	1.96E-05	5.83E-06	2.55E-05	Adult
							Total	**6.01E+01**	**1.67E+01**	**6.65E+01**	**1.43E+02**	

Table A.10: IRAT Stage 2 Assessment for the Gaseous Discharge Rates at the Proposed Annual Discharge Limit

				DPUR				Scaling factors			Annual dose (µSv/y)				
Radio-nuclide	**Bq/y**	**$T_{1/2}$ (days)**	**IRAT DPUR used**	**Food consumption**	**External irradiation**	**Inhalation**	**Total**	**Food consumption**	**External irradiation**	**Inhalation**	**Food consumption**	**External irradiation**	**Inhalation**	**Total**	**Age group**
Ag-110m	3.9E+01	2.50E+02	Ag-110m	3.10E-10	2.40E-09	1.70E-10	2.88E-09	3.30E-01	4.50E-02	4.50E-02	3.99E-09	4.21E-09	2.98E-10	8.50E-09	Adult
Am-241	6.6E-04	1.58E+05	Am-241	5.70E-10	1.30E-10	9.40E-07	9.41E-07	3.30E-01	4.50E-02	4.50E-02	1.24E-13	3.86E-15	2.79E-11	2.80E-11	Adult
Ar-41	5.2E+12	7.61E-02	Ar-41	0.00E+00	3.20E-12	0.00E+00	3.20E-12	3.30E-01	4.50E-02	4.50E-02	0.00E+00	7.49E-01	0.00E+00	7.49E-01	Adult
Ba-140	3.5E+04	1.28E+01	Ba-140	2.80E-12	1.20E-10	1.10E-10	2.33E-10	3.30E-01	4.50E-02	4.50E-02	3.23E-08	1.89E-07	1.73E-07	3.95E-07	Adult
C-14	1.7E+12	2.09E+06	C-14	3.30E-11	6.40E-17	3.50E-11	6.80E-11	3.30E-01	4.50E-02	4.50E-02	1.85E+01	4.90E-06	2.68E+00	2.12E+01	Infant
Ce-141	4.9E+04	3.25E+01	Ce-141	8.00E-13	8.90E-12	7.20E-11	8.17E-11	3.30E-01	4.50E-02	4.50E-02	1.29E-08	1.96E-08	1.59E-07	1.91E-07	Adult
Ce-144	4.5E+04	2.84E+02	Ce-144	2.40E-11	1.60E-11	8.60E-10	9.00E-10	3.30E-01	4.50E-02	4.50E-02	3.56E-07	3.24E-08	1.74E-06	2.13E-06	Infant
Cm-242	4.9E-01	1.63E+02	Cm-242	1.80E-11	6.70E-14	1.20E-07	1.20E-07	3.30E-01	4.50E-02	4.50E-02	2.91E-12	1.48E-15	2.65E-09	2.65E-09	Adult
Cm-243	4.9E-05	1.04E+04	Cm-243	3.80E-10	1.10E-09	7.00E-07	7.01E-07	3.30E-01	4.50E-02	4.50E-02	6.14E-15	2.43E-15	1.54E-12	1.55E-12	Adult
Cm-244	6.2E-03	6.61E+03	Cm-244	3.00E-10	1.90E-12	6.10E-07	6.10E-07	3.30E-01	4.50E-02	4.50E-02	6.14E-13	5.30E-16	1.70E-10	1.71E-10	Adult
Co-58	1.5E+05	7.08E+01	Co-58	4.40E-12	2.70E-10	3.60E-11	3.10E-10	3.30E-01	4.50E-02	4.50E-02	2.18E-07	1.82E-06	2.43E-07	2.28E-06	Adult
Co-60	1.5E+05	1.92E+03	Co-60	5.30E-11	1.10E-08	2.20E-10	1.13E-08	3.30E-01	4.50E-02	4.50E-02	2.62E-06	7.43E-05	1.49E-06	7.84E-05	Adult
Cr-51	1.3E+05	2.77E+01	Cr-51	1.30E-13	3.50E-12	8.30E-13	4.46E-12	3.30E-01	4.50E-02	4.50E-02	5.58E-09	2.05E-08	4.86E-09	3.09E-08	Adult
Cs-134	9.4E+03	7.53E+02	Cs-134	4.70E-10	3.60E-09	1.50E-10	4.22E-09	3.30E-01	4.50E-02	4.50E-02	1.46E-06	1.52E-06	6.35E-08	3.04E-06	Adult
Cs-137	5.7E+03	1.10E+04	Cs-137	3.80E-10	6.50E-09	1.00E-10	6.98E-09	3.30E-01	4.50E-02	4.50E-02	7.15E-07	1.67E-06	2.57E-08	2.41E-06	Adult
Fe-59	2.4E+04	4.46E+01	Fe-59	1.60E-11	2.00E-10	8.30E-11	2.99E-10	3.30E-01	4.50E-02	4.50E-02	1.27E-07	2.16E-07	8.96E-08	4.32E-07	Adult
H-3	1.0E+13	4.48E+03	H-3	2.70E-13	0.00E+00	6.90E-13	9.60E-13	3.30E-01	4.50E-02	4.50E-02	8.91E-01	0.00E+00	3.11E-01	1.20E+00	Offspring
I-131	3.2E+08	8.04E+00	I-131	4.10E-09	3.80E-11	3.90E-10	4.53E-09	3.30E-01	4.50E-02	4.50E-02	4.33E-01	5.47E-04	5.62E-03	4.39E-01	Infant
I-132	1.1E+08	9.58E-02	I-132	0.00E+00	1.30E-11	2.10E-12	1.51E-11	3.30E-01	4.50E-02	4.50E-02	0.00E+00	6.44E-05	1.04E-05	7.47E-05	Adult
I-133	7.3E+07	8.66E-01	I-133	7.20E-11	7.60E-12	9.70E-11	1.77E-10	3.30E-01	4.50E-02	4.50E-02	1.73E-03	2.50E-05	3.19E-04	2.08E-03	Infant
I-135	4.3E+07	2.75E-01	I-135	1.90E-12	7.80E-12	2.00E-11	2.97E-11	3.30E-01	4.50E-02	4.50E-02	2.70E-05	1.51E-05	3.87E-05	8.08E-05	Infant
Kr-85	1.3E+09	3.91E+03	Kr-85	0.00E+00	1.30E-14	0.00E+00	1.30E-14	3.30E-01	4.50E-02	4.50E-02	0.00E+00	7.61E-07	0.00E+00	7.61E-07	Adult
Kr-85m	1.0E+10	1.87E-01	Kr-85m	0.00E+00	3.60E-13	0.00E+00	3.60E-13	3.30E-01	4.50E-02	4.50E-02	0.00E+00	1.62E-04	0.00E+00	1.62E-04	Adult
Kr-87	9.8E+03	5.30E-02	Kr-87	0.00E+00	2.10E-12	0.00E+00	2.10E-12	3.30E-01	4.50E-02	4.50E-02	0.00E+00	9.28E-10	0.00E+00	9.28E-10	Adult
Kr-88	9.3E+08	1.18E-01	Kr-88	0.00E+00	5.14E-12	0.00E+00	5.14E-12	3.30E-01	4.50E-02	4.50E-02	0.00E+00	2.15E-04	0.00E+00	2.15E-04	Adult
La-140	4.1E+04	1.68E+00	La-140	3.30E-13	2.10E-11	2.50E-11	4.63E-11	3.30E-01	4.50E-02	4.50E-02	4.46E-09	3.87E-08	4.61E-08	8.93E-08	Adult
Mn-54	9.0E+04	3.13E+02	Mn-54	2.80E-11	9.10E-10	3.40E-11	9.72E-10	3.30E-01	4.50E-02	4.50E-02	8.32E-07	3.69E-06	1.38E-07	4.65E-06	Adult
Nb-95	1.1E+05	3.51E+01	Nb-95	6.30E-13	1.10E-10	3.40E-11	1.45E-10	3.30E-01	4.50E-02	4.50E-02	2.29E-08	5.45E-07	1.68E-07	7.36E-07	Adult
Pu-238	9.4E-03	3.20E+04	Pu-238	6.00E-10	4.40E-13	1.00E-06	1.00E-06	3.30E-01	4.50E-02	4.50E-02	1.86E-12	1.86E-16	4.23E-10	4.25E-10	Adult
Pu-239	1.2E-03	8.81E+06	Pu-239	6.60E-10	7.00E-13	1.10E-06	1.10E-06	3.30E-01	4.50E-02	4.50E-02	2.61E-13	3.78E-17	5.94E-11	5.97E-11	Adult
Pu-240	1.9E-03	2.40E+06	Pu-240	6.60E-10	5.60E-13	1.10E-06	1.10E-06	3.30E-01	4.50E-02	4.50E-02	4.14E-13	4.79E-17	9.41E-11	9.45E-11	Adult
Sb-122	4.9E+02	2.70E+00	Cs-137	3.80E-10	6.50E-09	1.00E-10	6.98E-09	3.30E-01	4.50E-02	4.50E-02	6.14E-08	1.43E-07	2.21E-09	2.07E-07	Adult
Sb-124	4.9E+04	6.02E+01	Cs-137	3.80E-10	6.50E-09	1.00E-10	6.98E-09	3.30E-01	4.50E-02	4.50E-02	6.14E-06	1.43E-05	2.21E-07	2.07E-05	Adult
Sb-125	9.8E+03	1.01E+03	Sb-125	1.90E-11	1.20E-09	1.10E-10	1.33E-09	3.30E-01	4.50E-02	4.50E-02	6.14E-08	5.29E-07	4.85E-08	6.39E-07	Adult
Sr-89	4.1E+04	5.05E+01	Sr-89	2.20E-11	1.60E-14	1.30E-10	1.52E-10	3.30E-01	4.50E-02	4.50E-02	2.98E-07	2.95E-11	2.40E-07	5.38E-07	Infant
Sr-90	2.6E+03	1.04E+04	Sr-90	6.40E-10	3.20E-15	8.00E-10	1.44E-09	3.30E-01	4.50E-02	4.50E-02	5.49E-07	3.74E-13	9.36E-08	6.43E-07	Child
Xe-131m	2.9E+09	1.18E+01	Xe-131m	0.00E+00	1.85E-14	0.00E+00	1.85E-14	3.30E-01	4.50E-02	4.50E-02	0.00E+00	2.41E-06	0.00E+00	2.41E-06	Adult
Xe-133	2.0E+11	5.24E+00	Xe-133	0.00E+00	7.00E-14	0.00E+00	7.00E-14	3.30E-01	4.50E-02	4.50E-02	0.00E+00	6.30E-04	0.00E+00	6.30E-04	Adult
Xe-133m	1.8E+07	2.19E+00	Xe-133m	0.00E+00	6.78E-14	0.00E+00	6.78E-14	3.30E-01	4.50E-02	4.50E-02	0.00E+00	5.49E-08	0.00E+00	5.49E-08	Adult
Zn-65	4.1E+04	2.44E+02	Zn-65	1.00E-09	1.70E-10	3.50E-11	1.21E-09	3.30E-01	4.50E-02	4.50E-02	1.35E-05	3.14E-07	6.46E-08	1.39E-05	Infant
Zr-95	5.3E+04	6.40E+01	Zr-95	1.20E-12	3.70E-10	1.10E-10	4.81E-10	3.30E-01	4.50E-02	4.50E-02	2.10E-08	8.82E-07	2.62E-07	1.17E-06	Adult
										Total	**1.98E+01**	**7.51E-01**	**2.99E+00**	**2.36E+01**	

Table A.11: Stage 3 Assessment (μSv/y) for an Adult ('top two' Consumption Rate) due to Gaseous Discharges

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Ag-110m	1.86E-10	4.30E-12	2.18E-15	3.51E-09	2.30E-10	1.72E-13	2.76E-10	3.73E-12	8.37E-10	5.80E-09	3.90E-12	2.45E-11	9.65E-12	3.26E-10	3.10E-12	1.12E-08
Am-241	1.74E-11	5.63E-19	1.47E-23	3.32E-15	4.42E-20	6.87E-14	1.14E-14	5.10E-16	5.83E-17	4.05E-16	1.13E-15	2.66E-14	2.46E-16	5.31E-15	2.16E-16	1.75E-11
Np-237 (Am-241)	5.42E-24	4.24E-31	4.75E-34	3.94E-26	3.14E-28	2.54E-19	2.16E-20	9.60E-22	1.10E-22	7.63E-22	5.13E-21	8.60E-21	1.55E-20	4.69E-21	1.90E-22	3.12E-19
Ar-41	0.00E+00	2.61E-01	3.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.65E-01
Ba-140	1.12E-07	2.57E-10	1.29E-11	1.55E-07	8.18E-09	5.28E-11	3.30E-11	1.53E-10	4.11E-09	2.70E-08	5.01E-10	8.89E-09	1.33E-11	5.20E-11	1.03E-10	3.16E-07
La-140 (Ba-140)	6.40E-12	9.51E-13	7.51E-15	4.79E-12	5.64E-13	7.28E-12	4.02E-11	4.07E-11	1.12E-10	5.13E-10	3.73E-10	6.13E-09	7.88E-12	6.52E-11	6.51E-12	7.31E-09
C-14	2.14E+00	0.00E+00	1.04E-05	0.00E+00	0.00E+00	0.00E+00	8.87E-02	4.84E-01	1.02E+00	3.87E+00	4.30E-01	7.52E-01	2.79E+00	8.87E-02	2.58E-01	1.19E+01
Ce-141	9.86E-08	1.51E-10	7.31E-12	1.57E-08	1.03E-08	5.93E-11	2.05E-10	5.25E-12	4.10E-10	2.79E-09	1.94E-10	4.91E-09	2.08E-12	3.40E-10	4.26E-12	1.34E-07
Ce-144	1.02E-06	3.60E-11	2.16E-12	7.69E-08	2.72E-07	9.62E-10	1.22E-08	3.31E-10	3.43E-09	2.38E-08	1.80E-09	4.50E-08	1.17E-10	1.50E-08	2.15E-10	1.47E-06
Pr-144 (Ce-144)	1.84E-11	2.25E-12	3.28E-12	8.12E-14	1.13E-12	4.25E-17	2.00E-23	6.07E-98	1.40E-17	8.00E-42	9.96E-16	2.52E-14	1.67E-18	1.54E-23	2.29E-198	2.52E-11
Pr-144m (Ce-144)	0.00E+00	1.24E-12	0.00E+00	9.40E-14	4.45E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-12
Cm-242	1.60E-09	2.48E-18	0.00E+00	1.20E-15	7.44E-18	1.36E-12	6.13E-14	2.75E-15	3.21E-16	2.22E-15	4.31E-14	1.09E-12	4.96E-17	6.92E-14	2.79E-15	1.60E-09
Pu-238 (Cm-242)	1.96E-16	3.01E-26	0.00E+00	1.05E-22	1.20E-25	1.92E-13	4.09E-14	1.81E-15	2.07E-16	1.44E-15	6.46E-16	9.20E-15	5.60E-16	1.57E-14	6.34E-16	2.63E-13
Cm-243	9.55E-13	2.60E-19	3.25E-21	2.05E-15	1.93E-17	2.60E-15	5.71E-16	2.54E-17	2.91E-18	2.02E-17	6.11E-17	1.48E-15	2.97E-18	2.81E-16	1.14E-17	9.62E-13
Pu-239 (Cm-243)	2.08E-22	2.03E-29	1.09E-34	7.10E-25	7.96E-27	8.09E-25	2.58E-25	1.15E-26	1.31E-27	9.12E-27	2.53E-26	5.96E-25	5.73E-27	1.19E-25	4.85E-27	2.11E-22
Am-243 (Cm-243)	7.78E-23	9.27E-33	0.00E+00	6.25E-29	1.80E-31	2.47E-18	1.30E-19	5.78E-21	6.61E-22	4.59E-21	4.19E-21	5.98E-21	7.90E-21	2.95E-20	1.19E-21	2.66E-18
Cm-244	1.05E-10	7.01E-20	0.00E+00	4.25E-16	0.00E+00	2.45E-13	5.43E-14	2.42E-15	2.77E-16	1.92E-15	6.12E-15	1.50E-13	2.29E-16	2.76E-14	1.12E-15	1.05E-10
Pu-240 (Cm-244)	3.62E-20	5.35E-30	0.00E+00	2.19E-26	6.06E-30	9.41E-16	5.71E-17	2.53E-18	2.90E-19	2.01E-18	1.62E-18	2.61E-18	3.02E-18	1.32E-17	5.32E-19	1.02E-15
Co-58	1.51E-07	5.93E-09	5.13E-12	1.46E-06	1.35E-08	1.08E-10	1.17E-09	6.17E-11	1.49E-09	1.02E-08	1.81E-09	1.95E-08	2.03E-10	1.95E-09	5.30E-11	1.66E-06
Co-60	9.44E-07	1.48E-08	9.22E-12	6.24E-05	5.52E-08	1.40E-09	2.25E-08	1.23E-09	9.46E-09	6.57E-08	1.38E-08	1.13E-07	1.86E-08	3.35E-08	9.73E-10	6.37E-05
Cr-51	3.03E-09	1.67E-10	0.00E+00	1.64E-08	1.21E-11	1.75E-12	3.70E-11	1.87E-10	5.64E-11	3.82E-10	2.61E-11	6.62E-10	7.53E-14	6.32E-11	1.54E-10	2.12E-08
Cs-134	3.90E-08	5.93E-10	1.75E-12	1.23E-06	1.06E-08	4.52E-11	2.14E-08	1.17E-07	1.49E-07	1.03E-06	6.77E-08	4.52E-08	1.52E-07	4.17E-08	1.21E-07	3.03E-06
Cs-137	1.65E-08	0.00E+00	1.05E-12	1.39E-06	1.11E-08	4.56E-11	1.03E-08	5.59E-08	6.92E-08	4.81E-07	2.97E-08	2.16E-08	7.11E-08	2.15E-08	6.24E-08	2.24E-06
Ba-137m (Cs-137)	0.00E+00	3.33E-11	1.26E-13	1.84E-13	1.12E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.36E-11
Fe-59	5.58E-08	1.13E-09	2.34E-12	1.76E-07	4.33E-09	3.61E-11	1.44E-08	1.88E-11	2.69E-10	1.84E-09	5.72E-10	6.87E-09	1.71E-11	1.79E-08	1.55E-11	2.80E-07
H-3	1.70E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.77E-03	9.65E-03	7.86E-02	2.19E-02	1.47E-02	2.57E-02	9.56E-02	1.77E-03	5.15E-03	4.25E-01
I-131	1.48E-03	4.95E-06	6.74E-08	1.12E-03	2.12E-04	4.65E-06	1.99E-04	8.39E-04	1.62E-02	1.03E-01	1.71E-03	4.23E-03	3.28E-03	2.55E-04	4.06E-04	1.33E-01
Xe-131m (I-131)	0.00E+00	4.55E-12	1.19E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.74E-12
I-132	6.44E-06	1.00E-05	8.04E-08	2.65E-05	2.73E-06	9.55E-10	1.32E-10	2.71E-19	2.05E-08	1.03E-10	1.30E-08	3.28E-07	6.71E-10	5.98E-11	1.78E-32	4.61E-05
I-133	6.84E-05	1.79E-06	4.34E-08	4.53E-05	1.45E-05	7.34E-08	3.97E-07	1.97E-07	4.70E-05	1.47E-04	1.54E-06	2.82E-05	7.91E-07	2.44E-07	2.63E-09	3.55E-04
Xe-133 (I-133)	0.00E+00	1.96E-11	3.06E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E-11
Xe-133m (I-133)	0.00E+00	1.08E-11	4.30E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E-11
I-135	8.59E-06	2.63E-06	2.26E-08	2.32E-05	2.35E-06	3.59E-09	3.57E-09	1.02E-11	4.86E-07	2.72E-07	4.86E-08	1.18E-06	5.52E-09	1.74E-09	1.13E-16	3.88E-05
Xe-135 (I-135)	0.00E+00	3.47E-08	2.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-08
Xe-135m (I-135)	0.00E+00	5.76E-10	2.15E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.98E-10
Kr-85	0.00E+00	1.18E-07	4.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.47E-07
Kr-85m	0.00E+00	6.54E-05	3.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.88E-05
Kr-85 (Kr-85m)	0.00E+00	1.17E-13	3.73E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.90E-13
Kr-87	0.00E+00	2.91E-10	2.16E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.13E-10
Rb-87 (Kr-87)	7.93E-26	0.00E+00	9.84E-30	0.00E+00	1.15E-25	3.09E-28	1.83E-25	9.99E-25	6.48E-24	4.50E-23	5.14E-25	6.16E-25	2.24E-24	2.22E-25	6.47E-25	5.71E-23
Kr-88	0.00E+00	6.71E-05	4.85E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.76E-05
Rb-88 (Kr-88)	3.28E-07	8.81E-07	1.18E-07	3.27E-08	2.66E-08	7.80E-13	3.09E-15	1.49E-87	3.15E-10	9.76E-34	3.75E-11	9.41E-10	7.75E-12	3.18E-15	3.24E-185	1.39E-06
La-140	2.84E-08	3.69E-09	3.33E-11	2.22E-08	2.61E-09	5.93E-12	4.53E-12	1.79E-13	3.41E-11	1.57E-10	7.14E-11	1.77E-09	5.45E-13	5.71E-12	2.30E-14	5.90E-08
Mn-54	8.49E-08	3.05E-09	0.00E+00	2.99E-06	1.32E-10	8.17E-11	7.37E-09	1.01E-09	2.79E-09	1.94E-08	1.99E-09	1.39E-08	3.60E-09	1.25E-08	9.13E-10	3.14E-06
Nb-95	1.04E-07	3.42E-09	7.25E-13	4.23E-07	6.18E-10	6.36E-11	1.60E-14	8.20E-14	3.08E-12	2.10E-11	7.47E-10	9.53E-09	5.91E-11	2.70E-14	6.84E-14	5.41E-07
Pu-238	2.72E-10	3.90E-20	0.00E+00	1.51E-16	1.74E-19	9.51E-13	1.76E-13	7.82E-15	8.95E-16	6.22E-15	1.83E-14	4.36E-13	2.13E-15	8.44E-14	3.43E-15	2.74E-10

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
U-234 (Pu-238)	1.03E-22	3.71E-31	1.79E-33	2.00E-27	4.73E-30	4.28E-18	4.22E-27	2.30E-26	4.41E-25	3.06E-24	1.37E-19	1.04E-19	7.65E-19	1.02E-26	2.98E-26	5.29E-18
Pu-239	3.77E-11	4.06E-21	0.00E+00	3.17E-17	9.16E-20	1.54E-13	2.53E-14	1.13E-15	1.29E-16	8.95E-16	2.57E-15	6.05E-14	3.65E-16	1.19E-14	4.85E-16	3.80E-11
U-235 (Pu-239)	4.04E-27	1.49E-32	9.12E-36	1.52E-28	5.28E-31	1.95E-22	1.80E-31	9.79E-31	1.88E-29	1.30E-28	6.71E-24	4.99E-24	3.76E-23	4.35E-31	1.27E-30	2.44E-22
Pu-240	5.98E-11	8.21E-21	0.00E+00	3.77E-17	1.04E-20	2.43E-13	4.00E-14	1.78E-15	2.04E-16	1.42E-15	4.08E-15	9.58E-14	5.77E-16	1.89E-14	7.68E-16	6.02E-11
U-236 (Pu-240)	1.98E-25	5.01E-34	2.46E-36	2.22E-30	1.27E-33	9.56E-21	8.55E-30	4.66E-29	8.92E-28	6.20E-27	3.19E-22	2.37E-22	1.79E-21	2.07E-29	6.03E-29	1.19E-20
Sb-122	3.08E-10	8.82E-12	4.31E-13	8.57E-11	5.11E-11	8.19E-14	1.04E-11	2.63E-13	2.80E-12	1.50E-11	1.13E-12	2.73E-11	3.07E-14	1.37E-11	6.59E-14	5.25E-10
Sb-124	1.97E-07	3.49E-09	2.70E-11	7.32E-07	5.30E-08	1.36E-10	3.54E-08	1.87E-09	1.61E-09	1.10E-08	1.89E-09	2.09E-08	1.94E-10	6.53E-08	1.75E-09	1.13E-06
Sb-125	2.96E-08	1.68E-10	6.91E-13	4.43E-07	4.15E-09	3.68E-11	5.23E-09	2.85E-10	1.86E-10	1.29E-09	2.89E-10	2.32E-09	2.14E-10	1.09E-08	3.15E-10	4.98E-07
Te-125m (Sb-125)	1.60E-13	3.38E-17	1.37E-18	5.07E-15	5.71E-17	1.24E-11	1.02E-09	2.29E-10	1.54E-10	1.06E-09	5.07E-10	4.28E-10	1.02E-09	2.06E-09	3.54E-10	6.84E-09
Sr-89	1.57E-07	1.40E-13	3.77E-11	2.42E-11	6.80E-08	1.05E-10	6.45E-11	3.38E-10	1.10E-08	7.52E-08	1.53E-09	1.80E-08	4.37E-10	9.16E-11	2.42E-10	3.32E-07
Sr-90	5.89E-08	0.00E+00	6.06E-13	1.18E-14	2.15E-08	1.61E-10	3.31E-10	1.81E-09	5.34E-08	3.71E-07	4.85E-09	6.70E-08	3.95E-08	2.48E-10	7.22E-10	6.19E-07
Y-90 (Sr-90)	4.08E-13	1.18E-21	6.69E-16	9.50E-21	5.89E-14	1.03E-16	3.72E-18	9.29E-19	1.41E-15	7.54E-15	2.86E-15	6.91E-14	7.74E-17	4.86E-18	2.29E-19	5.49E-13
Xe-131m	0.00E+00	9.82E-07	2.89E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.27E-06
Xe-133	0.00E+00	3.09E-04	1.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E-04
Xe-133m	0.00E+00	2.09E-08	3.73E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.46E-08
Xe-133 (Xe-133m)	0.00E+00	2.68E-12	1.07E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E-12
Zn-65	4.13E-08	9.50E-10	7.21E-14	7.48E-07	3.51E-10	3.78E-11	2.75E-09	1.49E-08	3.41E-07	2.36E-06	1.43E-08	5.04E-08	3.41E-08	2.65E-09	7.55E-09	3.62E-06
Zr-95	1.60E-07	1.59E-09	4.96E-12	7.14E-07	1.19E-08	1.12E-10	1.70E-14	8.99E-14	3.95E-12	2.71E-11	7.86E-10	8.68E-09	2.72E-11	3.24E-14	8.74E-14	8.97E-07
Nb-95 (Zr-95)	3.23E-12	1.85E-14	1.39E-15	2.65E-12	1.97E-13	9.35E-16	7.88E-20	2.41E-19	1.14E-16	6.54E-16	1.18E-14	2.77E-13	3.42E-16	1.06E-19	8.05E-20	6.39E-12
Nb-95m (Zr-95)	6.31E-13	2.37E-14	4.41E-18	2.46E-12	3.59E-15	9.72E-12	9.40E-15	4.83E-14	3.21E-13	2.19E-12	2.78E-10	1.61E-09	5.09E-11	1.80E-14	4.58E-14	1.95E-09
Total	**2.31E+00**	**2.61E-01**	**3.61E-03**	**1.29E-03**	**2.32E-04**	**4.73E-06**	**9.07E-02**	**4.94E-01**	**1.11E+00**	**4.00E+00**	**4.46E-01**	**7.82E-01**	**2.89E+00**	**9.07E-02**	**2.64E-01**	**1.27E+01**

Table A.12: Stage 3 Assessment (µSv/y) for a Child ('top two' Consumption Rate) due to Gaseous Discharges

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Ag-110m	2.03E-10	2.58E-12	2.18E-15	1.79E-09	2.30E-10	1.87E-13	2.80E-10	6.94E-12	3.93E-09	8.08E-09	5.43E-12	1.95E-11	6.89E-12	3.30E-10	2.88E-12	1.49E-08
Am-241	1.15E-11	3.38E-19	1.47E-23	1.69E-15	4.42E-20	4.52E-14	6.87E-15	5.61E-16	1.62E-16	3.34E-16	9.32E-16	1.26E-14	1.04E-16	3.19E-15	1.19E-16	1.16E-11
Np-237 (Am-241)	3.58E-24	2.55E-31	4.75E-34	2.01E-26	3.14E-28	1.68E-19	1.18E-20	9.60E-22	2.77E-22	5.72E-22	3.85E-21	3.69E-21	5.94E-21	2.56E-21	9.52E-23	1.98E-19
Ar-41	0.00E+00	1.56E-01	3.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.60E-01
Ba-140	1.16E-07	1.54E-10	1.29E-11	7.87E-08	8.18E-09	5.44E-11	4.02E-11	3.42E-10	2.32E-08	4.52E-08	8.39E-10	8.50E-09	1.15E-11	6.32E-11	1.15E-10	2.81E-07
La-140 (Ba-140)	8.04E-12	5.71E-13	7.51E-15	2.44E-12	5.64E-13	9.15E-12	4.60E-11	8.54E-11	5.92E-10	8.07E-10	5.87E-10	5.51E-09	6.36E-12	7.47E-11	6.83E-12	7.74E-09
C-14	2.07E+00	0.00E+00	1.04E-05	0.00E+00	0.00E+00	0.00E+00	6.67E-02	6.67E-01	3.56E+00	4.01E+00	4.44E-01	4.44E-01	1.48E+00	6.67E-02	1.78E-01	1.30E+01
Ce-141	9.80E-08	9.08E-11	7.31E-12	7.98E-09	1.03E-08	5.89E-11	2.37E-10	1.11E-11	2.19E-09	4.42E-09	3.07E-10	4.44E-09	1.69E-12	3.92E-10	4.50E-12	1.28E-07
Ce-144	1.08E-06	2.16E-11	2.16E-12	3.91E-08	2.72E-07	1.02E-09	1.41E-08	7.00E-10	1.83E-08	3.77E-08	2.85E-09	4.08E-08	9.55E-11	1.73E-08	2.27E-10	1.52E-06
Pr-144 (Ce-144)	2.40E-11	1.35E-12	3.28E-12	4.13E-14	1.13E-12	5.55E-17	2.07E-23	1.15E-97	6.72E-17	1.14E-41	1.42E-15	2.06E-14	1.22E-18	1.60E-23	2.17E-198	2.98E-11
Pr-144m (Ce-144)	0.00E+00	7.44E-13	0.00E+00	4.78E-14	4.45E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.92E-13
Cm-242	1.55E-09	1.49E-18	0.00E+00	6.13E-16	7.44E-18	1.32E-12	6.69E-14	5.50E-15	1.62E-15	3.33E-15	6.47E-14	9.35E-13	3.82E-17	7.55E-14	2.79E-15	1.55E-09
Pu-238 (Cm-242)	1.30E-16	1.81E-26	0.00E+00	5.32E-23	1.20E-25	1.27E-13	2.33E-14	1.89E-15	5.47E-16	1.13E-15	5.06E-16	4.11E-15	2.25E-16	8.94E-15	3.31E-16	1.68E-13
Cm-243	6.60E-13	1.56E-19	3.25E-21	1.05E-15	1.93E-17	1.80E-15	3.32E-16	2.71E-17	7.84E-18	1.62E-17	4.89E-17	6.77E-16	1.22E-18	1.63E-16	6.09E-18	6.64E-13
Pu-239 (Cm-243)	1.40E-22	1.22E-29	1.09E-34	3.62E-25	7.96E-27	5.45E-25	1.55E-25	1.26E-26	3.65E-27	7.53E-27	2.09E-26	2.81E-25	2.42E-27	7.15E-26	2.67E-27	1.41E-22
Am-243 (Cm-243)	5.16E-23	5.56E-33	0.00E+00	3.18E-29	1.80E-31	1.64E-18	7.67E-20	6.25E-21	1.80E-21	3.72E-21	3.39E-21	2.77E-21	3.28E-21	1.74E-20	6.44E-22	1.76E-18
Cm-244	7.28E-11	4.21E-20	0.00E+00	2.16E-16	0.00E+00	1.69E-13	3.46E-14	2.82E-15	8.16E-16	1.68E-15	5.35E-15	7.48E-14	1.03E-16	1.75E-14	6.55E-16	7.31E-11
Pu-240 (Cm-244)	2.41E-20	3.21E-30	0.00E+00	1.11E-26	6.06E-30	6.24E-16	3.36E-17	2.74E-18	7.90E-19	1.63E-18	1.31E-18	1.21E-18	1.26E-18	7.75E-18	2.88E-19	6.75E-16
Co-58	1.56E-07	3.56E-09	5.13E-12	7.41E-07	1.35E-08	1.13E-10	1.46E-09	1.41E-10	8.64E-09	1.77E-08	3.12E-09	1.92E-08	1.79E-10	2.44E-09	6.09E-11	9.68E-07
Co-60	9.78E-07	8.87E-09	9.22E-12	3.18E-05	5.52E-08	1.45E-09	3.98E-08	3.97E-09	7.73E-08	1.59E-07	3.35E-08	1.57E-07	2.32E-08	5.92E-08	1.57E-09	3.34E-05
Cr-51	3.73E-09	1.00E-10	0.00E+00	8.35E-09	1.21E-11	2.16E-12	4.14E-11	3.84E-10	2.92E-10	5.88E-10	4.02E-11	5.82E-10	5.94E-14	7.08E-11	1.58E-10	1.44E-08
Cs-134	2.17E-08	3.56E-10	1.75E-12	6.26E-07	1.06E-08	2.51E-11	8.62E-09	8.59E-08	2.76E-07	5.70E-07	3.74E-08	1.43E-08	4.29E-08	1.68E-08	4.44E-08	1.76E-06
Cs-137	9.17E-09	0.00E+00	1.05E-12	7.09E-07	1.11E-08	2.53E-11	4.30E-09	4.30E-08	1.34E-07	2.77E-07	1.72E-08	7.12E-09	2.10E-08	9.00E-09	2.40E-08	1.27E-06
Ba-137m (Cs-137)	0.00E+00	2.00E-11	1.26E-13	9.36E-14	1.12E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E-11
Fe-59	5.74E-08	6.77E-10	2.34E-12	8.96E-08	4.33E-09	3.71E-11	2.06E-08	4.90E-11	1.77E-09	3.61E-09	1.12E-09	7.69E-09	1.72E-11	2.55E-08	2.03E-11	2.13E-07
H-3	1.50E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-03	1.23E-02	2.54E-01	2.09E-02	1.41E-02	1.41E-02	4.70E-02	1.23E-03	3.29E-03	5.18E-01
I-131	2.63E-03	2.97E-06	6.74E-08	5.70E-04	2.12E-04	8.25E-06	2.57E-04	1.98E-03	9.67E-02	1.83E-01	3.03E-03	4.28E-03	2.98E-03	3.29E-04	4.80E-04	2.96E-01
Xe-131m (I-131)	0.00E+00	2.73E-12	1.19E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.92E-12
I-132	1.04E-05	6.00E-06	8.04E-08	1.35E-05	2.73E-06	1.54E-09	1.54E-10	5.79E-19	1.11E-07	1.65E-10	2.09E-08	3.01E-07	5.52E-10	6.97E-11	1.91E-32	3.31E-05
I-133	1.20E-04	1.08E-06	4.34E-08	2.31E-05	1.45E-05	1.29E-07	5.04E-07	4.57E-07	2.76E-04	2.56E-04	2.68E-06	2.81E-05	7.08E-07	3.09E-07	3.05E-09	7.24E-04
Xe-133 (I-133)	0.00E+00	1.17E-11	3.06E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E-11
Xe-133m (I-133)	0.00E+00	6.50E-12	4.30E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.93E-12
I-135	1.47E-05	1.58E-06	2.26E-08	1.18E-05	2.35E-06	6.13E-09	4.60E-09	2.42E-11	2.91E-06	4.84E-07	8.61E-08	1.19E-06	5.03E-09	2.25E-09	1.34E-16	3.51E-05
Xe-135 (I-135)	0.00E+00	2.08E-08	2.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.11E-08
Xe-135m (I-135)	0.00E+00	3.46E-10	2.15E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.68E-10
Kr-85	0.00E+00	7.08E-08	4.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.00E-07
Kr-85m	0.00E+00	3.93E-05	3.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.27E-05
Kr-85 (Kr-85m)	0.00E+00	7.01E-14	3.73E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.43E-13
Kr-87	0.00E+00	1.74E-10	2.16E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.96E-10
Rb-87 (Kr-87)	1.21E-25	0.00E+00	9.84E-30	0.00E+00	1.15E-25	4.70E-28	2.06E-25	2.06E-24	3.38E-23	6.98E-23	7.96E-25	5.45E-25	1.78E-24	2.51E-25	6.69E-25	1.10E-22
Kr-88	0.00E+00	4.03E-05	4.85E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E-05
Rb-88 (Kr-88)	4.53E-07	5.29E-07	1.18E-07	1.66E-08	2.66E-08	1.08E-12	3.18E-15	2.82E-87	1.50E-09	1.38E-33	5.32E-11	7.62E-10	5.63E-12	3.28E-15	3.06E-185	1.15E-06
La-140	3.56E-08	2.21E-09	3.33E-11	1.13E-08	2.61E-09	7.45E-12	5.19E-12	3.76E-13	1.81E-10	2.47E-10	1.12E-10	1.60E-09	4.40E-13	6.54E-12	2.42E-14	5.39E-08
Mn-54	9.40E-08	1.83E-09	0.00E+00	1.53E-06	1.32E-10	9.04E-11	7.36E-09	1.85E-09	1.30E-08	2.66E-08	2.73E-09	1.10E-08	2.53E-09	1.25E-08	8.35E-10	1.71E-06
Nb-95	1.05E-07	2.05E-09	7.25E-13	2.15E-07	6.18E-10	6.45E-11	1.65E-14	1.56E-13	1.48E-11	2.98E-11	1.06E-09	7.73E-09	4.31E-11	2.79E-14	6.48E-14	3.33E-07
Pu-238	1.80E-10	2.34E-20	0.00E+00	7.71E-17	1.74E-19	6.29E-13	1.00E-13	8.16E-15	2.36E-15	4.86E-15	1.43E-14	1.95E-13	8.56E-16	4.80E-14	1.79E-15	1.81E-10
U-234 (Pu-238)	9.75E-23	2.22E-31	1.79E-33	1.02E-27	4.73E-30	4.06E-18	3.48E-27	3.48E-26	1.68E-24	3.47E-24	1.55E-19	6.70E-20	4.44E-19	8.43E-27	2.25E-26	4.73E-18

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Pu-239	2.51E-11	2.43E-21	0.00E+00	1.62E-17	9.16E-20	1.02E-13	1.49E-14	1.22E-15	3.51E-16	7.25E-16	2.09E-15	2.80E-14	1.52E-16	7.02E-15	2.62E-16	2.53E-11
U-235 (Pu-239)	3.87E-27	8.92E-33	9.12E-36	7.76E-29	5.28E-31	1.87E-22	1.48E-31	1.48E-30	7.15E-29	1.48E-28	7.60E-24	3.23E-24	2.18E-23	3.59E-31	9.57E-31	2.20E-22
Pu-240	3.97E-11	4.93E-21	0.00E+00	1.92E-17	1.04E-20	1.61E-13	2.36E-14	1.92E-15	5.56E-16	1.15E-15	3.30E-15	4.43E-14	2.40E-16	1.11E-14	4.15E-16	3.99E-11
U-236 (Pu-240)	1.93E-25	3.00E-34	2.46E-36	1.13E-30	1.27E-33	9.29E-21	6.94E-30	6.94E-29	3.36E-27	6.93E-27	3.56E-22	1.51E-22	1.02E-21	1.68E-29	4.49E-29	1.08E-20
Sb-122	3.84E-10	5.29E-12	4.31E-13	4.36E-11	5.11E-11	1.02E-13	1.24E-11	5.72E-13	1.54E-11	2.45E-11	1.84E-12	2.54E-11	2.57E-14	1.62E-11	7.17E-14	5.81E-10
Sb-124	2.05E-07	2.09E-09	2.70E-11	3.73E-07	5.30E-08	1.41E-10	4.02E-08	3.88E-09	8.46E-09	1.72E-08	2.94E-09	1.86E-08	1.55E-10	7.40E-08	1.82E-09	8.01E-07
Sb-125	2.90E-08	1.01E-10	6.91E-13	2.25E-07	4.15E-09	3.60E-11	5.45E-09	5.44E-10	8.98E-10	1.85E-09	4.14E-10	1.90E-09	1.57E-10	1.13E-08	3.00E-10	2.81E-07
Te-125m (Sb-125)	1.56E-13	2.03E-17	1.37E-18	2.58E-15	5.71E-17	1.21E-11	1.21E-09	4.99E-10	8.51E-10	1.73E-09	8.31E-10	4.00E-10	8.56E-10	2.46E-09	3.86E-10	9.24E-09
Sr-89	1.62E-07	8.40E-14	3.77E-11	1.23E-11	6.80E-08	1.08E-10	7.85E-11	7.53E-10	6.19E-08	1.26E-07	2.56E-09	1.72E-08	3.75E-10	1.11E-10	2.70E-10	4.39E-07
Sr-90	5.77E-08	0.00E+00	6.06E-13	5.98E-15	2.15E-08	1.58E-10	3.87E-10	3.87E-09	2.89E-07	5.97E-07	7.80E-09	6.16E-08	3.25E-08	2.90E-10	7.73E-10	1.07E-06
Y-90 (Sr-90)	5.08E-13	7.11E-22	6.69E-16	4.83E-21	5.89E-14	1.28E-16	4.43E-18	2.03E-18	7.77E-15	1.24E-14	4.68E-15	6.48E-14	6.51E-17	5.79E-18	2.50E-19	6.57E-13
Xe-131m	0.00E+00	5.89E-07	2.89E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.78E-07
Xe-133	0.00E+00	1.85E-04	1.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E-04
Xe-133m	0.00E+00	1.25E-08	3.73E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.62E-08
Xe-133 (Xe-133m)	0.00E+00	1.61E-12	1.07E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-12
Zn-65	4.28E-08	5.70E-10	7.21E-14	3.80E-07	3.51E-10	3.92E-11	2.46E-09	2.44E-08	1.41E-06	2.91E-06	1.76E-08	3.54E-08	2.15E-08	2.37E-09	6.19E-09	4.85E-06
Zr-95	1.57E-07	9.53E-10	4.96E-12	3.63E-07	1.19E-08	1.10E-10	1.86E-14	1.80E-13	1.99E-11	4.07E-11	1.18E-09	7.44E-09	2.09E-11	3.54E-14	8.74E-14	5.42E-07
Nb-95 (Zr-95)	3.40E-12	1.11E-14	1.39E-15	1.35E-12	1.97E-13	9.82E-16	9.21E-20	5.18E-19	6.17E-16	1.05E-15	1.90E-14	2.54E-13	2.82E-16	1.24E-19	8.62E-20	5.24E-12
Nb-95m (Zr-95)	6.39E-13	1.42E-14	4.41E-18	1.25E-12	3.59E-15	9.86E-12	9.72E-15	9.17E-14	1.54E-12	3.11E-12	3.96E-10	1.31E-09	3.72E-11	1.87E-14	4.34E-14	1.76E-09
Total	**2.22E+00**	**1.56E-01**	**3.61E-03**	**6.56E-04**	**2.32E-04**	**8.39E-06**	**6.82E-02**	**6.81E-01**	**3.91E+00**	**4.21E+00**	**4.61E-01**	**4.62E-01**	**1.53E+00**	**6.83E-02**	**1.82E-01**	**1.40E+01**

Table A.13: Stage 3 Assessment (µSv/y) for an Infant ('top two' Consumption Rate) due to Gaseous Discharges

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Ag-110m	1.64E-10	2.01E-12	2.18E-15	1.21E-09	2.30E-10	1.51E-13	2.51E-10	3.73E-12	1.41E-08	2.18E-08	8.77E-12	1.75E-11	5.57E-12	2.96E-10	1.55E-12	3.81E-08
Am-241	6.82E-12	2.63E-19	1.47E-23	1.15E-15	4.42E-20	2.69E-14	3.85E-15	1.89E-16	3.63E-16	5.62E-16	9.40E-16	7.04E-15	5.25E-17	1.79E-15	4.00E-17	6.86E-12
Np-237 (Am-241)	2.25E-24	1.98E-31	4.75E-34	1.36E-26	3.14E-28	1.05E-19	7.49E-21	3.67E-22	7.06E-22	1.09E-21	4.41E-21	2.35E-21	3.40E-21	1.63E-21	3.64E-23	1.26E-19
Ar-41	0.00E+00	1.22E-01	3.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E-01
Ba-140	1.05E-07	1.20E-10	1.29E-11	5.34E-08	8.18E-09	4.93E-11	4.16E-11	2.12E-10	9.58E-08	1.40E-07	1.56E-09	8.79E-09	1.07E-11	6.54E-11	7.15E-11	4.13E-07
La-140 (Ba-140)	8.73E-12	4.44E-13	7.51E-15	1.65E-12	5.64E-13	9.93E-12	4.75E-11	5.29E-11	2.44E-09	2.50E-09	1.09E-09	5.69E-09	5.91E-12	7.70E-11	4.23E-12	1.19E-08
C-14	1.68E+00	0.00E+00	1.04E-05	0.00E+00	0.00E+00	0.00E+00	4.45E-02	2.67E-01	9.50E+00	8.02E+00	5.33E-01	2.96E-01	8.89E-01	4.45E-02	7.12E-02	2.13E+01
Ce-141	8.08E-08	7.06E-11	7.31E-12	5.41E-09	1.03E-08	4.86E-11	2.68E-10	7.55E-12	9.93E-09	1.50E-08	6.27E-10	5.03E-09	1.73E-12	4.44E-10	3.06E-12	1.28E-07
Ce-144	1.08E-06	1.68E-11	2.16E-12	2.65E-08	2.72E-07	1.02E-09	1.67E-08	4.97E-10	8.67E-08	1.34E-07	6.06E-09	4.82E-08	1.01E-10	2.05E-08	1.61E-10	1.69E-06
Pr-144 (Ce-144)	2.92E-11	1.05E-12	3.28E-12	2.80E-14	1.13E-12	6.75E-17	2.55E-23	8.50E-98	3.30E-16	4.20E-41	3.14E-15	2.52E-14	1.35E-18	1.97E-23	1.60E-198	3.47E-11
Pr-144m (Ce-144)	0.00E+00	5.78E-13	0.00E+00	3.25E-14	4.45E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.11E-13
Cm-242	1.32E-09	1.16E-18	0.00E+00	4.16E-16	7.44E-18	1.12E-12	7.06E-14	3.48E-15	6.85E-15	1.05E-14	1.23E-13	9.87E-13	3.63E-17	7.97E-14	1.77E-15	1.32E-09
Pu-238 (Cm-242)	7.52E-17	1.40E-26	0.00E+00	3.61E-23	1.20E-25	7.35E-14	1.29E-14	6.31E-16	1.22E-15	1.88E-15	5.06E-16	2.28E-15	1.12E-16	4.97E-15	1.10E-16	9.82E-14
Cm-243	4.48E-13	1.21E-19	3.25E-21	7.09E-16	1.93E-17	1.22E-15	2.28E-16	1.12E-17	2.16E-17	3.33E-17	6.05E-17	4.65E-16	7.53E-19	1.12E-16	2.51E-18	4.51E-13
Pu-239 (Cm-243)	8.22E-23	9.48E-30	1.09E-34	2.45E-25	7.96E-27	3.20E-25	8.67E-26	4.25E-27	8.19E-27	1.27E-26	2.11E-26	1.57E-25	1.22E-27	4.01E-26	8.97E-28	8.31E-23
Am-243 (Cm-243)	2.85E-23	4.32E-33	0.00E+00	2.16E-29	1.80E-31	9.05E-19	3.98E-20	1.94E-21	3.74E-21	5.79E-21	3.17E-21	1.43E-21	1.53E-21	9.00E-21	2.00E-22	9.72E-19
Cm-244	5.30E-11	3.27E-20	0.00E+00	1.47E-16	0.00E+00	1.23E-13	2.39E-14	1.17E-15	2.26E-15	3.49E-15	6.65E-15	5.17E-14	6.38E-17	1.21E-14	2.71E-16	5.32E-11
Pu-240 (Cm-244)	1.33E-20	2.50E-30	0.00E+00	7.55E-27	6.06E-30	3.45E-16	1.74E-17	8.51E-19	1.64E-18	2.53E-18	1.22E-18	6.26E-19	5.86E-19	4.02E-18	8.94E-20	3.74E-16
Co-58	1.46E-07	2.76E-09	5.13E-12	5.03E-07	1.35E-08	1.05E-10	1.25E-09	7.34E-11	2.98E-08	4.56E-08	4.84E-09	1.66E-08	1.39E-10	2.11E-09	3.15E-11	7.65E-07
Co-60	7.64E-07	6.90E-09	9.22E-12	2.15E-05	5.52E-08	1.13E-09	3.25E-08	1.95E-09	2.53E-07	3.91E-07	4.93E-08	1.28E-07	1.71E-08	4.84E-08	7.72E-10	2.32E-05
Cr-51	4.09E-09	7.78E-11	0.00E+00	5.67E-09	1.21E-11	2.37E-12	4.07E-11	2.26E-10	1.15E-09	1.73E-09	7.12E-11	5.72E-10	5.26E-14	6.96E-11	9.35E-11	1.38E-08
Cs-134	1.03E-08	2.77E-10	1.75E-12	4.25E-07	1.06E-08	1.19E-11	3.28E-09	1.96E-08	4.21E-07	6.51E-07	2.57E-08	5.44E-09	1.47E-08	6.38E-09	1.01E-08	1.60E-06
Cs-137	4.61E-09	0.00E+00	1.05E-12	4.81E-07	1.11E-08	1.27E-11	1.72E-09	1.03E-08	2.15E-07	3.33E-07	1.24E-08	2.85E-09	7.57E-09	3.60E-09	5.76E-09	1.09E-06
Ba-137m (Cs-137)	0.00E+00	1.56E-11	1.26E-13	6.35E-14	1.12E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E-11
Fe-59	4.67E-08	5.27E-10	2.34E-12	6.08E-08	4.33E-09	3.03E-11	1.90E-08	2.71E-11	6.54E-09	9.98E-09	1.86E-09	7.09E-09	1.43E-11	2.35E-08	1.13E-11	1.81E-07
H-3	1.08E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.58E-04	5.15E-03	7.06E-01	4.37E-02	1.77E-02	9.81E-03	2.94E-02	8.58E-04	1.37E-03	9.23E-01
I-131	3.43E-03	2.31E-06	6.74E-08	3.87E-04	2.12E-04	1.08E-05	2.96E-04	1.37E-03	4.46E-01	6.33E-01	6.30E-03	4.94E-03	3.10E-03	3.80E-04	3.33E-04	1.10E+00
Xe-131m (I-131)	0.00E+00	2.12E-12	1.19E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.31E-12
I-132	1.57E-05	4.67E-06	8.04E-08	9.15E-06	2.73E-06	2.32E-09	1.98E-10	4.49E-19	5.71E-07	6.38E-10	4.86E-08	3.88E-07	6.41E-10	8.99E-11	1.48E-32	3.33E-05
I-133	1.96E-04	8.38E-07	4.34E-08	1.57E-05	1.45E-05	2.10E-07	7.39E-07	4.02E-07	1.62E-03	1.12E-03	7.07E-06	4.12E-05	9.34E-07	4.54E-07	2.69E-09	3.02E-03
Xe-133 (I-133)	0.00E+00	9.13E-12	3.06E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-11
Xe-133m (I-133)	0.00E+00	5.05E-12	4.30E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.48E-12
I-135	2.37E-05	1.23E-06	2.26E-08	8.01E-06	2.35E-06	9.90E-09	6.21E-09	1.96E-11	1.57E-05	1.96E-06	2.09E-07	1.61E-06	6.10E-09	3.03E-09	1.08E-16	5.48E-05
Xe-135 (I-135)	0.00E+00	1.62E-08	2.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E-08
Xe-135m (I-135)	0.00E+00	2.69E-10	2.15E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.91E-10
Kr-85	0.00E+00	5.50E-08	4.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-07
Kr-85m	0.00E+00	3.05E-05	3.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.39E-05
Kr-85 (Kr-85m)	0.00E+00	5.46E-14	3.73E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.28E-13
Kr-87	0.00E+00	1.36E-10	2.16E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E-10
Rb-87 (Kr-87)	1.55E-25	0.00E+00	9.84E-30	0.00E+00	1.15E-25	6.04E-28	2.22E-25	1.33E-24	1.45E-22	2.25E-22	1.54E-24	5.86E-25	1.72E-24	2.70E-25	4.31E-25	3.76E-22
Kr-88	0.00E+00	3.13E-05	4.85E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.18E-05
Rb-88 (Kr-88)	5.86E-07	4.11E-07	1.18E-07	1.13E-08	2.66E-08	1.40E-12	3.87E-15	2.06E-87	7.31E-09	5.04E-33	1.16E-10	9.26E-10	6.16E-12	3.99E-15	2.23E-185	1.16E-06
La-140	3.87E-08	1.72E-09	3.33E-11	7.66E-09	2.61E-09	8.09E-12	5.36E-12	2.33E-13	7.47E-10	7.65E-10	2.09E-10	1.65E-09	4.09E-13	6.75E-12	1.50E-14	5.41E-08
Mn-54	8.36E-08	1.42E-09	0.00E+00	1.03E-06	1.32E-10	8.05E-11	5.85E-09	8.83E-10	4.11E-08	6.35E-08	3.90E-09	8.71E-09	1.81E-09	9.89E-09	3.99E-10	1.26E-06
Nb-95	8.57E-08	1.60E-09	7.25E-13	1.46E-07	6.18E-10	5.25E-11	1.60E-14	9.05E-14	5.72E-11	8.67E-11	1.85E-09	7.50E-09	3.77E-11	2.70E-14	3.78E-14	2.43E-07
Pu-238	1.04E-10	1.82E-20	0.00E+00	5.23E-17	1.74E-19	3.64E-13	5.55E-14	2.72E-15	5.24E-15	8.11E-15	1.43E-14	1.08E-13	4.28E-16	2.67E-14	5.97E-16	1.05E-10
U-234 (Pu-238)	7.70E-23	1.73E-31	1.79E-33	6.90E-28	4.73E-30	3.20E-18	2.04E-27	1.22E-26	3.94E-24	6.09E-24	1.63E-19	3.92E-20	2.34E-19	4.94E-27	7.90E-27	3.64E-18
Pu-239	1.38E-11	1.89E-21	0.00E+00	1.10E-17	9.16E-20	5.64E-14	7.72E-15	3.78E-16	7.29E-16	1.13E-15	1.95E-15	1.45E-14	7.08E-17	3.64E-15	8.15E-17	1.39E-11
U-235 (Pu-239)	3.10E-27	6.94E-33	9.12E-36	5.26E-29	5.28E-31	1.50E-22	9.03E-32	5.42E-31	1.75E-28	2.70E-28	8.35E-24	1.97E-24	1.20E-23	2.19E-31	3.50E-31	1.72E-22

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Pu-240	2.19E-11	3.83E-21	0.00E+00	1.30E-17	1.04E-20	8.91E-14	1.22E-14	5.99E-16	1.15E-15	1.79E-15	3.08E-15	2.30E-14	1.12E-16	5.76E-15	1.29E-16	2.20E-11
U-236 (Pu-240)	1.48E-25	2.34E-34	2.46E-36	7.68E-31	1.27E-33	7.12E-21	4.30E-30	2.58E-29	8.31E-27	1.29E-26	3.97E-22	9.38E-23	5.70E-22	1.04E-29	1.67E-29	8.18E-21
Sb-122	4.19E-10	4.12E-12	4.31E-13	2.96E-11	5.11E-11	1.11E-13	1.34E-11	3.71E-13	6.65E-11	7.96E-11	3.58E-12	2.75E-11	2.50E-14	1.75E-11	4.65E-14	7.13E-10
Sb-124	1.76E-07	1.63E-09	2.70E-11	2.53E-07	5.30E-08	1.22E-10	4.12E-08	2.39E-09	3.47E-08	5.31E-08	5.43E-09	1.91E-08	1.43E-10	7.59E-08	1.12E-09	7.17E-07
Sb-125	2.35E-08	7.84E-11	6.91E-13	1.53E-07	4.15E-09	2.92E-11	5.28E-09	3.16E-10	3.48E-09	5.38E-09	7.22E-10	1.84E-09	1.37E-10	1.10E-08	1.74E-10	2.09E-07
Te-125m (Sb-125)	1.24E-13	1.58E-17	1.37E-18	1.75E-15	5.71E-17	9.54E-12	1.34E-09	3.31E-10	3.76E-09	5.75E-09	1.65E-09	4.43E-10	8.52E-10	2.72E-09	2.56E-10	1.71E-08
Sr-89	1.47E-07	6.54E-14	3.77E-11	8.35E-12	6.80E-08	9.81E-11	8.12E-11	4.67E-10	2.56E-07	3.91E-07	4.77E-09	1.78E-08	3.49E-10	1.15E-10	1.67E-10	8.86E-07
Sr-90	4.29E-08	0.00E+00	6.06E-13	4.06E-15	2.15E-08	1.17E-10	1.57E-10	9.43E-10	4.69E-07	7.26E-07	5.69E-09	2.50E-08	1.19E-08	1.18E-10	1.88E-10	1.30E-06
Y-90 (Sr-90)	5.70E-13	5.53E-22	6.69E-16	3.28E-21	5.89E-14	1.44E-16	5.00E-18	1.38E-18	3.51E-14	4.19E-14	9.53E-15	7.32E-14	6.62E-17	6.54E-18	1.70E-19	7.90E-13
Xe-131m	0.00E+00	4.58E-07	2.89E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.47E-07
Xe-133	0.00E+00	1.44E-04	1.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E-04
Xe-133m	0.00E+00	9.74E-09	3.73E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-08
Xe-133 (Xe-133m)	0.00E+00	1.25E-12	1.07E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-12
Zn-65	3.99E-08	4.43E-10	7.21E-14	2.58E-07	3.51E-10	3.66E-11	2.05E-09	1.22E-08	4.71E-06	7.27E-06	2.64E-08	2.95E-08	1.61E-08	1.97E-09	3.10E-09	1.24E-05
Zr-95	1.27E-07	7.41E-10	4.96E-12	2.47E-07	1.19E-08	8.90E-11	1.83E-14	1.06E-13	7.84E-11	1.20E-10	2.09E-09	7.31E-09	1.85E-11	3.47E-14	5.15E-14	3.96E-07
Nb-95 (Zr-95)	3.03E-12	8.61E-15	1.39E-15	9.16E-13	1.97E-13	8.74E-16	1.05E-19	3.54E-19	2.81E-15	3.59E-15	3.88E-14	2.90E-13	2.89E-16	1.41E-19	5.89E-20	4.49E-12
Nb-95m (Zr-95)	5.21E-13	1.11E-14	4.41E-18	8.50E-13	3.59E-15	8.03E-12	9.43E-15	5.33E-14	5.97E-12	9.05E-12	6.91E-10	1.27E-09	3.24E-11	1.81E-14	2.52E-14	2.02E-09
Total	**1.79E+00**	**1.22E-01**	**3.61E-03**	**4.45E-04**	**2.32E-04**	**1.10E-05**	**4.57E-02**	**2.74E-01**	**1.07E+01**	**8.70E+00**	**5.57E-01**	**3.11E-01**	**9.22E-01**	**4.57E-02**	**7.29E-02**	**2.35E+01**

Table A.14: Stage 3 Assessment (μSv/y) for an Adult (Mean Consumption Rate) due to Gaseous Discharges

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Ag-110m	1.86E-10	4.30E-12	2.18E-15	3.51E-09	2.30E-10	1.72E-13	2.76E-10	3.73E-12	8.37E-10	1.93E-09	3.90E-12	2.45E-11	4.45E-12	3.26E-10	3.10E-12	7.34E-09
Am-241	1.74E-11	5.63E-19	1.47E-23	3.32E-15	4.42E-20	6.87E-14	1.14E-14	5.10E-16	5.83E-17	1.35E-16	1.13E-15	2.66E-14	1.14E-16	5.31E-15	2.16E-16	1.75E-11
Np-237 (Am-241)	5.42E-24	4.24E-31	4.75E-34	3.94E-26	3.14E-28	2.54E-19	2.16E-20	9.60E-22	1.10E-22	2.54E-22	5.13E-21	8.60E-21	7.13E-21	4.69E-21	1.90E-22	3.03E-19
Ar-41	0.00E+00	2.61E-01	3.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.65E-01
Ba-140	1.12E-07	2.57E-10	1.29E-11	1.55E-07	8.18E-09	5.28E-11	3.30E-11	1.53E-10	4.11E-09	9.01E-09	5.01E-10	8.89E-09	6.16E-12	5.20E-11	1.03E-10	2.98E-07
La-140 (Ba-140)	6.40E-12	9.51E-13	7.51E-15	4.79E-12	5.64E-13	7.28E-12	4.02E-11	4.07E-11	1.12E-10	1.71E-10	3.73E-10	6.13E-09	3.64E-12	6.52E-11	6.51E-12	6.96E-09
C-14	2.14E+00	0.00E+00	1.04E-05	0.00E+00	0.00E+00	0.00E+00	8.87E-02	4.84E-01	1.02E+00	1.29E+00	4.30E-01	7.52E-01	1.29E+00	8.87E-02	2.58E-01	7.84E+00
Ce-141	9.86E-08	1.51E-10	7.31E-12	1.57E-08	1.03E-08	5.93E-11	2.05E-10	5.25E-12	4.10E-10	9.31E-10	1.94E-10	4.91E-09	9.62E-13	3.40E-10	4.26E-12	1.32E-07
Ce-144	1.02E-06	3.60E-11	2.16E-12	7.69E-08	2.72E-07	9.62E-10	1.22E-08	3.31E-10	3.43E-09	7.93E-09	1.80E-09	4.50E-08	5.42E-11	1.50E-08	2.15E-10	1.46E-06
Pr-144 (Ce-144)	1.84E-11	2.25E-12	3.28E-12	8.12E-14	1.13E-12	4.25E-17	2.00E-23	6.07E-98	1.40E-17	2.67E-42	9.96E-16	2.52E-14	7.70E-19	1.54E-23	2.29E-198	2.52E-11
Pr-144m (Ce-144)	0.00E+00	1.24E-12	0.00E+00	9.40E-14	4.45E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-12
Cm-242	1.60E-09	2.48E-18	0.00E+00	1.20E-15	7.44E-18	1.36E-12	6.13E-14	2.75E-15	3.21E-16	7.40E-16	4.31E-14	1.09E-12	2.29E-17	6.92E-14	2.79E-15	1.60E-09
Pu-238 (Cm-242)	1.96E-16	3.01E-26	0.00E+00	1.05E-22	1.20E-25	1.92E-13	4.09E-14	1.81E-15	2.07E-16	4.80E-16	6.46E-16	9.20E-15	2.58E-16	1.57E-14	6.34E-16	2.62E-13
Cm-243	9.55E-13	2.60E-19	3.25E-21	2.05E-15	1.93E-17	2.60E-15	5.71E-16	2.54E-17	2.91E-18	6.74E-18	6.11E-17	1.48E-15	1.37E-18	2.81E-16	1.14E-17	9.62E-13
Pu-239 (Cm-243)	2.08E-22	2.03E-29	1.09E-34	7.10E-25	7.96E-27	8.09E-25	2.58E-25	1.15E-26	1.31E-27	3.04E-27	2.53E-26	5.96E-25	2.64E-27	1.19E-25	4.85E-27	2.11E-22
Am-243 (Cm-243)	7.78E-23	9.27E-33	0.00E+00	6.25E-29	1.80E-31	2.47E-18	1.30E-19	5.78E-21	6.61E-22	1.53E-21	4.19E-21	5.98E-21	3.65E-21	2.95E-20	1.19E-21	2.65E-18
Cm-244	1.05E-10	7.01E-20	0.00E+00	4.25E-16	0.00E+00	2.45E-13	5.43E-14	2.42E-15	2.77E-16	6.41E-16	6.12E-15	1.50E-13	1.06E-16	2.76E-14	1.12E-15	1.05E-10
Pu-240 (Cm-244)	3.62E-20	5.35E-30	0.00E+00	2.19E-26	6.06E-30	9.41E-16	5.71E-17	2.53E-18	2.90E-19	6.71E-19	1.62E-18	2.61E-18	1.40E-18	1.32E-17	5.32E-19	1.02E-15
Co-58	1.51E-07	5.93E-09	5.13E-12	1.46E-06	1.35E-08	1.08E-10	1.17E-09	6.17E-11	1.49E-09	3.41E-09	1.81E-09	1.95E-08	9.38E-11	1.95E-09	5.30E-11	1.66E-06
Co-60	9.44E-07	1.48E-08	9.22E-12	6.24E-05	5.52E-08	1.40E-09	2.25E-08	1.23E-09	9.46E-09	2.19E-08	1.38E-08	1.13E-07	8.60E-09	3.35E-08	9.73E-10	6.36E-05
Cr-51	3.03E-09	1.67E-10	0.00E+00	1.64E-08	1.21E-11	1.75E-12	3.70E-11	1.87E-10	5.64E-11	1.27E-10	2.61E-11	6.62E-10	3.47E-14	6.32E-11	1.54E-10	2.09E-08
Cs-134	3.90E-08	5.93E-10	1.75E-12	1.23E-06	1.06E-08	4.52E-11	2.14E-08	1.17E-07	1.49E-07	3.44E-07	6.77E-08	4.52E-08	6.99E-08	4.17E-08	1.21E-07	2.26E-06
Cs-137	1.65E-08	0.00E+00	1.05E-12	1.39E-06	1.11E-08	4.56E-11	1.03E-08	5.59E-08	6.92E-08	1.60E-07	2.97E-08	2.16E-08	3.28E-08	2.15E-08	6.24E-08	1.88E-06
Ba-137m (Cs-137)	0.00E+00	3.33E-11	1.26E-13	1.84E-13	1.12E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.36E-11
Fe-59	5.58E-08	1.13E-09	2.34E-12	1.76E-07	4.33E-09	3.61E-11	1.44E-08	1.88E-11	2.69E-10	6.14E-10	5.72E-10	6.87E-09	7.92E-12	1.79E-08	1.55E-11	2.79E-07
H-3	1.70E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.77E-03	9.65E-03	7.86E-02	7.28E-03	1.47E-02	2.57E-02	4.42E-02	1.77E-03	5.15E-03	3.59E-01
I-131	1.48E-03	4.95E-06	6.74E-08	1.12E-03	2.12E-04	4.65E-06	1.99E-04	8.39E-04	1.62E-02	3.44E-02	1.71E-03	4.23E-03	1.51E-03	2.55E-04	4.06E-04	6.26E-02
Xe-131m (I-131)	0.00E+00	4.55E-12	1.19E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.74E-12
I-132	6.44E-06	1.00E-05	8.04E-08	2.65E-05	2.73E-06	9.55E-10	1.32E-10	2.71E-19	2.05E-08	3.42E-11	1.30E-08	3.28E-07	3.10E-10	5.98E-11	1.78E-32	4.61E-05
I-133	6.84E-05	1.79E-06	4.34E-08	4.53E-05	1.45E-05	7.34E-08	3.97E-07	1.97E-07	4.70E-05	4.89E-05	1.54E-06	2.82E-05	3.65E-07	2.44E-07	2.63E-09	2.57E-04
Xe-133 (I-133)	0.00E+00	1.96E-11	3.06E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E-11
Xe-133m (I-133)	0.00E+00	1.08E-11	4.30E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E-11
I-135	8.59E-06	2.63E-06	2.26E-08	2.32E-05	2.35E-06	3.59E-09	3.57E-09	1.02E-11	4.86E-07	9.08E-08	4.86E-08	1.18E-06	2.55E-09	1.74E-09	1.13E-16	3.86E-05
Xe-135 (I-135)	0.00E+00	3.47E-08	2.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-08
Xe-135m (I-135)	0.00E+00	5.76E-10	2.15E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.98E-10
Kr-85	0.00E+00	1.18E-07	4.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.47E-07
Kr-85m	0.00E+00	6.54E-05	3.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.88E-05
Kr-85 (Kr-85m)	0.00E+00	1.17E-13	3.73E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.90E-13
Kr-87	0.00E+00	2.91E-10	2.16E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.13E-10
Rb-87 (Kr-87)	7.93E-26	0.00E+00	9.84E-30	0.00E+00	1.15E-25	3.09E-28	1.83E-25	9.99E-25	6.48E-24	1.50E-23	5.14E-25	6.16E-25	1.03E-24	2.22E-25	6.47E-25	2.59E-23
Kr-88	0.00E+00	6.71E-05	4.85E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.76E-05
Rb-88 (Kr-88)	3.28E-07	8.81E-07	1.18E-07	3.27E-08	2.66E-08	7.80E-13	3.09E-15	1.49E-87	3.15E-10	3.25E-34	3.75E-11	9.41E-10	3.58E-12	3.18E-15	3.24E-185	1.39E-06
La-140	2.84E-08	3.69E-09	3.33E-11	2.22E-08	2.61E-09	5.93E-12	4.53E-12	1.79E-13	3.41E-11	5.23E-11	7.14E-11	1.77E-09	2.52E-13	5.71E-12	2.30E-14	5.89E-08
Mn-54	8.49E-08	3.05E-09	0.00E+00	2.99E-06	1.32E-10	8.17E-11	7.37E-09	1.01E-09	2.79E-09	6.46E-09	1.99E-09	1.39E-08	1.66E-09	1.25E-08	9.13E-10	3.13E-06
Nb-95	1.04E-07	3.42E-09	7.25E-13	4.23E-07	6.18E-10	6.36E-11	1.60E-14	8.20E-14	3.08E-12	6.99E-12	7.47E-10	9.53E-09	2.73E-11	2.70E-14	6.84E-14	5.41E-07
Pu-238	2.72E-10	3.90E-20	0.00E+00	1.51E-16	1.74E-19	9.51E-13	1.76E-13	7.82E-15	8.95E-16	2.07E-15	1.83E-14	4.36E-13	9.84E-16	8.44E-14	3.43E-15	2.74E-10
U-234 (Pu-238)	1.03E-22	3.71E-31	1.79E-33	2.00E-27	4.73E-30	4.28E-18	4.22E-27	2.30E-26	4.41E-25	1.02E-24	1.37E-19	1.04E-19	3.53E-19	1.02E-26	2.98E-26	4.87E-18
Pu-239	3.77E-11	4.06E-21	0.00E+00	3.17E-17	9.16E-20	1.54E-13	2.53E-14	1.13E-15	1.29E-16	2.98E-16	2.57E-15	6.05E-14	1.69E-16	1.19E-14	4.85E-16	3.80E-11
U-235 (Pu-239)	4.04E-27	1.49E-32	9.12E-36	1.52E-28	5.28E-31	1.95E-22	1.80E-31	9.79E-31	1.88E-29	4.34E-29	6.71E-24	4.99E-24	1.74E-23	4.35E-31	1.27E-30	2.24E-22

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Pu-240	5.98E-11	8.21E-21	0.00E+00	3.77E-17	1.04E-20	2.43E-13	4.00E-14	1.78E-15	2.04E-16	4.72E-16	4.08E-15	9.58E-14	2.66E-16	1.89E-14	7.68E-16	6.02E-11
U-236 (Pu-240)	1.98E-25	5.01E-34	2.46E-36	2.22E-30	1.27E-33	9.56E-21	8.55E-30	4.66E-29	8.92E-28	2.07E-27	3.19E-22	2.37E-22	8.25E-22	2.07E-29	6.03E-29	1.09E-20
Sb-122	3.08E-10	8.82E-12	4.31E-13	8.57E-11	5.11E-11	8.19E-14	1.04E-11	2.63E-13	2.80E-12	5.01E-12	1.13E-12	2.73E-11	1.42E-14	1.37E-11	6.59E-14	5.15E-10
Sb-124	1.97E-07	3.49E-09	2.70E-11	7.32E-07	5.30E-08	1.36E-10	3.54E-08	1.87E-09	1.61E-09	3.68E-09	1.89E-09	2.09E-08	8.96E-11	6.53E-08	1.75E-09	1.12E-06
Sb-125	2.96E-08	1.68E-10	6.91E-13	4.43E-07	4.15E-09	3.68E-11	5.23E-09	2.85E-10	1.86E-10	4.31E-10	2.89E-10	2.32E-09	9.87E-11	1.09E-08	3.15E-10	4.97E-07
Te-125m (Sb-125)	1.60E-13	3.38E-17	1.37E-18	5.07E-15	5.71E-17	1.24E-11	1.02E-09	2.29E-10	1.54E-10	3.53E-10	5.07E-10	4.28E-10	4.71E-10	2.06E-09	3.54E-10	5.59E-09
Sr-89	1.57E-07	1.40E-13	3.77E-11	2.42E-11	6.80E-08	1.05E-10	6.45E-11	3.38E-10	1.10E-08	2.51E-08	1.53E-09	1.80E-08	2.02E-10	9.16E-11	2.42E-10	2.82E-07
Sr-90	5.89E-08	0.00E+00	6.06E-13	1.18E-14	2.15E-08	1.61E-10	3.31E-10	1.81E-09	5.34E-08	1.24E-07	4.85E-09	6.70E-08	1.82E-08	2.48E-10	7.22E-10	3.51E-07
Y-90 (Sr-90)	4.08E-13	1.18E-21	6.69E-16	9.50E-21	5.89E-14	1.03E-16	3.72E-18	9.29E-19	1.41E-15	2.52E-15	2.86E-15	6.91E-14	3.57E-17	4.86E-18	2.29E-19	5.44E-13
Xe-131m	0.00E+00	9.82E-07	2.89E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.27E-06
Xe-133	0.00E+00	3.09E-04	1.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E-04
Xe-133m	0.00E+00	2.09E-08	3.73E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.46E-08
Xe-133 (Xe-133m)	0.00E+00	2.68E-12	1.07E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E-12
Zn-65	4.13E-08	9.50E-10	7.21E-14	7.48E-07	3.51E-10	3.78E-11	2.75E-09	1.49E-08	3.41E-07	7.87E-07	1.43E-08	5.04E-08	1.57E-08	2.65E-09	7.55E-09	2.03E-06
Zr-95	1.60E-07	1.59E-09	4.96E-12	7.14E-07	1.19E-08	1.12E-10	1.70E-14	8.99E-14	3.95E-12	9.05E-12	7.86E-10	8.68E-09	1.26E-11	3.24E-14	8.74E-14	8.97E-07
Nb-95 (Zr-95)	3.23E-12	1.85E-14	1.39E-15	2.65E-12	1.97E-13	9.35E-16	7.88E-20	2.41E-19	1.14E-16	2.18E-16	1.18E-14	2.77E-13	1.58E-16	1.06E-19	8.05E-20	6.39E-12
Nb-95m (Zr-95)	6.31E-13	2.37E-14	4.41E-18	2.46E-12	3.59E-15	9.72E-12	9.40E-15	4.83E-14	3.21E-13	7.29E-13	2.78E-10	1.61E-09	2.35E-11	1.80E-14	4.58E-14	1.93E-09
Total	**2.31E+00**	**2.61E-01**	**3.61E-03**	**1.29E-03**	**2.32E-04**	**4.73E-06**	**9.07E-02**	**4.94E-01**	**1.11E+00**	**1.33E+00**	**4.46E-01**	**7.82E-01**	**1.34E+00**	**9.07E-02**	**2.64E-01**	**8.53E+00**

Table A.15: Stage 3 Assessment (µSv/y) for a Child (Mean Consumption Rate) due to Gaseous Discharges

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Ag-110m	2.03E-10	2.58E-12	2.18E-15	1.79E-09	2.30E-10	1.87E-13	2.80E-10	6.94E-12	1.80E-09	2.69E-09	5.43E-12	1.95E-11	6.89E-12	3.30E-10	2.88E-12	7.37E-09
Am-241	1.15E-11	3.38E-19	1.47E-23	1.69E-15	4.42E-20	4.52E-14	6.87E-15	5.61E-16	7.43E-17	1.11E-16	9.32E-16	1.26E-14	1.04E-16	3.19E-15	1.19E-16	1.16E-11
Np-237 (Am-241)	3.58E-24	2.55E-31	4.75E-34	2.01E-26	3.14E-28	1.68E-19	1.18E-20	9.60E-22	1.27E-22	1.91E-22	3.85E-21	3.69E-21	5.94E-21	2.56E-21	9.52E-23	1.97E-19
Ar-41	0.00E+00	1.56E-01	3.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.60E-01
Ba-140	1.16E-07	1.54E-10	1.29E-11	7.87E-08	8.18E-09	5.44E-11	4.02E-11	3.42E-10	1.06E-08	1.51E-08	8.39E-10	8.50E-09	1.15E-11	6.32E-11	1.15E-10	2.39E-07
La-140 (Ba-140)	8.04E-12	5.71E-13	7.51E-15	2.44E-12	5.64E-13	9.15E-12	4.60E-11	8.54E-11	2.71E-10	2.69E-10	5.87E-10	5.51E-09	6.36E-12	7.47E-11	6.83E-12	6.88E-09
C-14	2.07E+00	0.00E+00	1.04E-05	0.00E+00	0.00E+00	0.00E+00	6.67E-02	6.67E-01	1.63E+00	1.34E+00	4.44E-01	4.44E-01	1.48E+00	6.67E-02	1.78E-01	8.39E+00
Ce-141	9.80E-08	9.08E-11	7.31E-12	7.98E-09	1.03E-08	5.89E-11	2.37E-10	1.11E-11	1.00E-09	1.47E-09	3.07E-10	4.44E-09	1.69E-12	3.92E-10	4.50E-12	1.24E-07
Ce-144	1.08E-06	2.16E-11	2.16E-12	3.91E-08	2.72E-07	1.02E-09	1.41E-08	7.00E-10	8.40E-09	1.26E-08	2.85E-09	4.08E-08	9.55E-11	1.73E-08	2.27E-10	1.49E-06
Pr-144 (Ce-144)	2.40E-11	1.35E-12	3.28E-12	4.13E-14	1.13E-12	5.55E-17	2.07E-23	1.15E-97	3.08E-17	3.80E-42	1.42E-15	2.06E-14	1.22E-18	1.60E-23	2.17E-198	2.98E-11
Pr-144m (Ce-144)	0.00E+00	7.44E-13	0.00E+00	4.78E-14	4.45E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.92E-13
Cm-242	1.55E-09	1.49E-18	0.00E+00	6.13E-16	7.44E-18	1.32E-12	6.69E-14	5.50E-15	7.43E-16	1.11E-15	6.47E-14	9.35E-13	3.82E-17	7.55E-14	2.79E-15	1.55E-09
Pu-238 (Cm-242)	1.30E-16	1.81E-26	0.00E+00	5.32E-23	1.20E-25	1.27E-13	2.33E-14	1.89E-15	2.50E-16	3.76E-16	5.06E-16	4.11E-15	2.25E-16	8.94E-15	3.31E-16	1.67E-13
Cm-243	6.60E-13	1.56E-19	3.25E-21	1.05E-15	1.93E-17	1.80E-15	3.32E-16	2.71E-17	3.59E-18	5.39E-18	4.89E-17	6.77E-16	1.22E-18	1.63E-16	6.09E-18	6.64E-13
Pu-239 (Cm-243)	1.40E-22	1.22E-29	1.09E-34	3.62E-25	7.96E-27	5.45E-25	1.55E-25	1.26E-26	1.67E-27	2.51E-27	2.09E-26	2.81E-25	2.42E-27	7.15E-26	2.67E-27	1.41E-22
Am-243 (Cm-243)	5.16E-23	5.56E-33	0.00E+00	3.18E-29	1.80E-31	1.64E-18	7.67E-20	6.25E-21	8.27E-22	1.24E-21	3.39E-21	2.77E-21	3.28E-21	1.74E-20	6.44E-22	1.75E-18
Cm-244	7.28E-11	4.21E-20	0.00E+00	2.16E-16	0.00E+00	1.69E-13	3.46E-14	2.82E-15	3.74E-16	5.61E-16	5.35E-15	7.48E-14	1.03E-16	1.75E-14	6.55E-16	7.31E-11
Pu-240 (Cm-244)	2.41E-20	3.21E-30	0.00E+00	1.11E-26	6.06E-30	6.24E-16	3.36E-17	2.74E-18	3.62E-19	5.43E-19	1.31E-18	1.21E-18	1.26E-18	7.75E-18	2.88E-19	6.73E-16
Co-58	1.56E-07	3.56E-09	5.13E-12	7.41E-07	1.35E-08	1.13E-10	1.46E-09	1.41E-10	3.95E-09	5.88E-09	3.12E-09	1.92E-08	1.79E-10	2.44E-09	6.09E-11	9.51E-07
Co-60	9.78E-07	8.87E-09	9.22E-12	3.18E-05	5.52E-08	1.45E-09	3.98E-08	3.97E-09	3.54E-08	5.31E-08	3.35E-08	1.57E-07	2.32E-08	5.92E-08	1.57E-09	3.33E-05
Cr-51	3.73E-09	1.00E-10	0.00E+00	8.35E-09	1.21E-11	2.16E-12	4.14E-11	3.84E-10	1.34E-10	1.96E-10	4.02E-11	5.82E-10	5.94E-14	7.08E-11	1.58E-10	1.38E-08
Cs-134	2.17E-08	3.56E-10	1.75E-12	6.26E-07	1.06E-08	2.51E-11	8.62E-09	8.59E-08	1.27E-07	1.90E-07	3.74E-08	1.43E-08	4.29E-08	1.68E-08	4.44E-08	1.23E-06
Cs-137	9.17E-09	0.00E+00	1.05E-12	7.09E-07	1.11E-08	2.53E-11	4.30E-09	4.30E-08	6.16E-08	9.24E-08	1.72E-08	7.12E-09	2.10E-08	9.00E-09	2.40E-08	1.01E-06
Ba-137m (Cs-137)	0.00E+00	2.00E-11	1.26E-13	9.36E-14	1.12E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E-11
Fe-59	5.74E-08	6.77E-10	2.34E-12	8.96E-08	4.33E-09	3.71E-11	2.06E-08	4.90E-11	8.14E-10	1.20E-09	1.12E-09	7.69E-09	1.72E-11	2.55E-08	2.03E-11	2.09E-07
H-3	1.50E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-03	1.23E-02	1.16E-01	6.98E-03	1.41E-02	1.41E-02	4.70E-02	1.23E-03	3.29E-03	3.66E-01
I-131	2.63E-03	2.97E-06	6.74E-08	5.70E-04	2.12E-04	8.25E-06	2.57E-04	1.98E-03	4.43E-02	6.10E-02	3.03E-03	4.28E-03	2.98E-03	3.29E-04	4.80E-04	1.22E-01
Xe-131m (I-131)	0.00E+00	2.73E-12	1.19E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.92E-12
I-132	1.04E-05	6.00E-06	8.04E-08	1.35E-05	2.73E-06	1.54E-09	1.54E-10	5.79E-19	5.07E-08	5.49E-11	2.09E-08	3.01E-07	5.52E-10	6.97E-11	1.91E-32	3.31E-05
I-133	1.20E-04	1.08E-06	4.34E-08	2.31E-05	1.45E-05	1.29E-07	5.04E-07	4.57E-07	1.27E-04	8.53E-05	2.68E-06	2.81E-05	7.08E-07	3.09E-07	3.05E-09	4.04E-04
Xe-133 (I-133)	0.00E+00	1.17E-11	3.06E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E-11
Xe-133m (I-133)	0.00E+00	6.50E-12	4.30E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.93E-12
I-135	1.47E-05	1.58E-06	2.26E-08	1.18E-05	2.35E-06	6.13E-09	4.60E-09	2.42E-11	1.33E-06	1.61E-07	8.61E-08	1.19E-06	5.03E-09	2.25E-09	1.34E-16	3.32E-05
Xe-135 (I-135)	0.00E+00	2.08E-08	2.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.11E-08
Xe-135m (I-135)	0.00E+00	3.46E-10	2.15E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.68E-10
Kr-85	0.00E+00	7.08E-08	4.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.00E-07
Kr-85m	0.00E+00	3.93E-05	3.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.27E-05
Kr-85 (Kr-85m)	0.00E+00	7.01E-14	3.73E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.43E-13
Kr-87	0.00E+00	1.74E-10	2.16E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.96E-10
Rb-87 (Kr-87)	1.21E-25	0.00E+00	9.84E-30	0.00E+00	1.15E-25	4.70E-28	2.06E-25	2.06E-24	1.55E-23	2.33E-23	7.96E-25	5.45E-25	1.78E-24	2.51E-25	6.69E-25	4.53E-23
Kr-88	0.00E+00	4.03E-05	4.85E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E-05
Rb-88 (Kr-88)	4.53E-07	5.29E-07	1.18E-07	1.66E-08	2.66E-08	1.08E-12	3.18E-15	2.82E-87	6.89E-10	4.61E-34	5.32E-11	7.62E-10	5.63E-12	3.28E-15	3.06E-185	1.14E-06
La-140	3.56E-08	2.21E-09	3.33E-11	1.13E-08	2.61E-09	7.45E-12	5.19E-12	3.76E-13	8.30E-11	8.24E-11	1.12E-10	1.60E-09	4.40E-13	6.54E-12	2.42E-14	5.37E-08
Mn-54	9.40E-08	1.83E-09	0.00E+00	1.53E-06	1.32E-10	9.04E-11	7.36E-09	1.85E-09	5.93E-09	8.87E-09	2.73E-09	1.10E-08	2.53E-09	1.25E-08	8.35E-10	1.67E-06
Nb-95	1.05E-07	2.05E-09	7.25E-13	2.15E-07	6.18E-10	6.45E-11	1.65E-14	1.56E-13	6.76E-12	9.90E-12	1.06E-09	7.73E-09	4.31E-11	2.79E-14	6.48E-14	3.33E-07
Pu-238	1.80E-10	2.34E-20	0.00E+00	7.71E-17	1.74E-19	6.29E-13	1.00E-13	8.16E-15	1.08E-15	1.62E-15	1.43E-14	1.95E-13	8.56E-16	4.80E-14	1.79E-15	1.81E-10
U-234 (Pu-238)	9.75E-23	2.22E-31	1.79E-33	1.02E-27	4.73E-30	4.06E-18	3.48E-27	3.48E-26	7.71E-25	1.16E-24	1.55E-19	6.70E-20	4.44E-19	8.43E-27	2.25E-26	4.73E-18
Pu-239	2.51E-11	2.43E-21	0.00E+00	1.62E-17	9.16E-20	1.02E-13	1.49E-14	1.22E-15	1.61E-16	2.42E-16	2.09E-15	2.80E-14	1.52E-16	7.02E-15	2.62E-16	2.53E-11
U-235 (Pu-239)	3.87E-27	8.92E-33	9.12E-36	7.76E-29	5.28E-31	1.87E-22	1.48E-31	1.48E-30	3.28E-29	4.92E-29	7.60E-24	3.23E-24	2.18E-23	3.59E-31	9.57E-31	2.20E-22

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Pu-240	3.97E-11	4.93E-21	0.00E+00	1.92E-17	1.04E-20	1.61E-13	2.36E-14	1.92E-15	2.55E-16	3.82E-16	3.30E-15	4.43E-14	2.40E-16	1.11E-14	4.15E-16	3.99E-11
U-236 (Pu-240)	1.93E-25	3.00E-34	2.46E-36	1.13E-30	1.27E-33	9.29E-21	6.94E-30	6.94E-29	1.54E-27	2.31E-27	3.56E-22	1.51E-22	1.02E-21	1.68E-29	4.49E-29	1.08E-20
Sb-122	3.84E-10	5.29E-12	4.31E-13	4.36E-11	5.11E-11	1.02E-13	1.24E-11	5.72E-13	7.05E-12	8.18E-12	1.84E-12	2.54E-11	2.57E-14	1.62E-11	7.17E-14	5.56E-10
Sb-124	2.05E-07	2.09E-09	2.70E-11	3.73E-07	5.30E-08	1.41E-10	4.02E-08	3.88E-09	3.88E-09	5.75E-09	2.94E-09	1.86E-08	1.55E-10	7.40E-08	1.82E-09	7.84E-07
Sb-125	2.90E-08	1.01E-10	6.91E-13	2.25E-07	4.15E-09	3.60E-11	5.45E-09	5.44E-10	4.12E-10	6.17E-10	4.14E-10	1.90E-09	1.57E-10	1.13E-08	3.00E-10	2.79E-07
Te-125m (Sb-125)	1.56E-13	2.03E-17	1.37E-18	2.58E-15	5.71E-17	1.21E-11	1.21E-09	4.99E-10	3.90E-10	5.78E-10	8.31E-10	4.00E-10	8.56E-10	2.46E-09	3.86E-10	7.62E-09
Sr-89	1.62E-07	8.40E-14	3.77E-11	1.23E-11	6.80E-08	1.08E-10	7.85E-11	7.53E-10	2.84E-08	4.20E-08	2.56E-09	1.72E-08	3.75E-10	1.11E-10	2.70E-10	3.22E-07
Sr-90	5.77E-08	0.00E+00	6.06E-13	5.98E-15	2.15E-08	1.58E-10	3.87E-10	3.87E-09	1.33E-07	1.99E-07	7.80E-09	6.16E-08	3.25E-08	2.90E-10	7.73E-10	5.19E-07
Y-90 (Sr-90)	5.08E-13	7.11E-22	6.69E-16	4.83E-21	5.89E-14	1.28E-16	4.43E-18	2.03E-18	3.56E-15	4.12E-15	4.68E-15	6.48E-14	6.51E-17	5.79E-18	2.50E-19	6.45E-13
Xe-131m	0.00E+00	5.89E-07	2.89E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.78E-07
Xe-133	0.00E+00	1.85E-04	1.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E-04
Xe-133m	0.00E+00	1.25E-08	3.73E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.62E-08
Xe-133 (Xe-133m)	0.00E+00	1.61E-12	1.07E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E-12
Zn-65	4.28E-08	5.70E-10	7.21E-14	3.80E-07	3.51E-10	3.92E-11	2.46E-09	2.44E-08	6.48E-07	9.69E-07	1.76E-08	3.54E-08	2.15E-08	2.37E-09	6.19E-09	2.15E-06
Zr-95	1.57E-07	9.53E-10	4.96E-12	3.63E-07	1.19E-08	1.10E-10	1.86E-14	1.80E-13	9.15E-12	1.36E-11	1.18E-09	7.44E-09	2.09E-11	3.54E-14	8.74E-14	5.42E-07
Nb-95 (Zr-95)	3.40E-12	1.11E-14	1.39E-15	1.35E-12	1.97E-13	9.82E-16	9.21E-20	5.18E-19	2.83E-16	3.50E-16	1.90E-14	2.54E-13	2.82E-16	1.24E-19	8.62E-20	5.23E-12
Nb-95m (Zr-95)	6.39E-13	1.42E-14	4.41E-18	1.25E-12	3.59E-15	9.86E-12	9.72E-15	9.17E-14	7.05E-13	1.04E-12	3.96E-10	1.31E-09	3.72E-11	1.87E-14	4.34E-14	1.76E-09
Total	**2.22E+00**	**1.56E-01**	**3.61E-03**	**6.56E-04**	**2.32E-04**	**8.39E-06**	**6.82E-02**	**6.81E-01**	**1.79E+00**	**1.41E+00**	**4.61E-01**	**4.62E-01**	**1.53E+00**	**6.83E-02**	**1.82E-01**	**9.04E+00**

Table A.16: Stage 3 Assessment (µSv/y) for an Infant (Mean Consumption Rate) due to Gaseous Discharges

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Ag-110m	1.64E-10	2.01E-12	2.18E-15	1.21E-09	2.30E-10	1.51E-13	2.51E-10	3.73E-12	5.73E-09	7.25E-09	8.77E-12	1.75E-11	5.57E-12	2.96E-10	1.55E-12	1.52E-08
Am-241	6.82E-12	2.63E-19	1.47E-23	1.15E-15	4.42E-20	2.69E-14	3.85E-15	1.89E-16	1.48E-16	1.87E-16	9.40E-16	7.04E-15	5.25E-17	1.79E-15	4.00E-17	6.86E-12
Np-237 (Am-241)	2.25E-24	1.98E-31	4.75E-34	1.36E-26	3.14E-28	1.05E-19	7.49E-21	3.67E-22	2.87E-22	3.64E-22	4.41E-21	2.35E-21	3.40E-21	1.63E-21	3.64E-23	1.25E-19
Ar-41	0.00E+00	1.22E-01	3.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E-01
Ba-140	1.05E-07	1.20E-10	1.29E-11	5.34E-08	8.18E-09	4.93E-11	4.16E-11	2.12E-10	3.89E-08	4.68E-08	1.56E-09	8.79E-09	1.07E-11	6.54E-11	7.15E-11	2.63E-07
La-140 (Ba-140)	8.73E-12	4.44E-13	7.51E-15	1.65E-12	5.64E-13	9.93E-12	4.75E-11	5.29E-11	9.92E-10	8.33E-10	1.09E-09	5.69E-09	5.91E-12	7.70E-11	4.23E-12	8.81E-09
C-14	1.68E+00	0.00E+00	1.04E-05	0.00E+00	0.00E+00	0.00E+00	4.45E-02	2.67E-01	3.86E+00	2.67E+00	5.33E-01	2.96E-01	8.89E-01	4.45E-02	7.12E-02	1.04E+01
Ce-141	8.08E-08	7.06E-11	7.31E-12	5.41E-09	1.03E-08	4.86E-11	2.68E-10	7.55E-12	4.04E-09	5.01E-09	6.27E-10	5.03E-09	1.73E-12	4.44E-10	3.06E-12	1.12E-07
Ce-144	1.08E-06	1.68E-11	2.16E-12	2.65E-08	2.72E-07	1.02E-09	1.67E-08	4.97E-10	3.52E-08	4.46E-08	6.06E-09	4.82E-08	1.01E-10	2.05E-08	1.61E-10	1.55E-06
Pr-144 (Ce-144)	2.92E-11	1.05E-12	3.28E-12	2.80E-14	1.13E-12	6.75E-17	2.55E-23	8.50E-98	1.34E-16	1.40E-41	3.14E-15	2.52E-14	1.35E-18	1.97E-23	1.60E-198	3.47E-11
Pr-144m (Ce-144)	0.00E+00	5.78E-13	0.00E+00	3.25E-14	4.45E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.11E-13
Cm-242	1.32E-09	1.16E-18	0.00E+00	4.16E-16	7.44E-18	1.12E-12	7.06E-14	3.48E-15	2.78E-15	3.52E-15	1.23E-13	9.87E-13	3.63E-17	7.97E-14	1.77E-15	1.32E-09
Pu-238 (Cm-242)	7.52E-17	1.40E-26	0.00E+00	3.61E-23	1.20E-25	7.35E-14	1.29E-14	6.31E-16	4.94E-16	6.26E-16	5.06E-16	2.28E-15	1.12E-16	4.97E-15	1.10E-16	9.62E-14
Cm-243	4.48E-13	1.21E-19	3.25E-21	7.09E-16	1.93E-17	1.22E-15	2.28E-16	1.12E-17	8.76E-18	1.11E-17	6.05E-17	4.65E-16	7.53E-19	1.12E-16	2.51E-18	4.51E-13
Pu-239 (Cm-243)	8.22E-23	9.48E-30	1.09E-34	2.45E-25	7.96E-27	3.20E-25	8.67E-26	4.25E-27	3.32E-27	4.22E-27	2.11E-26	1.57E-25	1.22E-27	4.01E-26	8.97E-28	8.31E-23
Am-243 (Cm-243)	2.85E-23	4.32E-33	0.00E+00	2.16E-29	1.80E-31	9.05E-19	3.98E-20	1.94E-21	1.52E-21	1.93E-21	3.17E-21	1.43E-21	1.53E-21	9.00E-21	2.00E-22	9.66E-19
Cm-244	5.30E-11	3.27E-20	0.00E+00	1.47E-16	0.00E+00	1.23E-13	2.39E-14	1.17E-15	9.16E-16	1.16E-15	6.65E-15	5.17E-14	6.38E-17	1.21E-14	2.71E-16	5.32E-11
Pu-240 (Cm-244)	1.33E-20	2.50E-30	0.00E+00	7.55E-27	6.06E-30	3.45E-16	1.74E-17	8.51E-19	6.66E-19	8.45E-19	1.22E-18	6.26E-19	5.86E-19	4.02E-18	8.94E-20	3.71E-16
Co-58	1.46E-07	2.76E-09	5.13E-12	5.03E-07	1.35E-08	1.05E-10	1.25E-09	7.34E-11	1.21E-08	1.52E-08	4.84E-09	1.66E-08	1.39E-10	2.11E-09	3.15E-11	7.17E-07
Co-60	7.64E-07	6.90E-09	9.22E-12	2.15E-05	5.52E-08	1.13E-09	3.25E-08	1.95E-09	1.03E-07	1.30E-07	4.93E-08	1.28E-07	1.71E-08	4.84E-08	7.72E-10	2.28E-05
Cr-51	4.09E-09	7.78E-11	0.00E+00	5.67E-09	1.21E-11	2.37E-12	4.07E-11	2.26E-10	4.67E-10	5.78E-10	7.12E-11	5.72E-10	5.26E-14	6.96E-11	9.35E-11	1.20E-08
Cs-134	1.03E-08	2.77E-10	1.75E-12	4.25E-07	1.06E-08	1.19E-11	3.28E-09	1.96E-08	1.71E-07	2.17E-07	2.57E-08	5.44E-09	1.47E-08	6.38E-09	1.01E-08	9.19E-07
Cs-137	4.61E-09	0.00E+00	1.05E-12	4.81E-07	1.11E-08	1.27E-11	1.72E-09	1.03E-08	8.74E-08	1.11E-07	1.24E-08	2.85E-09	7.57E-09	3.60E-09	5.76E-09	7.39E-07
Ba-137m (Cs-137)	0.00E+00	1.56E-11	1.26E-13	6.35E-14	1.12E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E-11
Fe-59	4.67E-08	5.27E-10	2.34E-12	6.08E-08	4.33E-09	3.03E-11	1.90E-08	2.71E-11	2.66E-09	3.33E-09	1.86E-09	7.09E-09	1.43E-11	2.35E-08	1.13E-11	1.70E-07
H-3	1.08E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.58E-04	5.15E-03	2.87E-01	1.46E-02	1.77E-02	9.81E-03	2.94E-02	8.58E-04	1.37E-03	4.75E-01
I-131	3.43E-03	2.31E-06	6.74E-08	3.87E-04	2.12E-04	1.08E-05	2.96E-04	1.37E-03	1.81E-01	2.11E-01	6.30E-03	4.94E-03	3.10E-03	3.80E-04	3.33E-04	4.13E-01
Xe-131m (I-131)	0.00E+00	2.12E-12	1.19E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.31E-12
I-132	1.57E-05	4.67E-06	8.04E-08	9.15E-06	2.73E-06	2.32E-09	1.98E-10	4.49E-19	2.32E-07	2.13E-10	4.86E-08	3.88E-07	6.41E-10	8.99E-11	1.48E-32	3.30E-05
I-133	1.96E-04	8.38E-07	4.34E-08	1.57E-05	1.45E-05	2.10E-07	7.39E-07	4.02E-07	6.58E-04	3.75E-04	7.07E-06	4.12E-05	9.34E-07	4.54E-07	2.69E-09	1.31E-03
Xe-133 (I-133)	0.00E+00	9.13E-12	3.06E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-11
Xe-133m (I-133)	0.00E+00	5.05E-12	4.30E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.48E-12
I-135	2.37E-05	1.23E-06	2.26E-08	8.01E-06	2.35E-06	9.90E-09	6.21E-09	1.96E-11	6.37E-06	6.52E-07	2.09E-07	1.61E-06	6.10E-09	3.03E-09	1.08E-16	4.42E-05
Xe-135 (I-135)	0.00E+00	1.62E-08	2.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E-08
Xe-135m (I-135)	0.00E+00	2.69E-10	2.15E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.91E-10
Kr-85	0.00E+00	5.50E-08	4.29E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-07
Kr-85m	0.00E+00	3.05E-05	3.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.39E-05
Kr-85 (Kr-85m)	0.00E+00	5.46E-14	3.73E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.28E-13
Kr-87	0.00E+00	1.36E-10	2.16E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E-10
Rb-87 (Kr-87)	1.55E-25	0.00E+00	9.84E-30	0.00E+00	1.15E-25	6.04E-28	2.22E-25	1.33E-24	5.91E-23	7.50E-23	1.54E-24	5.86E-25	1.72E-24	2.70E-25	4.31E-25	1.40E-22
Kr-88	0.00E+00	3.13E-05	4.85E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.18E-05
Rb-88 (Kr-88)	5.86E-07	4.11E-07	1.18E-07	1.13E-08	2.66E-08	1.40E-12	3.87E-15	2.06E-87	2.97E-09	1.68E-33	1.16E-10	9.26E-10	6.16E-12	3.99E-15	2.23E-185	1.16E-06
La-140	3.87E-08	1.72E-09	3.33E-11	7.66E-09	2.61E-09	8.09E-12	5.36E-12	2.33E-13	3.04E-10	2.55E-10	2.09E-10	1.65E-09	4.09E-13	6.75E-12	1.50E-14	5.32E-08
Mn-54	8.36E-08	1.42E-09	0.00E+00	1.03E-06	1.32E-10	8.05E-11	5.85E-09	8.83E-10	1.67E-08	2.11E-08	3.90E-09	8.71E-09	1.81E-09	9.89E-09	3.99E-10	1.19E-06
Nb-95	8.57E-08	1.60E-09	7.25E-13	1.46E-07	6.18E-10	5.25E-11	1.60E-14	9.05E-14	2.32E-11	2.89E-11	1.85E-09	7.50E-09	3.77E-11	2.70E-14	3.78E-14	2.43E-07
Pu-238	1.04E-10	1.82E-20	0.00E+00	5.23E-17	1.74E-19	3.64E-13	5.55E-14	2.72E-15	2.13E-15	2.70E-15	1.43E-14	1.08E-13	4.28E-16	2.67E-14	5.97E-16	1.05E-10
U-234 (Pu-238)	7.70E-23	1.73E-31	1.79E-33	6.90E-28	4.73E-30	3.20E-18	2.04E-27	1.22E-26	1.60E-24	2.03E-24	1.63E-19	3.92E-20	2.34E-19	4.94E-27	7.90E-27	3.64E-18
Pu-239	1.38E-11	1.89E-21	0.00E+00	1.10E-17	9.16E-20	5.64E-14	7.72E-15	3.78E-16	2.96E-16	3.76E-16	1.95E-15	1.45E-14	7.08E-17	3.64E-15	8.15E-17	1.39E-11
U-235 (Pu-239)	3.10E-27	6.94E-33	9.12E-36	5.26E-29	5.28E-31	1.50E-22	9.03E-32	5.42E-31	7.10E-29	9.00E-29	8.35E-24	1.97E-24	1.20E-23	2.19E-31	3.50E-31	1.72E-22

Radionuclide	Inhalation of Plume	Gamma from Plume	Beta from Plume	Gamma from Ground	Beta from Ground	Re-suspension	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat	Total
Pu-240	2.19E-11	3.83E-21	0.00E+00	1.30E-17	1.04E-20	8.91E-14	1.22E-14	5.99E-16	4.69E-16	5.95E-16	3.08E-15	2.30E-14	1.12E-16	5.76E-15	1.29E-16	2.20E-11
U-236 (Pu-240)	1.48E-25	2.34E-34	2.46E-36	7.68E-31	1.27E-33	7.12E-21	4.30E-30	2.58E-29	3.38E-27	4.29E-27	3.97E-22	9.38E-23	5.70E-22	1.04E-29	1.67E-29	8.18E-21
Sb-122	4.19E-10	4.12E-12	4.31E-13	2.96E-11	5.11E-11	1.11E-13	1.34E-11	3.71E-13	2.70E-11	2.65E-11	3.58E-12	2.75E-11	2.50E-14	1.75E-11	4.65E-14	6.20E-10
Sb-124	1.76E-07	1.63E-09	2.70E-11	2.53E-07	5.30E-08	1.22E-10	4.12E-08	2.39E-09	1.41E-08	1.77E-08	5.43E-09	1.91E-08	1.43E-10	7.59E-08	1.12E-09	6.61E-07
Sb-125	2.35E-08	7.84E-11	6.91E-13	1.53E-07	4.15E-09	2.92E-11	5.28E-09	3.16E-10	1.41E-09	1.79E-09	7.22E-10	1.84E-09	1.37E-10	1.10E-08	1.74E-10	2.03E-07
Te-125m (Sb-125)	1.24E-13	1.58E-17	1.37E-18	1.75E-15	5.71E-17	9.54E-12	1.34E-09	3.31E-10	1.53E-09	1.92E-09	1.65E-09	4.43E-10	8.52E-10	2.72E-09	2.56E-10	1.11E-08
Sr-89	1.47E-07	6.54E-14	3.77E-11	8.35E-12	6.80E-08	9.81E-11	8.12E-11	4.67E-10	1.04E-07	1.30E-07	4.77E-09	1.78E-08	3.49E-10	1.15E-10	1.67E-10	4.73E-07
Sr-90	4.29E-08	0.00E+00	6.06E-13	4.06E-15	2.15E-08	1.17E-10	1.57E-10	9.43E-10	1.91E-07	2.42E-07	5.69E-09	2.50E-08	1.19E-08	1.18E-10	1.88E-10	5.42E-07
Y-90 (Sr-90)	5.70E-13	5.53E-22	6.69E-16	3.28E-21	5.89E-14	1.44E-16	5.00E-18	1.38E-18	1.43E-14	1.40E-14	9.53E-15	7.32E-14	6.62E-17	6.54E-18	1.70E-19	7.41E-13
Xe-131m	0.00E+00	4.58E-07	2.89E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.47E-07
Xe-133	0.00E+00	1.44E-04	1.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E-04
Xe-133m	0.00E+00	9.74E-09	3.73E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-08
Xe-133 (Xe-133m)	0.00E+00	1.25E-12	1.07E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-12
Zn-65	3.99E-08	4.43E-10	7.21E-14	2.58E-07	3.51E-10	3.66E-11	2.05E-09	1.22E-08	1.91E-06	2.42E-06	2.64E-08	2.95E-08	1.61E-08	1.97E-09	3.10E-09	4.72E-06
Zr-95	1.27E-07	7.41E-10	4.96E-12	2.47E-07	1.19E-08	8.90E-11	1.83E-14	1.06E-13	3.19E-11	4.00E-11	2.09E-09	7.31E-09	1.85E-11	3.47E-14	5.15E-14	3.96E-07
Nb-95 (Zr-95)	3.03E-12	8.61E-15	1.39E-15	9.16E-13	1.97E-13	8.74E-16	1.05E-19	3.54E-19	1.14E-15	1.20E-15	3.88E-14	2.90E-13	2.89E-16	1.41E-19	5.89E-20	4.49E-12
Nb-95m (Zr-95)	5.21E-13	1.11E-14	4.41E-18	8.50E-13	3.59E-15	8.03E-12	9.43E-15	5.33E-14	2.42E-12	3.02E-12	6.91E-10	1.27E-09	3.24E-11	1.81E-14	2.52E-14	2.01E-09
Total	**1.79E+00**	**1.22E-01**	**3.61E-03**	**4.45E-04**	**2.32E-04**	**1.10E-05**	**4.57E-02**	**2.74E-01**	**4.33E+00**	**2.90E+00**	**5.57E-01**	**3.11E-01**	**9.22E-01**	**4.57E-02**	**7.29E-02**	**1.14E+01**

Table A.17: Annual Dose to the Representative Person (Fisherman Family Adult) (µSv/y)

	Marine high (µSv/y)	Dose due to Terrestrial mean consumption rate (µSv/y)										
Radionuclide	**Total**	**Cow liver**	**Cow meat**	**Cow milk**	**Cow milk products**	**Fruit**	**Green vegetables**	**Root vegetables**	**Sheep liver**	**Sheep meat**	**Total**	**Grand Total**
Ag-110m	1.32E-10	2.76E-10	3.73E-12	8.37E-10	1.93E-09	3.90E-12	2.45E-11	4.45E-12	3.26E-10	3.10E-12	3.41E-09	3.54E-09
Am-241	5.62E-12	1.14E-14	5.10E-16	5.83E-17	1.35E-16	1.13E-15	2.66E-14	1.14E-16	5.31E-15	2.16E-16	4.55E-14	5.67E-12
Np-237 (Am-241)	1.60E-17	2.16E-20	9.60E-22	1.10E-22	2.54E-22	5.13E-21	8.60E-21	7.13E-21	4.69E-21	1.90E-22	4.87E-20	1.60E-17
Ar-41	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	2.92E-10	3.30E-11	1.53E-10	4.11E-09	9.01E-09	5.01E-10	8.89E-09	6.16E-12	5.20E-11	1.03E-10	2.29E-08	2.32E-08
La-140 (Ba-140)	3.04E-09	4.02E-11	4.07E-11	1.12E-10	1.71E-10	3.73E-10	6.13E-09	3.64E-12	6.52E-11	6.51E-12	6.94E-09	9.98E-09
C-14	-	8.87E-02	4.84E-01	1.02E+00	1.29E+00	4.30E-01	7.52E-01	1.29E+00	8.87E-02	2.58E-01	5.70E+00	5.70E+00
Ce-141	8.49E-09	2.05E-10	5.25E-12	4.10E-10	9.31E-10	1.94E-10	4.91E-09	9.62E-13	3.40E-10	4.26E-12	7.00E-09	1.55E-08
Ce-144	4.65E-07	1.22E-08	3.31E-10	3.43E-09	7.93E-09	1.80E-09	4.50E-08	5.42E-11	1.50E-08	2.15E-10	8.60E-08	5.51E-07
Pr-144 (Ce-144)	-	2.00E-23	6.07E-98	1.40E-17	2.67E-42	9.96E-16	2.52E-14	7.70E-19	1.54E-23	2.29E-198	2.62E-14	2.62E-14
Pr-144m (Ce-144)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-242	6.41E-12	6.13E-14	2.75E-15	3.21E-16	7.40E-16	4.31E-14	1.09E-12	2.29E-17	6.92E-14	2.79E-15	1.27E-12	7.68E-12
Pu-238 (Cm-242)	3.53E-13	4.09E-14	1.81E-15	2.07E-16	4.80E-16	6.46E-16	9.20E-15	2.58E-16	1.57E-14	6.34E-16	6.98E-14	4.23E-13
Cm-243	3.45E-13	5.71E-16	2.54E-17	2.91E-18	6.74E-18	6.11E-17	1.48E-15	1.37E-18	2.81E-16	1.14E-17	2.44E-15	3.47E-13
Pu-239 (Cm-243)	4.63E-17	1.30E-19	5.78E-21	6.61E-22	1.53E-21	4.19E-21	5.98E-21	3.65E-21	2.95E-20	1.19E-21	1.82E-19	4.65E-17
Am-243 (Cm-243)	-	2.58E-25	1.15E-26	1.31E-27	3.04E-27	2.53E-26	5.96E-25	2.64E-27	1.19E-25	4.85E-27	1.02E-24	1.02E-24
Cm-244	1.72E-11	5.43E-14	2.42E-15	2.77E-16	6.41E-16	6.12E-15	1.50E-13	1.06E-16	2.76E-14	1.12E-15	2.43E-13	1.74E-11
Pu-240 (Cm-244)	1.41E-14	5.71E-17	2.53E-18	2.90E-19	6.71E-19	1.62E-18	2.61E-18	1.40E-18	1.32E-17	5.32E-19	8.00E-17	1.42E-14
Co-58	4.02E-07	1.17E-09	6.17E-11	1.49E-09	3.41E-09	1.81E-09	1.95E-08	9.38E-11	1.95E-09	5.30E-11	2.95E-08	4.32E-07
Co-60	1.48E-04	2.25E-08	1.23E-09	9.46E-09	2.19E-08	1.38E-08	1.13E-07	8.60E-09	3.35E-08	9.73E-10	2.25E-07	1.48E-04
Cr-51	1.61E-09	3.70E-11	1.87E-10	5.64E-11	1.27E-10	2.61E-11	6.62E-10	3.47E-14	6.32E-11	1.54E-10	1.31E-09	2.92E-09
Cs-134	4.72E-08	2.14E-08	1.17E-07	1.49E-07	3.44E-07	6.77E-08	4.52E-08	6.99E-08	4.17E-08	1.21E-07	9.77E-07	1.02E-06
Cs-137	5.77E-08	1.03E-08	5.59E-08	6.92E-08	1.60E-07	2.97E-08	2.16E-08	3.28E-08	2.15E-08	6.24E-08	4.63E-07	5.21E-07
Ba-137m (Cs-137)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	2.62E-05	-	-	-	-	-	-	-	-	-	0.00E+00	2.62E-05
Fe-59	2.99E-07	1.44E-08	1.88E-11	2.69E-10	6.14E-10	5.72E-10	6.87E-09	7.92E-12	1.79E-08	1.55E-11	4.07E-08	3.40E-07
H-3	3.34E-05	1.77E-03	9.65E-03	7.86E-02	7.28E-03	1.47E-02	2.57E-02	4.42E-02	1.77E-03	5.15E-03	1.89E-01	1.89E-01
I-131	4.11E-08	1.99E-04	8.39E-04	1.62E-02	3.44E-02	1.71E-03	4.23E-03	1.51E-03	2.55E-04	4.06E-04	5.97E-02	5.97E-02
Xe-131m (I-131)	7.73E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.73E-13
I-132	-	1.32E-10	2.71E-19	2.05E-08	3.42E-11	1.30E-08	3.28E-07	3.10E-10	5.98E-11	1.78E-32	3.62E-07	3.62E-07
I-133	-	3.97E-07	1.97E-07	4.70E-05	4.89E-05	1.54E-06	2.82E-05	3.65E-07	2.44E-07	2.63E-09	1.27E-04	1.27E-04
Xe-133 (I-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	0.00E+00	0.00E+00	0.00E+00
Xe-133m (I-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	0.00E+00	0.00E+00	0.00E+00
I-135	-	3.57E-09	1.02E-11	4.86E-07	9.08E-08	4.86E-08	1.18E-06	2.55E-09	1.74E-09	1.13E-16	1.81E-06	1.81E-06
Xe-135 (I-135)	-	0.00E+00	0.00E+00	0.00E+00	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-135m (I-135)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85 (Kr-85m)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-87 (Kr-87)	-	1.83E-25	9.99E-25	6.48E-24	1.50E-23	5.14E-25	6.16E-25	1.03E-24	2.22E-25	6.47E-25	2.57E-23	2.57E-23
Kr-88	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-88 (Kr-88)	-	3.09E-15	1.49E-87	3.15E-10	3.25E-34	3.75E-11	9.41E-10	3.58E-12	3.18E-15	3.24E-185	1.30E-09	1.30E-09
La-140	6.55E-10	4.53E-12	1.79E-13	3.41E-11	5.23E-11	7.14E-11	1.77E-09	2.52E-13	5.71E-12	2.30E-14	1.94E-09	2.59E-09
Mn-54	6.91E-06	7.37E-09	1.01E-09	2.79E-09	6.46E-09	1.99E-09	1.39E-08	1.66E-09	1.25E-08	9.13E-10	4.86E-08	6.96E-06
Nb-95	2.99E-07	1.60E-14	8.20E-14	3.08E-12	6.99E-12	7.47E-10	9.53E-09	2.73E-11	2.70E-14	6.84E-14	1.03E-08	3.09E-07
Ni-63	1.14E-07	-	-	-	-	-	-	-	-	-	0.00E+00	1.14E-07

	Marine high (µSv/y)	Dose due to Terrestrial mean consumption rate (µSv/y)										
Radionuclide	**Total**	**Cow liver**	**Cow meat**	**Cow milk**	**Cow milk products**	**Fruit**	**Green vegetables**	**Root vegetables**	**Sheep liver**	**Sheep meat**	**Total**	**Grand Total**
Pu-238	4.66E-10	1.76E-13	7.82E-15	8.95E-16	2.07E-15	1.83E-14	4.36E-13	9.84E-16	8.44E-14	3.43E-15	7.30E-13	4.67E-10
U-234 (Pu-238)	4.96E-17	4.22E-27	2.30E-26	4.41E-25	1.02E-24	1.37E-19	1.04E-19	3.53E-19	1.02E-26	2.98E-26	5.94E-19	5.02E-17
Pu-239	8.16E-11	2.53E-14	1.13E-15	1.29E-16	2.98E-16	2.57E-15	6.05E-14	1.69E-16	1.19E-14	4.85E-16	1.02E-13	8.17E-11
U-235 (Pu-239)	1.10E-19	1.80E-31	9.79E-31	1.88E-29	4.34E-29	6.71E-24	4.99E-24	1.74E-23	4.35E-31	1.27E-30	2.91E-23	1.10E-19
Pu-240	1.29E-10	4.00E-14	1.78E-15	2.04E-16	4.72E-16	4.08E-15	9.58E-14	2.66E-16	1.89E-14	7.68E-16	1.62E-13	1.29E-10
U-236 (Pu-240)	1.32E-19	8.55E-30	4.66E-29	8.92E-28	2.07E-27	3.19E-22	2.37E-22	8.25E-22	2.07E-29	6.03E-29	1.38E-21	1.33E-19
Ru-103	1.76E-08	-	-	-	-	-	-	-	-	-	0.00E+00	1.76E-08
Ru-106	1.53E-07	-	-	-	-	-	-	-	-	-	0.00E+00	1.53E-07
Sb-122	1.87E-11	1.04E-11	2.63E-13	2.80E-12	5.01E-12	1.13E-12	2.73E-11	1.42E-14	1.37E-11	6.59E-14	6.07E-11	7.94E-11
Sb-124	6.75E-08	3.54E-08	1.87E-09	1.61E-09	3.68E-09	1.89E-09	2.09E-08	8.96E-11	6.53E-08	1.75E-09	1.32E-07	2.00E-07
Sb-125	1.03E-07	5.23E-09	2.85E-10	1.86E-10	4.31E-10	2.89E-10	2.32E-09	9.87E-11	1.09E-08	3.15E-10	2.01E-08	1.23E-07
Te-125m (Sb-125)	4.60E-08	1.02E-09	2.29E-10	1.54E-10	3.53E-10	5.07E-10	4.28E-10	4.71E-10	2.06E-09	3.54E-10	5.58E-09	5.16E-08
Sr-89	1.02E-10	6.45E-11	3.38E-10	1.10E-08	2.51E-08	1.53E-09	1.80E-08	2.02E-10	9.16E-11	2.42E-10	5.66E-08	5.67E-08
Sr-90	1.33E-09	3.31E-10	1.81E-09	5.34E-08	1.24E-07	4.85E-09	6.70E-08	1.82E-08	2.48E-10	7.22E-10	2.71E-07	2.72E-07
Y-90 (Sr-90)	-	3.72E-18	9.29E-19	1.41E-15	2.52E-15	2.86E-15	6.91E-14	3.57E-17	4.86E-18	2.29E-19	7.59E-14	7.59E-14
Te-123m	2.21E-10	-	-	-	-	-	-	-	-	-	0.00E+00	2.21E-10
Te-123 (Te-123m)	3.69E-24	-	-	-	-	-	-	-	-	-	0.00E+00	3.69E-24
Xe-131m	-	0.00E+00	0.00E+00	0.00E+00	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-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	0.00E+00	0.00E+00	0.00E+00
Xe-133m	-	0.00E+00	0.00E+00	0.00E+00	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-133 (Xe-133m)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn-65	1.12E-05	2.75E-09	1.49E-08	3.41E-07	7.87E-07	1.43E-08	5.04E-08	1.57E-08	2.65E-09	7.55E-09	1.24E-06	1.24E-05
Zr-95	2.62E-07	1.70E-14	8.99E-14	3.95E-12	9.05E-12	7.86E-10	8.68E-09	1.26E-11	3.24E-14	8.74E-14	9.49E-09	2.71E-07
Nb-95 (Zr-95)	2.77E-07	9.40E-15	4.83E-14	3.21E-13	7.29E-13	2.78E-10	1.61E-09	2.35E-11	1.80E-14	4.58E-14	1.91E-09	2.79E-07
Nb-95m (Zr-95)	-	7.88E-20	2.41E-19	1.14E-16	2.18E-16	1.18E-14	2.77E-13	1.58E-16	1.06E-19	8.05E-20	2.89E-13	2.89E-13
Total	**2.29E-04**	**9.07E-02**	**4.94E-01**	**1.11E+00**	**1.33E+00**	**4.46E-01**	**7.82E-01**	**1.34E+00**	**9.07E-02**	**2.64E-01**	**5.95E+00**	**5.95E+00**

Note: Dash indicates that radionuclide is not included in the discharge route for the pathway indicated.
Zero means radionuclide has been included in the discharge but has no dose associated with it.

Table A.18: Annual Dose to the Representative Person (Fisherman Family Child) (µSv/y)

	Marine high (µSv/y)	Dose due to Terrestrial mean consumption rate (µSv/y)										
Radionuclide	**Total**	**Cow liver**	**Cow meat**	**Cow milk**	**Cow milk products**	**Fruit**	**Green vegetables**	**Root vegetables**	**Sheep liver**	**Sheep meat**	**Total**	**Grand Total**
Ag-110m	5.78E-11	2.80E-10	6.94E-12	1.80E-09	2.69E-09	5.43E-12	1.95E-11	6.89E-12	3.30E-10	2.88E-12	5.14E-09	5.20E-09
Am-241	1.47E-12	6.87E-15	5.61E-16	7.43E-17	1.11E-16	9.32E-16	1.26E-14	1.04E-16	3.19E-15	1.19E-16	2.46E-14	1.49E-12
Np-237 (Am-241)	2.70E-18	1.18E-20	9.60E-22	1.27E-22	1.91E-22	3.85E-21	3.69E-21	5.94E-21	2.56E-21	9.52E-23	2.92E-20	2.73E-18
Ar-41	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	1.16E-10	4.02E-11	3.42E-10	1.06E-08	1.51E-08	8.39E-10	8.50E-09	1.15E-11	6.32E-11	1.15E-10	3.56E-08	3.57E-08
La-140 (Ba-140)	5.52E-10	4.60E-11	8.54E-11	2.71E-10	2.69E-10	5.87E-10	5.51E-09	6.36E-12	7.47E-11	6.83E-12	6.86E-09	7.41E-09
C-14	-	6.67E-02	6.67E-01	1.63E+00	1.34E+00	4.44E-01	4.44E-01	1.48E+00	6.67E-02	1.78E-01	6.32E+00	6.32E+00
Ce-141	1.55E-09	2.37E-10	1.11E-11	1.00E-09	1.47E-09	3.07E-10	4.44E-09	1.69E-12	3.92E-10	4.50E-12	7.86E-09	9.41E-09
Ce-144	8.04E-08	1.41E-08	7.00E-10	8.40E-09	1.26E-08	2.85E-09	4.08E-08	9.55E-11	1.73E-08	2.27E-10	9.71E-08	1.77E-07
Pr-144 (Ce-144)	-	2.07E-23	1.15E-97	3.08E-17	3.80E-42	1.42E-15	2.06E-14	1.22E-18	1.60E-23	2.17E-198	2.21E-14	2.21E-14
Pr-144m (Ce-144)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-242	3.17E-12	6.69E-14	5.50E-15	7.43E-16	1.11E-15	6.47E-14	9.35E-13	3.82E-17	7.55E-14	2.79E-15	1.15E-12	4.32E-12
Pu-238 (Cm-242)	9.01E-14	2.33E-14	1.89E-15	2.50E-16	3.76E-16	5.06E-16	4.11E-15	2.25E-16	8.94E-15	3.31E-16	3.99E-14	1.30E-13
Cm-243	7.91E-14	3.32E-16	2.71E-17	3.59E-18	5.39E-18	4.89E-17	6.77E-16	1.22E-18	1.63E-16	6.09E-18	1.26E-15	8.04E-14
Pu-239 (Cm-243)	1.22E-17	7.67E-20	6.25E-21	8.27E-22	1.24E-21	3.39E-21	2.77E-21	3.28E-21	1.74E-20	6.44E-22	1.13E-19	1.23E-17
Am-243 (Cm-243)	-	1.55E-25	1.26E-26	1.67E-27	2.51E-27	2.09E-26	2.81E-25	2.42E-27	7.15E-26	2.67E-27	5.50E-25	5.50E-25
Cm-244	4.98E-12	3.46E-14	2.82E-15	3.74E-16	5.61E-16	5.35E-15	7.48E-14	1.03E-16	1.75E-14	6.55E-16	1.37E-13	5.12E-12
Pu-240 (Cm-244)	3.70E-15	3.36E-17	2.74E-18	3.62E-19	5.43E-19	1.31E-18	1.21E-18	1.26E-18	7.75E-18	2.88E-19	4.91E-17	3.75E-15
Co-58	9.00E-08	1.46E-09	1.41E-10	3.95E-09	5.88E-09	3.12E-09	1.92E-08	1.79E-10	2.44E-09	6.09E-11	3.64E-08	1.26E-07
Co-60	2.46E-05	3.98E-08	3.97E-09	3.54E-08	5.31E-08	3.35E-08	1.57E-07	2.32E-08	5.92E-08	1.57E-09	4.07E-07	2.50E-05
Cr-51	3.88E-10	4.14E-11	3.84E-10	1.34E-10	1.96E-10	4.02E-11	5.82E-10	5.94E-14	7.08E-11	1.58E-10	1.61E-09	1.99E-09
Cs-134	7.10E-09	8.62E-09	8.59E-08	1.27E-07	1.90E-07	3.74E-08	1.43E-08	4.29E-08	1.68E-08	4.44E-08	5.67E-07	5.74E-07
Cs-137	8.71E-09	4.30E-09	4.30E-08	6.16E-08	9.24E-08	1.72E-08	7.12E-09	2.10E-08	9.00E-09	2.40E-08	2.80E-07	2.88E-07
Ba-137m (Cs-137)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	2.11E-05	-	-	-	-	-	-	-	-	-	0.00E+00	2.11E-05
Fe-59	1.70E-07	2.06E-08	4.90E-11	8.14E-10	1.20E-09	1.12E-09	7.69E-09	1.72E-11	2.55E-08	2.03E-11	5.69E-08	2.27E-07
H-3	9.45E-06	1.23E-03	1.23E-02	1.16E-01	6.98E-03	1.41E-02	1.41E-02	4.70E-02	1.23E-03	3.29E-03	2.16E-01	2.16E-01
I-131	2.12E-08	2.57E-04	1.98E-03	4.43E-02	6.10E-02	3.03E-03	4.28E-03	2.98E-03	3.29E-04	4.80E-04	1.19E-01	1.19E-01
Xe-131m (I-131)	1.09E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E-13
I-132	-	1.54E-10	5.79E-19	5.07E-08	5.49E-11	2.09E-08	3.01E-07	5.52E-10	6.97E-11	1.91E-32	3.73E-07	3.73E-07
I-133	-	5.04E-07	4.57E-07	1.27E-04	8.53E-05	2.68E-06	2.81E-05	7.08E-07	3.09E-07	3.05E-09	2.45E-04	2.45E-04
Xe-133 (I-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	0.00E+00	0.00E+00	0.00E+00
Xe-133m (I-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	0.00E+00	0.00E+00	0.00E+00
I-135	-	4.60E-09	2.42E-11	1.33E-06	1.61E-07	8.61E-08	1.19E-06	5.03E-09	2.25E-09	1.34E-16	2.78E-06	2.78E-06
Xe-135 (I-135)	-	0.00E+00	0.00E+00	0.00E+00	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-135m (I-135)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85 (Kr-85m)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-87 (Kr-87)	-	2.06E-25	2.06E-24	1.55E-23	2.33E-23	7.96E-25	5.45E-25	1.78E-24	2.51E-25	6.69E-25	4.51E-23	4.51E-23
Kr-88	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-88 (Kr-88)	-	3.18E-15	2.82E-87	6.89E-10	4.61E-34	5.32E-11	7.62E-10	5.63E-12	3.28E-15	3.06E-185	1.51E-09	1.51E-09
La-140	1.29E-10	5.19E-12	3.76E-13	8.30E-11	8.24E-11	1.12E-10	1.60E-09	4.40E-13	6.54E-12	2.42E-14	1.89E-09	2.02E-09
Mn-54	1.35E-06	7.36E-09	1.85E-09	5.93E-09	8.87E-09	2.73E-09	1.10E-08	2.53E-09	1.25E-08	8.35E-10	5.36E-08	1.40E-06
Nb-95	4.58E-08	1.65E-14	1.56E-13	6.76E-12	9.90E-12	1.06E-09	7.73E-09	4.31E-11	2.79E-14	6.48E-14	8.85E-09	5.47E-08
Ni-63	4.83E-08	-	-	-	-	-	-	-	-	-	0.00E+00	4.83E-08

	Marine high (µSv/y)	Dose due to Terrestrial mean consumption rate (µSv/y)										
Radionuclide	**Total**	**Cow liver**	**Cow meat**	**Cow milk**	**Cow milk products**	**Fruit**	**Green vegetables**	**Root vegetables**	**Sheep liver**	**Sheep meat**	**Total**	**Grand Total**
Pu-238	1.19E-10	1.00E-13	8.16E-15	1.08E-15	1.62E-15	1.43E-14	1.95E-13	8.56E-16	4.80E-14	1.79E-15	3.71E-13	1.19E-10
U-234 (Pu-238)	1.42E-17	3.48E-27	3.48E-26	7.71E-25	1.16E-24	1.55E-19	6.70E-20	4.44E-19	8.43E-27	2.25E-26	6.66E-19	1.49E-17
Pu-239	2.15E-11	1.49E-14	1.22E-15	1.61E-16	2.42E-16	2.09E-15	2.80E-14	1.52E-16	7.02E-15	2.62E-16	5.40E-14	2.16E-11
U-235 (Pu-239)	1.65E-20	1.48E-31	1.48E-30	3.28E-29	4.92E-29	7.60E-24	3.23E-24	2.18E-23	3.59E-31	9.57E-31	3.26E-23	1.65E-20
Pu-240	3.40E-11	2.36E-14	1.92E-15	2.55E-16	3.82E-16	3.30E-15	4.43E-14	2.40E-16	1.11E-14	4.15E-16	8.55E-14	3.41E-11
U-236 (Pu-240)	3.79E-20	6.94E-30	6.94E-29	1.54E-27	2.31E-27	3.56E-22	1.51E-22	1.02E-21	1.68E-29	4.49E-29	1.53E-21	3.94E-20
Ru-103	8.84E-09	-	-	-	-	-	-	-	-	-	0.00E+00	8.84E-09
Ru-106	8.06E-08	-	-	-	-	-	-	-	-	-	0.00E+00	8.06E-08
Sb-122	8.19E-12	1.24E-11	5.72E-13	7.05E-12	8.18E-12	1.84E-12	2.54E-11	2.57E-14	1.62E-11	7.17E-14	7.17E-11	7.99E-11
Sb-124	2.54E-08	4.02E-08	3.88E-09	3.88E-09	5.75E-09	2.94E-09	1.86E-08	1.55E-10	7.40E-08	1.82E-09	1.51E-07	1.77E-07
Sb-125	2.66E-08	5.45E-09	5.44E-10	4.12E-10	6.17E-10	4.14E-10	1.90E-09	1.57E-10	1.13E-08	3.00E-10	2.11E-08	4.77E-08
Te-125m (Sb-125)	2.06E-08	1.21E-09	4.99E-10	3.90E-10	5.78E-10	8.31E-10	4.00E-10	8.56E-10	2.46E-09	3.86E-10	7.61E-09	2.82E-08
Sr-89	4.17E-11	7.85E-11	7.53E-10	2.84E-08	4.20E-08	2.56E-09	1.72E-08	3.75E-10	1.11E-10	2.70E-10	9.17E-08	9.18E-08
Sr-90	3.68E-10	3.87E-10	3.87E-09	1.33E-07	1.99E-07	7.80E-09	6.16E-08	3.25E-08	2.90E-10	7.73E-10	4.39E-07	4.40E-07
Y-90 (Sr-90)	-	4.43E-18	2.03E-18	3.56E-15	4.12E-15	4.68E-15	6.48E-14	6.51E-17	5.79E-18	2.50E-19	7.72E-14	7.72E-14
Te-123m	9.72E-11	-	-	-	-	-	-	-	-	-	0.00E+00	9.72E-11
Te-123 (Te-123m)	9.72E-25	-	-	-	-	-	-	-	-	-	0.00E+00	9.72E-25
Xe-131m	-	0.00E+00	0.00E+00	0.00E+00	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-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	0.00E+00	0.00E+00	0.00E+00
Xe-133m	-	0.00E+00	0.00E+00	0.00E+00	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-133 (Xe-133m)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zn-65	4.46E-06	2.46E-09	2.44E-08	6.48E-07	9.69E-07	1.76E-08	3.54E-08	2.15E-08	2.37E-09	6.19E-09	1.73E-06	6.19E-06
Zr-95	4.12E-08	1.86E-14	1.80E-13	9.15E-12	1.36E-11	1.18E-09	7.44E-09	2.09E-11	3.54E-14	8.74E-14	8.66E-09	4.99E-08
Nb-95 (Zr-95)	4.11E-08	9.72E-15	9.17E-14	7.05E-13	1.04E-12	3.96E-10	1.31E-09	3.72E-11	1.87E-14	4.34E-14	1.75E-09	4.28E-08
Nb-95m (Zr-95)	-	9.21E-20	5.18E-19	2.83E-16	3.50E-16	1.90E-14	2.54E-13	2.82E-16	1.24E-19	8.62E-20	2.74E-13	2.74E-13
Total	**6.17E-05**	**6.82E-02**	**6.81E-01**	**1.79E+00**	**1.41E+00**	**4.61E-01**	**4.62E-01**	**1.53E+00**	**6.83E-02**	**1.82E-01**	**6.65E+00**	**6.65E+00**

Note: Dash indicates that radionuclide is not included in the discharge route for the pathway indicated.
Zero means radionuclide has been included in the discharge but has no dose associated with it.

Table A.19: Annual Dose to the Representative Person (Fisherman Family Infant) (µSv/y)

	Marine high (µSv/y)	Dose due to Terrestrial mean consumption rate (µSv/y)										
Radionuclide	**Total**	**Cow liver**	**Cow meat**	**Cow milk**	**Cow milk products**	**Fruit**	**Green vegetables**	**Root vegetables**	**Sheep liver**	**Sheep meat**	**Total**	**Grand Total**
Ag-110m	2.52E-12	2.51E-10	3.73E-12	5.73E-09	7.25E-09	8.77E-12	1.75E-11	5.57E-12	2.96E-10	1.55E-12	1.36E-08	1.36E-08
Am-241	1.24E-14	3.85E-15	1.89E-16	1.48E-16	1.87E-16	9.40E-16	7.04E-15	5.25E-17	1.79E-15	4.00E-17	1.42E-14	2.66E-14
Np-237 (Am-241)	2.02E-19	7.49E-21	3.67E-22	2.87E-22	3.64E-22	4.41E-21	2.35E-21	3.40E-21	1.63E-21	3.64E-23	2.03E-20	2.22E-19
Ar-41	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140	3.31E-11	4.16E-11	2.12E-10	3.89E-08	4.68E-08	1.56E-09	8.79E-09	1.07E-11	6.54E-11	7.15E-11	9.65E-08	9.65E-08
La-140 (Ba-140)	4.92E-11	4.75E-11	5.29E-11	9.92E-10	8.33E-10	1.09E-09	5.69E-09	5.91E-12	7.70E-11	4.23E-12	8.79E-09	8.84E-09
C-14	-	4.45E-02	2.67E-01	3.86E+00	2.67E+00	5.33E-01	2.96E-01	8.89E-01	4.45E-02	7.12E-02	8.68E+00	8.68E+00
Ce-141	1.22E-10	2.68E-10	7.55E-12	4.04E-09	5.01E-09	6.27E-10	5.03E-09	1.73E-12	4.44E-10	3.06E-12	1.54E-08	1.56E-08
Ce-144	6.58E-09	1.67E-08	4.97E-10	3.52E-08	4.46E-08	6.06E-09	4.82E-08	1.01E-10	2.05E-08	1.61E-10	1.72E-07	1.79E-07
Pr-144 (Ce-144)	-	2.55E-23	8.50E-98	1.34E-16	1.40E-41	3.14E-15	2.52E-14	1.35E-18	1.97E-23	1.60E-198	2.85E-14	2.85E-14
Pr-144m (Ce-144)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-242	8.70E-15	7.06E-14	3.48E-15	2.78E-15	3.52E-15	1.23E-13	9.87E-13	3.63E-17	7.97E-14	1.77E-15	1.27E-12	1.28E-12
Pu-238 (Cm-242)	2.18E-15	1.29E-14	6.31E-16	4.94E-16	6.26E-16	5.06E-16	2.28E-15	1.12E-16	4.97E-15	1.10E-16	2.26E-14	2.48E-14
Cm-243	1.65E-15	2.28E-16	1.12E-17	8.76E-18	1.11E-17	6.05E-17	4.65E-16	7.53E-19	1.12E-16	2.51E-18	9.00E-16	2.55E-15
Pu-239 (Cm-243)	2.87E-19	3.98E-20	1.94E-21	1.52E-21	1.93E-21	3.17E-21	1.43E-21	1.53E-21	9.00E-21	2.00E-22	6.05E-20	3.48E-19
Am-243 (Cm-243)	-	8.67E-26	4.25E-27	3.32E-27	4.22E-27	2.11E-26	1.57E-25	1.22E-27	4.01E-26	8.97E-28	3.19E-25	3.19E-25
Cm-244	8.54E-15	2.39E-14	1.17E-15	9.16E-16	1.16E-15	6.65E-15	5.17E-14	6.38E-17	1.21E-14	2.71E-16	9.79E-14	1.06E-13
Pu-240 (Cm-244)	8.78E-17	1.74E-17	8.51E-19	6.66E-19	8.45E-19	1.22E-18	6.26E-19	5.86E-19	4.02E-18	8.94E-20	2.63E-17	1.14E-16
Co-58	7.85E-09	1.25E-09	7.34E-11	1.21E-08	1.52E-08	4.84E-09	1.66E-08	1.39E-10	2.11E-09	3.15E-11	5.24E-08	6.02E-08
Co-60	2.36E-06	3.25E-08	1.95E-09	1.03E-07	1.30E-07	4.93E-08	1.28E-07	1.71E-08	4.84E-08	7.72E-10	5.11E-07	2.87E-06
Cr-51	5.07E-11	4.07E-11	2.26E-10	4.67E-10	5.78E-10	7.12E-11	5.72E-10	5.26E-14	6.96E-11	9.35E-11	2.12E-09	2.17E-09
Cs-134	1.00E-09	3.28E-09	1.96E-08	1.71E-07	2.17E-07	2.57E-08	5.44E-09	1.47E-08	6.38E-09	1.01E-08	4.73E-07	4.74E-07
Cs-137	1.15E-09	1.72E-09	1.03E-08	8.74E-08	1.11E-07	1.24E-08	2.85E-09	7.57E-09	3.60E-09	5.76E-09	2.43E-07	2.44E-07
Ba-137m (Cs-137)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-55	3.06E-07	-	-	-	-	-	-	-	-	-	0.00E+00	3.06E-07
Fe-59	3.56E-09	1.90E-08	2.71E-11	2.66E-09	3.33E-09	1.86E-09	7.09E-09	1.43E-11	2.35E-08	1.13E-11	5.75E-08	6.10E-08
H-3	2.45E-06	8.58E-04	5.15E-03	2.87E-01	1.46E-02	1.77E-02	9.81E-03	2.94E-02	8.58E-04	1.37E-03	3.67E-01	3.67E-01
I-131	2.63E-09	2.96E-04	1.37E-03	1.81E-01	2.11E-01	6.30E-03	4.94E-03	3.10E-03	3.80E-04	3.33E-04	4.09E-01	4.09E-01
Xe-131m (I-131)	1.09E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E-14
I-132	-	1.98E-10	4.49E-19	2.32E-07	2.13E-10	4.86E-08	3.88E-07	6.41E-10	8.99E-11	1.48E-32	6.70E-07	6.70E-07
I-133	-	7.39E-07	4.02E-07	6.58E-04	3.75E-04	7.07E-06	4.12E-05	9.34E-07	4.54E-07	2.69E-09	1.08E-03	1.08E-03
Xe-133 (I-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	0.00E+00	0.00E+00	0.00E+00
Xe-133m (I-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	0.00E+00	0.00E+00	0.00E+00
I-135	-	6.21E-09	1.96E-11	6.37E-06	6.52E-07	2.09E-07	1.61E-06	6.10E-09	3.03E-09	1.08E-16	8.86E-06	8.86E-06
Xe-135 (I-135)	-	0.00E+00	0.00E+00	0.00E+00	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-135m (I-135)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85m	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85 (Kr-85m)	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-87 (Kr-87)	-	2.22E-25	1.33E-24	5.91E-23	7.50E-23	1.54E-24	5.86E-25	1.72E-24	2.70E-25	4.31E-25	1.40E-22	1.40E-22
Kr-88	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rb-88 (Kr-88)	-	3.87E-15	2.06E-87	2.97E-09	1.68E-33	1.16E-10	9.26E-10	6.16E-12	3.99E-15	2.23E-185	4.02E-09	4.02E-09
La-140	1.10E-11	5.36E-12	2.33E-13	3.04E-10	2.55E-10	2.09E-10	1.65E-09	4.09E-13	6.75E-12	1.50E-14	2.43E-09	2.44E-09
Mn-54	9.14E-08	5.85E-09	8.83E-10	1.67E-08	2.11E-08	3.90E-09	8.71E-09	1.81E-09	9.89E-09	3.99E-10	6.93E-08	1.61E-07
Nb-95	4.43E-09	1.60E-14	9.05E-14	2.32E-11	2.89E-11	1.85E-09	7.50E-09	3.77E-11	2.70E-14	3.78E-14	9.44E-09	1.39E-08
Ni-63	1.41E-08	-	-	-	-	-	-	-	-	-	0.00E+00	1.41E-08

	Marine high (µSv/y)	Dose due to Terrestrial mean consumption rate (µSv/y)										
Radionuclide	**Total**	**Cow liver**	**Cow meat**	**Cow milk**	**Cow milk products**	**Fruit**	**Green vegetables**	**Root vegetables**	**Sheep liver**	**Sheep meat**	**Total**	**Grand Total**
Pu-238	2.81E-12	5.55E-14	2.72E-15	2.13E-15	2.70E-15	1.43E-14	1.08E-13	4.28E-16	2.67E-14	5.97E-16	2.13E-13	3.02E-12
U-234 (Pu-238)	4.89E-19	2.04E-27	1.22E-26	1.60E-24	2.03E-24	1.63E-19	3.92E-20	2.34E-19	4.94E-27	7.90E-27	4.36E-19	9.25E-19
Pu-239	4.76E-13	7.72E-15	3.78E-16	2.96E-16	3.76E-16	1.95E-15	1.45E-14	7.08E-17	3.64E-15	8.15E-17	2.90E-14	5.05E-13
U-235 (Pu-239)	1.60E-21	9.03E-32	5.42E-31	7.10E-29	9.00E-29	8.35E-24	1.97E-24	1.20E-23	2.19E-31	3.50E-31	2.23E-23	1.62E-21
Pu-240	7.54E-13	1.22E-14	5.99E-16	4.69E-16	5.95E-16	3.08E-15	2.30E-14	1.12E-16	5.76E-15	1.29E-16	4.59E-14	8.00E-13
U-236 (Pu-240)	1.32E-21	4.30E-30	2.58E-29	3.38E-27	4.29E-27	3.97E-22	9.38E-23	5.70E-22	1.04E-29	1.67E-29	1.06E-21	2.38E-21
Ru-103	1.61E-11	-	-	-	-	-	-	-	-	-	0.00E+00	1.61E-11
Ru-106	1.32E-10	-	-	-	-	-	-	-	-	-	0.00E+00	1.32E-10
Sb-122	6.27E-12	1.34E-11	3.71E-13	2.70E-11	2.65E-11	3.58E-12	2.75E-11	2.50E-14	1.75E-11	4.65E-14	1.16E-10	1.22E-10
Sb-124	1.75E-08	4.12E-08	2.39E-09	1.41E-08	1.77E-08	5.43E-09	1.91E-08	1.43E-10	7.59E-08	1.12E-09	1.77E-07	1.95E-07
Sb-125	1.35E-08	5.28E-09	3.16E-10	1.41E-09	1.79E-09	7.22E-10	1.84E-09	1.37E-10	1.10E-08	1.74E-10	2.27E-08	3.62E-08
Te-125m (Sb-125)	7.12E-09	1.34E-09	3.31E-10	1.53E-09	1.92E-09	1.65E-09	4.43E-10	8.52E-10	2.72E-09	2.56E-10	1.10E-08	1.82E-08
Sr-89	1.63E-11	8.12E-11	4.67E-10	1.04E-07	1.30E-07	4.77E-09	1.78E-08	3.49E-10	1.15E-10	1.67E-10	2.58E-07	2.58E-07
Sr-90	5.38E-11	1.57E-10	9.43E-10	1.91E-07	2.42E-07	5.69E-09	2.50E-08	1.19E-08	1.18E-10	1.88E-10	4.77E-07	4.77E-07
Y-90 (Sr-90)	-	5.00E-18	1.38E-18	1.43E-14	1.40E-14	9.53E-15	7.32E-14	6.62E-17	6.54E-18	1.70E-19	1.11E-13	1.11E-13
Te-123m	3.07E-11	-	-	-	-	-	-	-	-	-	0.00E+00	3.07E-11
Te-123 (Te-123m)	1.85E-25	-	-	-	-	-	-	-	-	-	0.00E+00	1.85E-25
Xe-131m	-	0.00E+00	0.00E+00	0.00E+00	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-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	0.00E+00	0.00E+00	0.00E+00
Xe-133m	-	0.00E+00	0.00E+00	0.00E+00	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-133 (Xe-133m)	-	0.00E+00	0.00E+00	0.00E+00	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-135	-	-	-	-	-	-	-	-	-	-	0.00E+00	0.00E+00
Cs-135 (Xe-135)	-	-	-	-	-	-	-	-	-	-	0.00E+00	0.00E+00
Zn-65	7.36E-08	2.05E-09	1.22E-08	1.91E-06	2.42E-06	2.64E-08	2.95E-08	1.61E-08	1.97E-09	3.10E-09	4.42E-06	4.49E-06
Zr-95	3.81E-09	1.83E-14	1.06E-13	3.19E-11	4.00E-11	2.09E-09	7.31E-09	1.85E-11	3.47E-14	5.15E-14	9.49E-09	1.33E-08
Nb-95 (Zr-95)	4.11E-09	9.43E-15	5.33E-14	2.42E-12	3.02E-12	6.91E-10	1.27E-09	3.24E-11	1.81E-14	2.52E-14	2.00E-09	6.11E-09
Nb-95m (Zr-95)	-	1.05E-19	3.54E-19	1.14E-15	1.20E-15	3.88E-14	2.90E-13	2.89E-16	1.41E-19	5.89E-20	3.31E-13	3.31E-13
Total	**5.37E-06**	**4.57E-02**	**2.74E-01**	**4.33E+00**	**2.90E+00**	**5.57E-01**	**3.11E-01**	**9.22E-01**	**4.57E-02**	**7.29E-02**	**9.45E+00**	**9.45E+00**

Note: Dash indicates that radionuclide is not included in the discharge route for the pathway indicated.
Zero means radionuclide has been included in the discharge but has no dose associated with it.

Table A.20: Annual Dose to the Representative Person (Local Resident Family Adult) (µSv/y)

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	**Total (µSv/y)**	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**Total**	**Grand total**
Ag-110m	1.12E-08	3.30E-12	1.44E-12	6.56E-12	6.01E-13	1.19E-11	1.12E-08
Am-241	1.75E-11	1.04E-14	9.11E-15	4.16E-13	7.64E-14	5.12E-13	1.80E-11
Np-237 (Am-241)	3.12E-19	5.65E-20	2.78E-20	2.27E-19	1.30E-20	3.24E-19	6.36E-19
Ar-41	2.65E-01	-	-	-	-	0.00E+00	2.65E-01
Ba-140	3.16E-07	3.22E-13	1.38E-11	6.43E-12	1.47E-11	3.53E-11	3.16E-07
La-140 (Ba-140)	7.31E-09	8.88E-12	3.84E-12	8.88E-12	2.03E-11	4.19E-11	7.35E-09
C-14	1.19E+01	-	-	-	-	0.00E+00	1.19E+01
Ce-141	1.34E-07	2.00E-11	4.29E-12	3.99E-11	4.55E-11	1.10E-10	1.34E-07
Ce-144	1.47E-06	8.93E-10	1.93E-10	1.79E-09	2.05E-09	4.93E-09	1.48E-06
Pr-144 (Ce-144)	2.52E-11	-	-	-	-	0.00E+00	2.52E-11
Pr-144m (Ce-144)	1.33E-12	-	-	-	-	0.00E+00	1.33E-12
Cm-242	1.60E-09	8.82E-15	3.81E-15	5.29E-13	6.45E-14	6.06E-13	1.60E-09
Pu-238 (Cm-242)	2.63E-13	1.67E-15	3.76E-15	2.51E-14	7.65E-15	3.82E-14	3.01E-13
Cm-243	9.62E-13	3.32E-16	1.44E-16	1.99E-14	2.42E-15	2.28E-14	9.85E-13
Pu-239 (Cm-243)	2.66E-18	2.19E-19	5.13E-19	3.28E-18	1.00E-18	5.01E-18	7.67E-18
Am-243 (Cm-243)	2.11E-22	-	-	-	-	0.00E+00	2.11E-22
Cm-244	1.05E-10	2.38E-14	1.03E-14	1.43E-12	1.74E-13	1.64E-12	1.07E-10
Pu-240 (Cm-244)	1.02E-15	6.60E-17	1.54E-16	9.88E-16	3.02E-16	1.51E-15	2.53E-15
Co-58	1.66E-06	3.49E-09	1.51E-09	1.75E-09	1.60E-09	8.35E-09	1.67E-06
Co-60	6.37E-05	1.93E-07	8.36E-08	9.66E-08	8.81E-08	4.61E-07	6.42E-05
Cr-51	2.12E-08	9.60E-12	1.65E-11	1.54E-11	1.76E-11	5.91E-11	2.12E-08
Cs-134	3.03E-06	1.32E-10	1.93E-09	1.32E-10	1.01E-10	2.30E-09	3.03E-06
Cs-137	2.24E-06	1.09E-10	1.60E-09	1.09E-10	8.31E-11	1.90E-09	2.24E-06
Ba-137m (Cs-137)	3.36E-11	-	-	-	-	0.00E+00	3.36E-11
Fe-55	-	2.83E-07	1.23E-07	1.70E-06	7.77E-07	2.88E-06	2.88E-06
Fe-59	2.80E-07	2.81E-09	1.21E-09	1.69E-08	7.71E-09	2.86E-08	3.08E-07
H-3	4.25E-01	6.20E-07	2.76E-06	6.20E-07	2.83E-07	4.28E-06	4.25E-01
I-131	1.33E-01	2.25E-10	9.64E-10	2.25E-10	1.03E-08	1.17E-08	1.33E-01
Xe-131m (I-131)	5.74E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.74E-12

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	**Total (µSv/y)**	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**Total**	**Grand total**
I-132	4.61E-05	-	-	-	-	0.00E+00	4.61E-05
I-133	3.55E-04	-	-	-	-	0.00E+00	3.55E-04
Xe-133 (I-133)	1.12E-11	-	-	-	-	0.00E+00	1.12E-11
Xe-133m (I-133)	2.27E-11	-	-	-	-	0.00E+00	2.27E-11
I-135	3.88E-05	-	-	-	-	0.00E+00	3.88E-05
Xe-135 (I-135)	5.98E-10	-	-	-	-	0.00E+00	5.98E-10
Xe-135m (I-135)	3.50E-08	-	-	-	-	0.00E+00	3.50E-08
Kr-85	5.47E-07	-	-	-	-	0.00E+00	5.47E-07
Kr-85m	6.88E-05	-	-	-	-	0.00E+00	6.88E-05
Kr-85 (Kr-85m)	4.90E-13	-	-	-	-	0.00E+00	4.90E-13
Kr-87	3.13E-10	-	-	-	-	0.00E+00	3.13E-10
Rb-87 (Kr-87)	5.71E-23	-	-	-	-	0.00E+00	5.71E-23
Kr-88	6.76E-05	-	-	-	-	0.00E+00	6.76E-05
Rb-88 (Kr-88)	1.39E-06	-	-	-	-	0.00E+00	1.39E-06
La-140	5.90E-08	-	-	-	-	0.00E+00	5.90E-08
Mn-54	3.14E-06	8.85E-10	3.07E-09	8.85E-08	4.86E-09	9.73E-08	3.24E-06
Nb-95	5.41E-07	4.97E-11	3.21E-11	2.49E-10	3.41E-10	6.72E-10	5.42E-07
Ni-63	-	1.73E-09	7.56E-09	3.45E-09	1.58E-09	1.43E-08	1.43E-08
Pu-238	2.74E-10	2.22E-12	4.85E-12	3.32E-11	1.01E-11	5.04E-11	3.24E-10
U-234 (Pu-238)	5.29E-18	5.15E-19	2.63E-19	1.55E-18	2.36E-18	4.69E-18	9.97E-18
Pu-239	3.80E-11	3.87E-13	8.49E-13	5.81E-12	1.77E-12	8.82E-12	4.68E-11
U-235 (Pu-239)	2.44E-22	2.97E-23	1.53E-23	8.91E-23	1.36E-22	2.70E-22	5.14E-22
Pu-240	6.02E-11	6.10E-13	1.34E-12	9.17E-12	2.79E-12	1.39E-11	7.41E-11
U-236 (Pu-240)	1.19E-20	1.41E-21	7.24E-22	4.23E-21	6.43E-21	1.28E-20	2.47E-20
Ru-103	-	6.49E-11	5.61E-12	1.30E-09	5.94E-10	1.96E-09	1.96E-09
Ru-106	-	5.70E-10	5.00E-11	1.14E-08	5.21E-09	1.72E-08	1.72E-08
Sb-122	5.25E-10	3.86E-14	2.66E-12	3.10E-14	1.42E-14	2.74E-12	5.28E-10
Sb-124	1.13E-06	1.17E-10	8.12E-09	9.39E-11	4.29E-11	8.37E-09	1.13E-06
Sb-125	4.98E-07	9.76E-11	6.88E-09	7.80E-11	3.57E-11	7.09E-09	5.05E-07
Te-125m (Sb-125)	6.84E-09	6.09E-10	2.92E-09	6.09E-10	2.79E-09	6.93E-09	1.38E-08
Sr-89	3.32E-07	1.60E-12	6.93E-12	8.03E-13	1.83E-12	1.12E-11	3.32E-07

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	**Total (µSv/y)**	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**Total**	**Grand total**
Sr-90	6.19E-07	1.12E-11	4.96E-11	5.58E-12	1.28E-11	7.92E-11	6.20E-07
Y-90 (Sr-90)	5.49E-13	-	-	-	-	0.00E+00	5.49E-13
Te-123m	-	3.37E-12	1.46E-11	3.37E-12	1.54E-11	3.67E-11	3.67E-11
Te-123 (Te-123m)	-	4.96E-26	2.59E-25	4.96E-26	2.27E-25	5.85E-25	5.85E-25
Xe-131m	1.27E-06	-	-	-	-	0.00E+00	1.27E-06
Xe-133	3.23E-04	-	-	-	-	0.00E+00	3.23E-04
Xe-133m	2.46E-08	-	-	-	-	0.00E+00	2.46E-08
Xe-133 (Xe-133m)	2.79E-12	-	-	-	-	0.00E+00	2.79E-12
Zn-65	3.62E-06	5.71E-07	4.96E-08	3.43E-07	1.04E-08	9.74E-07	4.59E-06
Zr-95	8.97E-07	2.03E-11	8.77E-12	5.08E-10	1.40E-10	6.77E-10	8.98E-07
Nb-95 (Zr-95)	1.95E-09	2.85E-12	1.87E-12	1.42E-11	1.95E-11	3.84E-11	1.99E-09
Nb-95m (Zr-95)	6.39E-12	-	-	-	-	0.00E+00	6.39E-12
Total	**1.27E+01**	**1.68E-06**	**3.05E-06**	**2.89E-06**	**1.20E-06**	**8.81E-06**	**1.27E+01**

* High rate indicates consumption of food at the “Top Two” consumption rate.
Note: Dash indicates that radionuclide is not included in the discharge route for the pathway indicated.
Zero means radionuclide has been included in the discharge but has no dose associated with it.

Table A.21: Annual Dose to the Representative Person (Local Resident Family Child) (µSv/y)

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	**Total (µSv/y)**	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**Total**	**Grand total**
Ag-110m	1.49E-08	4.37E-12	1.07E-12	8.71E-12	0.00E+00	1.42E-11	1.49E-08
Am-241	1.16E-11	8.20E-15	4.01E-15	3.27E-13	0.00E+00	3.39E-13	1.19E-11
Np-237 (Am-241)	1.98E-19	4.04E-20	1.11E-20	1.62E-19	0.00E+00	2.14E-19	4.11E-19
Ar-41	1.60E-01	-	-	-	-	0.00E+00	1.60E-01
Ba-140	2.81E-07	5.12E-13	1.23E-11	1.03E-11	0.00E+00	2.31E-11	2.81E-07
La-140 (Ba-140)	7.74E-09	1.33E-11	3.23E-12	1.33E-11	0.00E+00	2.98E-11	7.77E-09
C-14	1.30E+01	-	-	-	-	0.00E+00	1.30E+01
Ce-141	1.28E-07	3.01E-11	3.63E-12	6.02E-11	0.00E+00	9.39E-11	1.29E-07
Ce-144	1.52E-06	1.35E-09	1.64E-10	2.70E-09	0.00E+00	4.21E-09	1.53E-06
Pr-144 (Ce-144)	2.98E-11	-	-	-	-	0.00E+00	2.98E-11
Pr-144m (Ce-144)	7.92E-13	-	-	-	-	0.00E+00	7.92E-13
Cm-242	1.55E-09	1.26E-14	3.05E-15	7.56E-13	0.00E+00	7.72E-13	1.55E-09
Pu-238 (Cm-242)	1.68E-13	1.25E-15	1.57E-15	1.87E-14	0.00E+00	2.15E-14	1.90E-13
Cm-243	6.64E-13	2.53E-16	6.16E-17	1.52E-14	0.00E+00	1.55E-14	6.80E-13
Pu-239 (Cm-243)	1.76E-18	1.69E-19	2.21E-19	2.53E-18	0.00E+00	2.92E-18	4.68E-18
Am-243 (Cm-243)	1.41E-22	-	-	-	-	0.00E+00	1.41E-22
Cm-244	7.31E-11	1.98E-14	4.83E-15	1.19E-12	0.00E+00	1.21E-12	7.43E-11
Pu-240 (Cm-244)	6.75E-16	5.09E-17	6.64E-17	7.62E-16	0.00E+00	8.79E-16	1.55E-15
Co-58	9.68E-07	5.73E-09	1.39E-09	2.88E-09	0.00E+00	1.00E-08	9.78E-07
Co-60	3.34E-05	4.45E-07	1.08E-07	2.23E-07	0.00E+00	7.76E-07	3.42E-05
Cr-51	1.44E-08	1.41E-11	1.36E-11	2.25E-11	0.00E+00	5.02E-11	1.44E-08
Cs-134	1.76E-06	6.94E-11	5.70E-10	6.94E-11	0.00E+00	7.09E-10	1.76E-06
Cs-137	1.27E-06	5.96E-11	4.94E-10	5.96E-11	0.00E+00	6.13E-10	1.27E-06
Ba-137m (Cs-137)	2.02E-11	-	-	-	-	0.00E+00	2.02E-11
Fe-55	-	6.73E-07	1.64E-07	4.05E-06	0.00E+00	4.89E-06	4.89E-06
Fe-59	2.13E-07	5.24E-09	1.27E-09	3.15E-08	0.00E+00	3.80E-08	2.51E-07
H-3	5.18E-01	5.66E-07	1.41E-06	5.66E-07	0.00E+00	2.54E-06	5.18E-01
I-131	2.96E-01	3.79E-10	9.11E-10	3.79E-10	0.00E+00	1.67E-09	2.96E-01
Xe-131m (I-131)	3.92E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.92E-12
I-132	3.31E-05	-	-	-	-	0.00E+00	3.31E-05

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	**Total (µSv/y)**	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**Total**	**Grand total**
I-133	7.24E-04	-	-	-	-	0.00E+00	7.24E-04
Xe-133 (I-133)	6.93E-12	-	-	-	-	0.00E+00	6.93E-12
Xe-133m (I-133)	1.48E-11	-	-	-	-	0.00E+00	1.48E-11
I-135	3.51E-05	-	-	-	-	0.00E+00	3.51E-05
Xe-135 (I-135)	3.68E-10	-	-	-	-	0.00E+00	3.68E-10
Xe-135m (I-135)	2.11E-08	-	-	-	-	0.00E+00	2.11E-08
Kr-85	5.00E-07	-	-	-	-	0.00E+00	5.00E-07
Kr-85m	4.27E-05	-	-	-	-	0.00E+00	4.27E-05
Kr-85 (Kr-85m)	4.43E-13	-	-	-	-	0.00E+00	4.43E-13
Kr-87	1.96E-10	-	-	-	-	0.00E+00	1.96E-10
Rb-87 (Kr-87)	1.96E-10	-	-	-	-	0.00E+00	1.96E-10
Kr-88	4.08E-05	-	-	-	-	0.00E+00	4.08E-05
Rb-88 (Kr-88)	1.15E-06	-	-	-	-	0.00E+00	1.15E-06
La-140	5.39E-08	-	-	-	-	0.00E+00	5.39E-08
Mn-54	1.71E-06	1.16E-09	2.25E-09	1.16E-07	0.00E+00	1.19E-07	1.83E-06
Nb-95	3.33E-07	6.73E-11	2.44E-11	3.37E-10	0.00E+00	4.29E-10	3.33E-07
Ni-63	-	2.30E-09	5.65E-09	4.60E-09	0.00E+00	1.26E-08	1.26E-08
Pu-238	1.81E-10	1.65E-12	2.02E-12	2.47E-11	0.00E+00	2.84E-11	2.09E-10
U-234 (Pu-238)	4.73E-18	5.56E-19	1.59E-19	1.67E-18	0.00E+00	2.39E-18	7.11E-18
Pu-239	2.53E-11	2.98E-13	3.67E-13	4.48E-12	0.00E+00	5.15E-12	3.04E-11
U-235 (Pu-239)	2.20E-22	3.21E-23	9.25E-24	9.61E-23	0.00E+00	1.37E-22	3.57E-22
Pu-240	3.99E-11	4.71E-13	5.79E-13	7.08E-12	0.00E+00	8.13E-12	4.81E-11
U-236 (Pu-240)	1.08E-20	1.50E-21	4.32E-22	4.50E-21	0.00E+00	6.43E-21	1.72E-20
Ru-103	-	9.52E-11	4.61E-12	1.91E-09	0.00E+00	2.01E-09	2.01E-09
Ru-106	-	8.73E-10	4.28E-11	1.75E-08	0.00E+00	1.84E-08	1.84E-08
Sb-122	5.81E-10	5.99E-14	2.32E-12	4.82E-14	0.00E+00	2.43E-12	5.83E-10
Sb-124	8.01E-07	1.74E-10	6.75E-09	1.40E-10	0.00E+00	7.06E-09	8.08E-07
Sb-125	2.81E-07	1.33E-10	5.25E-09	1.06E-10	0.00E+00	5.49E-09	2.87E-07
Te-125m (Sb-125)	9.24E-09	9.50E-10	2.55E-09	9.50E-10	0.00E+00	4.45E-09	1.37E-08
Sr-89	4.39E-07	2.56E-12	6.19E-12	1.28E-12	0.00E+00	1.00E-11	4.39E-07
Sr-90	1.07E-06	1.71E-11	4.25E-11	8.54E-12	0.00E+00	6.81E-11	1.07E-06
Y-90 (Sr-90)	6.57E-13	-	-	-	-	0.00E+00	6.57E-13

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	**Total (µSv/y)**	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**Total**	**Grand total**
Te-123m	-	4.82E-12	1.17E-11	4.82E-12	0.00E+00	2.13E-11	2.13E-11
Te-123 (Te-123m)	-	4.35E-26	1.27E-25	4.35E-26	0.00E+00	2.14E-25	2.14E-25
Xe-131m	8.78E-07	-	-	-	-	0.00E+00	8.78E-07
Xe-133	1.99E-04	-	-	-	-	0.00E+00	1.99E-04
Xe-133m	1.62E-08	-	-	-	-	0.00E+00	1.62E-08
Xe-133 (Xe-133m)	1.72E-12	-	-	-	-	0.00E+00	1.72E-12
Zn-65	4.85E-06	6.70E-07	3.26E-08	4.02E-07	0.00E+00	1.10E-06	5.96E-06
Zr-95	5.42E-07	2.90E-11	7.01E-12	7.26E-10	0.00E+00	7.62E-10	5.42E-07
Nb-95 (Zr-95)	1.76E-09	3.86E-12	1.42E-12	1.93E-11	0.00E+00	2.46E-11	1.78E-09
Nb-95m (Zr-95)	5.24E-12	-	-	-	-	0.00E+00	5.24E-12
Total	**1.40E+01**	**2.37E-06**	**1.74E-06**	**5.42E-06**	**0.00E+00**	**9.54E-06**	**1.40E+01**

* High rate indicates consumption of food at the "Top Two" consumption rate.
Note: Dash indicates that radionuclide is not included in the discharge route for the pathway indicated.
Zero means radionuclide has been included in the discharge but has no dose associated with it.

Table A.22: Annual Dose to the Representative Person (Local Resident Family Infant) (µSv/y)

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	Total (µSv/y)	Crustaceans	Fish	Molluscs	Seaweed	Total	Grand total
Ag-110m	3.81E-08	0.00E+00	1.68E-12	0.00E+00	0.00E+00	1.68E-12	3.81E-08
Am-241	6.86E-12	0.00E+00	3.93E-15	0.00E+00	0.00E+00	3.93E-15	6.87E-12
Np-237 (Am-241)	1.26E-19	0.00E+00	1.24E-20	0.00E+00	0.00E+00	1.24E-20	1.39E-19
Ar-41	1.26E-01	-	-	-	-	0.00E+00	1.26E-01
Ba-140	4.13E-07	0.00E+00	2.23E-11	0.00E+00	0.00E+00	2.23E-11	4.13E-07
La-140 (Ba-140)	1.19E-08	0.00E+00	5.83E-12	0.00E+00	0.00E+00	5.83E-12	1.19E-08
C-14	2.13E+01	-	-	-	-	0.00E+00	2.13E+01
Ce-141	1.28E-07	0.00E+00	7.19E-12	0.00E+00	0.00E+00	7.19E-12	1.28E-07
Ce-144	1.69E-06	0.00E+00	3.39E-10	0.00E+00	0.00E+00	3.39E-10	1.69E-06
Pr-144 (Ce-144)	3.47E-11	-	-	-	-	0.00E+00	3.47E-11
Pr-144m (Ce-144)	6.11E-13	-	-	-	-	0.00E+00	6.11E-13
Cm-242	1.32E-09	0.00E+00	5.63E-15	0.00E+00	0.00E+00	5.63E-15	1.32E-09
Pu-238 (Cm-242)	9.82E-14	0.00E+00	1.52E-15	0.00E+00	0.00E+00	1.52E-15	9.97E-14
Cm-243	4.51E-13	0.00E+00	7.41E-17	0.00E+00	0.00E+00	7.41E-17	4.51E-13
Pu-239 (Cm-243)	9.72E-19	0.00E+00	2.01E-19	0.00E+00	0.00E+00	2.01E-19	1.17E-18
Am-243 (Cm-243)	8.31E-23	-	-	-	-	0.00E+00	8.31E-23
Cm-244	5.32E-11	0.00E+00	5.83E-15	0.00E+00	0.00E+00	5.83E-15	5.32E-11
Pu-240 (Cm-244)	3.74E-16	0.00E+00	6.02E-17	0.00E+00	0.00E+00	6.02E-17	4.34E-16
Co-58	7.65E-07	0.00E+00	2.09E-09	0.00E+00	0.00E+00	2.09E-09	7.67E-07
Co-60	2.32E-05	0.00E+00	1.55E-07	0.00E+00	0.00E+00	1.55E-07	2.34E-05
Cr-51	1.38E-08	0.00E+00	2.33E-11	0.00E+00	0.00E+00	2.33E-11	1.38E-08
Cs-134	1.60E-06	0.00E+00	3.80E-10	0.00E+00	0.00E+00	3.80E-10	1.60E-06
Cs-137	1.09E-06	0.00E+00	3.46E-10	0.00E+00	0.00E+00	3.46E-10	1.09E-06
Ba-137m (Cs-137)	1.58E-11	-	-	-	-	0.00E+00	1.58E-11
Fe-55	-	0.00E+00	2.09E-07	0.00E+00	0.00E+00	2.09E-07	2.09E-07
Fe-59	1.81E-07	0.00E+00	2.04E-09	0.00E+00	0.00E+00	2.04E-09	1.83E-07
H-3	9.23E-01	0.00E+00	1.72E-06	0.00E+00	0.00E+00	1.72E-06	9.23E-01
I-131	1.10E+00	0.00E+00	1.84E-09	0.00E+00	0.00E+00	1.84E-09	1.10E+00
Xe-131m (I-131)	3.31E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.31E-12
I-132	3.33E-05	-	-	-	-	0.00E+00	3.33E-05

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	**Total (µSv/y)**	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**Total**	**Grand total**
I-133	3.02E-03	-	-	-	-	0.00E+00	3.02E-03
Xe-133 (I-133)	5.48E-12	-	-	-	-	0.00E+00	5.48E-12
Xe-133m (I-133)	1.22E-11	-	-	-	-	0.00E+00	1.22E-11
I-135	5.48E-05	-	-	-	-	0.00E+00	5.48E-05
Xe-135 (I-135)	2.91E-10	-	-	-	-	0.00E+00	2.91E-10
Xe-135m (I-135)	1.65E-08	-	-	-	-	0.00E+00	1.65E-08
Kr-85	4.84E-07	-	-	-	-	0.00E+00	4.84E-07
Kr-85m	3.39E-05	-	-	-	-	0.00E+00	3.39E-05
Kr-85 (Kr-85m)	4.28E-13	-	-	-	-	0.00E+00	4.28E-13
Kr-87	1.58E-10	-	-	-	-	0.00E+00	1.58E-10
Rb-87 (Kr-87)	1.58E-10	-	-	-	-	0.00E+00	1.58E-10
Kr-88	3.18E-05	-	-	-	-	0.00E+00	3.18E-05
Rb-88 (Kr-88)	1.16E-06	-	-	-	-	0.00E+00	1.16E-06
La-140	5.41E-08	-	-	-	-	0.00E+00	5.41E-08
Mn-54	1.26E-06	0.00E+00	3.13E-09	0.00E+00	0.00E+00	3.13E-09	1.26E-06
Nb-95	2.43E-07	0.00E+00	4.14E-11	0.00E+00	0.00E+00	4.14E-11	2.43E-07
Ni-63	-	0.00E+00	9.88E-09	0.00E+00	0.00E+00	9.88E-09	9.88E-09
Pu-238	1.05E-10	0.00E+00	1.97E-12	0.00E+00	0.00E+00	1.97E-12	1.07E-10
U-234 (Pu-238)	3.64E-18	0.00E+00	1.63E-19	0.00E+00	0.00E+00	1.63E-19	3.80E-18
Pu-239	1.39E-11	0.00E+00	3.33E-13	0.00E+00	0.00E+00	3.33E-13	1.42E-11
U-235 (Pu-239)	1.72E-22	0.00E+00	9.88E-24	0.00E+00	0.00E+00	9.88E-24	1.82E-22
Pu-240	2.20E-11	0.00E+00	5.25E-13	0.00E+00	0.00E+00	5.25E-13	2.26E-11
U-236 (Pu-240)	8.18E-21	0.00E+00	4.67E-22	0.00E+00	0.00E+00	4.67E-22	8.65E-21
Ru-103	-	0.00E+00	8.25E-12	0.00E+00	0.00E+00	8.25E-12	8.25E-12
Ru-106	-	0.00E+00	8.16E-11	0.00E+00	0.00E+00	8.16E-11	8.16E-11
Sb-122	7.13E-10	0.00E+00	4.39E-12	0.00E+00	0.00E+00	4.39E-12	7.17E-10
Sb-124	7.17E-07	0.00E+00	1.21E-08	0.00E+00	0.00E+00	1.21E-08	7.29E-07
Sb-125	2.09E-07	0.00E+00	8.90E-09	0.00E+00	0.00E+00	8.90E-09	2.18E-07
Te-125m (Sb-125)	1.71E-08	0.00E+00	4.94E-09	0.00E+00	0.00E+00	4.94E-09	2.21E-08
Sr-89	8.86E-07	0.00E+00	1.12E-11	0.00E+00	0.00E+00	1.12E-11	8.86E-07
Sr-90	1.30E-06	0.00E+00	3.02E-11	0.00E+00	0.00E+00	3.02E-11	1.30E-06
Y-90 (Sr-90)	7.90E-13	-	-	-	-	0.00E+00	7.90E-13

	High rate*	Dose due to marine mean consumption rate (µSv/y)					
Radionuclide	**Total (µSv/y)**	**Crustaceans**	**Fish**	**Molluscs**	**Seaweed**	**Total**	**Grand total**
Te-123m	-	0.00E+00	2.15E-11	0.00E+00	0.00E+00	2.15E-11	2.15E-11
Te-123 (Te-123m)	-	0.00E+00	1.28E-25	0.00E+00	0.00E+00	1.28E-25	1.28E-25
Xe-131m	7.47E-07	-	-	-	-	0.00E+00	7.47E-07
Xe-133	1.58E-04	-	-	-	-	0.00E+00	1.58E-04
Xe-133m	1.35E-08	-	-	-	-	0.00E+00	1.35E-08
Xe-133 (Xe-133m)	1.36E-12	-	-	-	-	0.00E+00	1.36E-12
Zn-65	1.24E-05	0.00E+00	4.75E-08	0.00E+00	0.00E+00	4.75E-08	1.24E-05
Zr-95	3.96E-07	0.00E+00	1.21E-11	0.00E+00	0.00E+00	1.21E-11	3.96E-07
Nb-95 (Zr-95)	2.02E-09	0.00E+00	2.41E-12	0.00E+00	0.00E+00	2.41E-12	2.02E-09
Nb-95m (Zr-95)	4.49E-12	-	-	-	-	0.00E+00	4.49E-12
Total	**2.35E+01**	**0.00E+00**	**2.18E-06**	**0.00E+00**	**0.00E+00**	**2.18E-06**	**2.35E+01**

* High rate indicates consumption of food at the “Top Two” consumption rate.
Note: Dash indicates that radionuclide is not included in the discharge route for the pathway indicated.
Zero means radionuclide has been included in the discharge but has no dose associated with it.

Table A.23: Short-term Activity Discharge (Bq)

Radionuclide	Activity discharged in 24 hrs (Bq)	Fraction of proposed annual limit
Kr-85	1.1E+09	0.85
Kr-85m	5.5E+09	0.55
Kr-87	5.0E+03	0.51
Kr-88	5.5E+08	0.59
Xe-131m	2.6E+09	0.90
Xe-133	1.8E+11	0.90
Xe-133m	1.4E+07	0.78

Table A.24: Predicted Air Concentrations and Deposition Rates per Unit Release

	Kr -85			
Distance (m)	Air conc. (Bq/m^3)	Dry dep. ($Bq/m^2/s$)	Wet dep. ($Bq/m^2/s$)	Total dep. ($Bq/m^2/s$)
100	4.88E-05	0.00E+00	0.00E+00	0.00E+00
200	3.30E-05	0.00E+00	0.00E+00	0.00E+00
270	2.25E-05	0.00E+00	0.00E+00	0.00E+00
300	1.93E-05	0.00E+00	0.00E+00	0.00E+00
400	1.24E-05	0.00E+00	0.00E+00	0.00E+00
500	8.66E-06	0.00E+00	0.00E+00	0.00E+00
600	6.38E-06	0.00E+00	0.00E+00	0.00E+00
700	4.90E-06	0.00E+00	0.00E+00	0.00E+00
800	3.88E-06	0.00E+00	0.00E+00	0.00E+00
900	3.16E-06	0.00E+00	0.00E+00	0.00E+00
1000	2.62E-06	0.00E+00	0.00E+00	0.00E+00

Table A.25: Predicted Adult Short-term Effective Dose (Sv)

Radionuclide	Adult cloud gamma dose (Sv)	Adult cloud beta dose (Sv)	Total dose (Sv)
Kr-85	3.57E-12	3.31E-10	3.35E-10
Kr-85m	5.08E-10	1.71E-09	2.21E-09
Kr-87	2.68E-15	1.02E-14	1.29E-14
Kr-88	7.20E-10	2.63E-10	9.83E-10
Xe-131m	1.25E-11	2.37E-10	2.50E-10
Xe-133	3.32E-09	1.15E-08	1.49E-08
Xe-133m	2.43E-13	2.66E-12	2.90E-12
Total	**4.57E-09**	**1.41E-08**	**1.86E-08**

Table A.26: Predicted Child Short-term Effective Dose (Sv)

Radionuclide	Child cloud gamma dose (Sv)	Child cloud beta dose (Sv)	Total dose (Sv)
Kr-85	2.14E-12	3.31E-10	3.33E-10
Kr-85m	3.05E-10	1.71E-09	2.01E-09
Kr-87	1.61E-15	1.02E-14	1.18E-14
Kr-88	4.32E-10	2.63E-10	6.95E-10
Xe-131m	7.51E-12	2.37E-10	2.45E-10
Xe-133	1.99E-09	1.15E-08	1.35E-08
Xe-133m	1.46E-13	2.66E-12	2.81E-12
Total	**2.74E-09**	**1.41E-08**	**1.68E-08**

Table A.27: Predicted Infant Short-term Effective Dose (Sv)

Radionuclide	Infant cloud gamma dose (Sv)	Infant cloud beta dose (Sv)	Total dose (Sv)
Kr-85	1.67E-12	3.31E-10	3.33E-10
Kr-85m	2.37E-10	1.71E-09	1.94E-09
Kr-87	1.25E-15	1.02E-14	1.14E-14
Kr-88	3.36E-10	2.63E-10	5.99E-10
Xe-131m	5.84E-12	2.37E-10	2.43E-10
Xe-133	1.55E-09	1.15E-08	1.31E-08
Xe-133m	1.14E-13	2.66E-12	2.77E-12
Total	**2.13E-09**	**1.41E-08**	**1.62E-08**

Table A.28: Build-Up of Activity in the Marine Environment for the Stage 1 Assessment

Radionuclide	Unfiltered seawater (Bq/l) $	Seabed sediment (Bq/kg) $
Ag-110m	1.69E-12	1.92E-10
Am-241	1.39E-14	1.31E-09
Ba-140	1.11E-09	3.35E-08
Ce-141	3.85E-09	5.81E-06
Ce-144	2.25E-08	2.64E-04
Cm-242	1.93E-13	1.37E-09
Cm-243	5.83E-16	4.66E-11
Cm-244	5.22E-14	3.82E-09
Co-58	9.18E-09	2.08E-05
Co-60	1.08E-07	3.52E-03
Cr-51	5.44E-09	2.45E-06
Cs-134	1.66E-09	1.32E-06
Cs-137	1.97E-09	4.82E-06
Fe-55	1.68E-06	1.84E-02
Fe-59	3.26E-09	2.33E-06
H-3	2.38E-01	4.10E-01
I-131	9.42E-09	2.51E-09
La-140*	9.14E-10	1.06E-07
Mn-54	4.76E-08	4.24E-04
Nb-95*	1.75E-08	4.56E-05
Ni-63	1.50E-07	7.08E-03
Pu-238*	6.27E-13	2.95E-08
Pu-239*	1.01E-13	5.03E-09
Pu-240*	1.59E-13	7.94E-09
Ru-103	6.97E-09	4.59E-08
Ru-106	5.78E-09	2.98E-07
Sb-122	9.48E-12	1.32E-11
Sb-124	1.43E-08	4.30E-07
Sb-125	2.49E-08	8.45E-06
Sr-89	2.38E-09	6.01E-08
Sr-90	1.39E-09	1.14E-06
Te-123m	1.78E-11	1.03E-09
Te-125m	3.04E-09	8.28E-06
Xe-131m	3.77E-09	2.57E-09
Zn-65	2.39E-08	4.30E-05
Zr-95	7.51E-09	2.10E-05

*Includes contribution from progeny of parent radionuclides, i.e. La-140 includes contribution from decay of Ba-140, Nb-95 from decay of Zr-95, Pu-238 from decay of Cm-242, Pu-239 from decay of Cm-243 and Pu-240 from decay of Cm-244.
$ These concentrations are those predicted in the local compartment.

Table A.29: Build-Up of Activity in the Terrestrial Environment for the Stage 1 Assessment

Radionuclide	Activity concentration in soil after 60 years continuous discharge (Bq/kg)
Ag-110m	6.61E-09
Am-241	4.25E-12
Ba-137m	8.20E-13
Ba-140	2.53E-07
C-14	1.50E+02
Ce-141	9.65E-07
Ce-144	8.59E-06
Cm-242	5.56E-11
Cm-243	1.84E-13
Cm-244	1.79E-11
Co-58	7.10E-06
Co-60	1.57E-04
Cr-51	2.16E-06
Cs-134	4.22E-06
Cs-137	2.17E-05
Fe-59	6.74E-07
H-3	1.20E+02
I-131	1.27E-02
I-132	5.03E-05
I-133	3.03E-04
I-135	5.65E-05
La-140*	2.92E-07
Mn-54	1.86E-05
Nb-95*	4.83E-06
Np-237	3.84E-17
Pr-144	7.03E-12
Pu-238*	6.47E-11
Pu-239*	8.07E-12
Pu-240*	1.28E-11
Rb-87	1.10E-21
Rb-88	1.46E-07
Sb-122	7.22E-10
Sb-124	1.94E-06
Sb-125	5.77E-06
Sr-89	1.33E-06
Sr-90	9.84E-06
Te-125m	5.73E-06
U-234	4.25E-15
U-235	2.18E-19
U-236	1.04E-17
Y-90	4.16E-13
Zn-65	6.78E-06
Zr-95	2.24E-06

*Table A.29 includes contribution from progeny of parent radionuclides, i.e. La-140 includes contribution from decay of Ba-140, Nb-95 from decay of Zr-95, Pu-238 from decay of Cm-242, Pu-239 from decay of Cm-243 and Pu-240 from decay of Cm-244.

Table A.30: Predicted Noble Gas Air Concentrations at 100m for the Stage 1 Assessment

Radionuclide	Air concentration (Bq/m^3)
Ar-41	9.83E+00
Kr-85	2.47E-03
Kr-85m	1.90E-02
Kr-87	1.85E-08
Kr-88	1.77E-03
Xe-131m	5.51E-03
Xe-133	3.80E-01
Xe-133m	3.42E-05
Xe-135*	6.02E-08
Xe-135m*	2.11E-06

*From decay of I-135

Table A.31: Parameters Used for the ERICA Marine Assessment

Assessment name	UK ABWR marine	
Tier	2	
Isotopes	See table 6.3-3	
Organisms	Default species: note these have been modified slightly from ERICA v1.1 Bird, Benthic fish, Mollusc – bivalve, Crustacean, Macroalgae, Mammal, Pelagic fish, Phytoplankton, Polychaete worm, Reptile, Sea anemones & True coral, Vascular plant, Zooplankton	
Ecosystem	Marine	
Dose rate screening values	10 µGy/h	
Uncertainty factor (UF)	5	
Media activity concentration	Site-specific media concentration as presented in Table A.28	
Distribution coefficient (Kd) (Emboldened values taken from taken from IAEA TRS422 Ocean margin)	Ag	2.66E+04
	Am	5.33E+06
	Ba	5.33E+03
	Ce	7.99E+06
	Cm	5.33E+06
	Co	7.99E+05
	Cr	1.33E+05
	Cs	1.07E+04
	Fe	**3.00E+08**
	H	2.66E+00
	I	1.86E+02
	La	7.99E+06
	Mn	5.33E+06
	Nb	2.13E+06
	Ni	5.33E+04
	Pu	2.66E+05
	Ru	1.07E+05
	Sb	5.33E+03
	Sr	2.13E+01
	Te	2.66E+03
	Zn	1.86E+05
	Zr	5.33E+06
Occupancy factors	Default	
Radiation weighting factors	Default	
Percentage dry weight value	100%	

Table A.32: Concentration Ratios

Element	Benthic fish	Bird	Crustacean	Mammal	Mollusc - bivalve	Pelagic fish	Phytoplankton	Reptile	Vascular plant	Zooplankton	Macroalgae	Polychaete worm	Sea anemones & True coral
Ag	1.10E+04	2.20E+04	3.60E+04	2.20E+04	3.60E+04	1.10E+04	6.90E+04	2.20E+04	3.90E+03	6.00E+03	3.90E+03	2.70E+04	1.30E+02
Am	4.20E+02	4.09E+02	5.00E+02	1.35E+03	9.90E+04	4.20E+02	2.10E+05	1.35E+03	4.30E+02	4.00E+03	4.30E+02	9.90E+04	4.50E+01
Ba	2.50E+01	1.64E+02	4.95E+01	1.64E+02	1.50E+02	2.50E+01	1.88E+02	1.64E+02	3.00E+00	6.80E+01	2.93E+01	4.60E-01	9.53E+01
Ce	3.90E+02	2.20E+03	1.00E+02	2.20E+03	2.20E+03	3.90E+02	1.10E+04	2.20E+03	1.60E+02	6.00E+03	2.10E+03	2.20E+03	1.30E+02
Cm	1.40E+03	4.09E+02	5.00E+02	1.35E+03	1.50E+04	1.40E+03	2.70E+05	1.35E+03	1.20E+04	6.30E+03	1.20E+04	1.50E+04	4.50E+01
Co	5.30E+03	5.00E+02	3.50E+03	5.00E+02	5.30E+03	5.30E+03	3.10E+03	5.00E+02	3.28E+02	4.80E+03	1.70E+03	8.03E+03	6.08E+02
Cr	2.00E+02	2.00E+03	1.00E+02	2.00E+03	2.00E+03	2.00E+02	5.00E+03	2.00E+03	6.00E+03	1.00E+03	6.00E+03	2.00E+03	2.00E+03
Cs	8.40E+01	4.80E+02	5.30E+01	2.20E+02	5.00E+01	8.40E+01	8.50E+00	4.80E+02	1.00E+01	1.30E+02	9.60E+01	1.80E+02	2.30E+02
Fe	3.00E+04	2.50E+04	5.00E+05	2.00E+07	5.00E+05	3.00E+04	4.00E+05	2.50E+04	3.00E+04	7.00E+05	2.00E+04	1.00E+05	2.50E+04
H	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
I	9.00E+00	8.80E+03	3.92E+01	8.80E+03	8.80E+03	9.00E+00	9.50E+02	8.80E+03	2.40E+01	3.10E+03	4.20E+03	8.80E+03	8.80E+03
La	1.13E+04	1.13E+04	5.70E+03	1.13E+04	1.13E+04	1.13E+04	1.10E+04	1.13E+04	1.10E+04	1.13E+04	1.10E+04	1.13E+04	1.13E+04
Mn	2.60E+03	4.50E+03	4.50E+04	4.50E+03	1.20E+04	2.60E+03	3.50E+03	4.50E+03	3.00E+04	2.50E+03	8.60E+03	3.20E+03	1.00E+01
Nb	3.00E+01	8.80E+02	1.00E+02	8.80E+02	8.80E+02	3.00E+01	1.00E+03	8.80E+02	4.90E+02	2.00E+04	4.90E+02	8.80E+02	8.80E+02
Ni	2.50E+02	5.00E+02	1.27E+03	5.00E+02	6.40E+03	2.50E+02	5.70E+02	5.00E+02	9.50E+02	5.00E+02	9.50E+02	4.20E+03	6.40E+03
Pu	1.40E+03	4.09E+02	1.16E+02	1.35E+03	1.10E+03	1.40E+03	1.26E+05	1.35E+03	4.05E+03	6.30E+03	4.05E+03	1.53E+03	4.90E+02
Ru	2.94E+01	1.62E+03	1.00E+02	1.62E+03	1.62E+03	2.94E+01	6.68E+03	1.62E+03	1.20E+03	3.00E+04	1.20E+03	1.62E+03	2.85E+01
Sb	6.00E+02	8.30E+03	3.00E+02	8.30E+03	4.70E+02	6.00E+02	1.00E+03	8.30E+03	2.25E+02	1.31E+03	2.25E+02	4.50E+03	9.00E+01
Sr	2.50E+01	1.64E+02	4.95E+01	1.64E+02	1.50E+02	2.50E+01	1.88E+02	1.64E+02	3.00E+00	6.80E+01	2.93E+01	4.60E-01	9.53E+01
Te	6.90E+02	8.30E+03	1.00E+03	8.30E+03	1.50E+03	6.90E+02	1.31E+04	8.30E+03	4.25E+02	1.00E+03	4.25E+02	4.50E+03	1.00E+01
Zn	2.50E+04	2.50E+04	3.00E+05	2.50E+04	8.00E+04	2.50E+04	1.00E+04	2.50E+04	2.00E+03	1.00E+05	2.00E+03	2.50E+04	2.50E+04
Zr	8.52E+01	8.52E+01	4.90E+01	8.52E+01	3.30E+03	8.52E+01	3.30E+04	8.52E+01	1.10E+03	2.17E+04	1.66E+03	3.30E+03	1.30E+02

N.B. Values entered in red above have been taken from IAEA TRS422 with the flowing mapping for IAEA species onto ERICA reference species.

- Fish taken to be analogues for benthic fish and pelagic fish
- Cephalopods taken to be analogues for polychaete worms
- Cetaceans taken to be analogues for mammals.

Values entered in blue above have been taken from the most limiting element for the particular organism. Values entered in black above have been taken from ERICA Assessment Tool November 2014.

Table A.33: Parameters Used for the ERICA Terrestrial Assessment

Assessment name	UK ABWR terrestrial
Tier	2
Isotopes	See table 6.3-4
Organisms	ERICA v1.2 uses a modified list of RAP from ERICA v1.1 (mainly name changes) Amphibian, Annelid, Arthropod – detritivorous, Bird, Flying insects, Grasses & Herbs, Lichen & Bryophytes, Mammal – large, Mammal - small-burrowing, Mollusc – gastropod, Reptile, Shrub, Tree
Ecosystem	Terrestrial
Dose rate screening values	10 µGy/h
Uncertainty factor (UF)	5
Media activity concentration	Site-specific media concentration as presented in Tables A.29 and A.30
Concentration ratio (CR)	Default values used with the exception of Fe, Pr, Rb and Y. CR value for Carbon was used for these elements for each species
Occupancy factors	Default
Radiation weighting factors	Default
Percentage dry weight value	100%

Table A.34: Calculated Dose Rates (µGy/h) and RQ for Marine Biota

Organism	**Total Dose Rate per organism [µGy/h]**	**Screening Value (µGy/h)**	**Risk Quotient (expected value) [unitless]**	**Risk Quotient (conservative value) [unitless]**
Benthic fish	4.96E-06	1.00E+01	4.96E-07	2.48E-06
Bird	2.50E-06	1.00E+01	2.50E-07	1.25E-06
Crustacean	1.21E-05	1.00E+01	1.21E-06	6.05E-06
Macroalgae	4.96E-06	1.00E+01	4.96E-07	2.48E-06
Mammal	3.06E-04	1.00E+01	3.06E-05	1.53E-04
Mollusc - bivalve	1.18E-05	1.00E+01	1.18E-06	5.89E-06
Pelagic fish	2.55E-06	1.00E+01	2.55E-07	1.28E-06
Phytoplankton	7.32E-06	1.00E+01	7.32E-07	3.66E-06
Polychaete worm	8.78E-06	1.00E+01	8.78E-07	4.39E-06
Reptile	2.75E-06	1.00E+01	2.75E-07	1.37E-06
Sea anemones & True coral	4.98E-06	1.00E+01	4.98E-07	2.49E-06
Vascular plant	5.05E-06	1.00E+01	5.05E-07	2.53E-06
Zooplankton	1.16E-05	1.00E+01	1.16E-06	5.82E-06

Table A.35: Calculated Dose Rates (µGy/h) and RQ for Terrestrial Biota

Organism	Total Dose Rate per Organism [µGy/h]	Screening Value (µGy/h)	Risk Quotient (expected value) [unitless]	Risk Quotient (conservative value) [unitless]
Amphibian	5.89E+00	1.00E+01	5.89E-01	2.94E+00
Annelid	1.99E+00	1.00E+01	1.99E-01	9.93E-01
Arthropod - detritivorous	1.99E+00	1.00E+01	1.99E-01	9.95E-01
Bird	6.09E+00	1.00E+01	6.09E-01	3.05E+00
Flying insects	1.98E+00	1.00E+01	1.98E-01	9.91E-01
Grasses & Herbs	3.96E+00	1.00E+01	3.96E-01	1.98E+00
Lichen & Bryophytes	4.00E+00	1.00E+01	4.00E-01	2.00E+00
Mammal - large	6.09E+00	1.00E+01	6.09E-01	3.05E+00
Mammal - small-burrowing	6.09E+00	1.00E+01	6.09E-01	3.05E+00
Mollusc - gastropod	1.99E+00	1.00E+01	1.99E-01	9.95E-01
Reptile	6.09E+00	1.00E+01	6.09E-01	3.05E+00
Shrub	3.96E+00	1.00E+01	3.96E-01	1.98E+00
Tree	5.92E+00	1.00E+01	5.92E-01	2.96E+00

Table A.36: Calculated Dose Rates (µGy/h) and RQ for Terrestrial Biota Resulting from the Discharge of Noble Gases

Organism	Total dose rate per organism (µGy/h)	Screening value (µGy/h)	Risk quotient (expected value)	Risk quotient (conservative value)
Amphibian	3.00E-03	1.00E+01	3.00E-04	1.50E-03
Annelid	7.61E-07	1.00E+01	7.61E-08	3.81E-07
Arthropod - detritivorous	3.39E-03	1.00E+01	3.39E-04	1.70E-03
Bird	2.72E-03	1.00E+01	2.72E-04	1.36E-03
Invertebrate - detritivorous	8.14E-07	1.00E+01	8.14E-08	4.07E-07
Flying Insects	3.25E-03	1.00E+01	3.25E-04	1.63E-03
Grasses & Herbs	6.35E-03	1.00E+01	6.35E-04	3.18E-03
Lichen & bryophytes	3.61E-03	1.00E+01	3.61E-04	1.80E-03
Mammal - Large	1.58E-03	1.00E+01	1.58E-04	7.92E-04
Mammal - Small	6.86E-07	1.00E+01	6.86E-08	3.43E-07
Mollusc - Gastropod	3.16E-03	1.00E+01	3.16E-04	1.58E-03
Reptile	2.94E-03	1.00E+01	2.94E-04	1.47E-03
Tree	4.08E-03	1.00E+01	4.08E-04	2.04E-03
Shrub	3.65E-03	1.00E+01	3.65E-04	1.83E-03

Table A.37: Collective Dose (man Sv) truncated to 500 years to the UK Population due to Liquid Discharges

Radionuclide	Fish	Crustaceans	Molluscs	Beach sediment gammas	Global circulation	Total
Ag-110m	1.92E-14	4.61E-14	1.24E-13	3.61E-17	0.00E+00	1.89E-13
Am-241	1.92E-16	1.66E-16	8.17E-15	2.79E-18	0.00E+00	8.53E-15
Ba-140	1.98E-14	2.85E-15	5.75E-14	1.89E-16	0.00E+00	8.04E-14
Ce-141	9.89E-15	1.85E-13	3.74E-13	1.84E-14	0.00E+00	5.87E-13
Ce-144	5.63E-13	8.56E-12	1.74E-11	6.21E-13	0.00E+00	2.72E-11
Cm-242	1.07E-17	8.40E-17	5.12E-15	1.11E-19	0.00E+00	5.22E-15
Cm-243	9.03E-19	3.70E-18	2.39E-16	3.50E-19	0.00E+00	2.44E-16
Cm-244	5.36E-17	2.54E-16	1.61E-14	3.74E-20	0.00E+00	1.64E-14
Co-58	4.44E-12	3.36E-11	1.72E-11	8.75E-13	0.00E+00	5.61E-11
Co-60	4.24E-10	2.03E-09	1.08E-09	4.35E-10	0.00E+00	3.98E-09
Cr-51	3.67E-14	8.90E-14	1.45E-13	3.06E-15	0.00E+00	2.74E-13
Cs-134	4.73E-11	2.26E-12	3.22E-12	1.82E-13	0.00E+00	5.29E-11
Cs-137	7.85E-11	2.52E-12	3.85E-12	4.65E-13	0.00E+00	8.54E-11
Fe-55	1.00E-09	3.31E-09	2.24E-08	1.67E-12	0.00E+00	2.67E-08
Fe-59	3.42E-12	2.69E-11	1.67E-10	1.16E-13	0.00E+00	1.97E-10
H-3	1.46E-07	1.54E-08	2.48E-08	0.00E+00	1.53E-07	3.39E-07
I-131	1.13E-12	1.96E-12	1.97E-12	2.71E-17	0.00E+00	5.06E-12
La-140*	1.54E-14	1.13E-13	1.15E-13	8.66E-15	0.00E+00	2.51E-13
Mn-54	1.17E-11	8.84E-12	9.20E-10	1.63E-11	0.00E+00	9.57E-10
Nb-95*	8.90E-14	4.96E-13	2.52E-12	1.50E-12	0.00E+00	4.61E-12
Ni-63	1.70E-10	2.75E-11	6.90E-11	0.00E+00	0.00E+00	2.67E-10
Np-237 (Am-241)	2.16E-20	1.39E-20	1.01E-19	1.61E-22	0.00E+00	1.37E-19
Pu-238*	1.08E-13	3.50E-14	6.56E-13	5.96E-20	0.00E+00	7.99E-13
Pu-239*	3.38E-14	7.71E-15	1.52E-13	3.62E-20	0.00E+00	1.94E-13
Pu-240*	5.28E-14	1.21E-14	2.39E-13	1.89E-18	0.00E+00	3.04E-13
Ru-103	1.59E-14	6.25E-13	1.32E-11	8.09E-16	0.00E+00	1.38E-11
Ru-106	9.38E-13	9.03E-12	2.58E-10	5.07E-15	0.00E+00	2.68E-10
Sb-122	2.34E-15	3.32E-16	2.66E-16	1.46E-19	0.00E+00	2.94E-15
Sb-124	3.20E-11	1.20E-12	1.05E-12	3.20E-14	0.00E+00	3.43E-11
Sb-125	2.22E-10	1.90E-12	2.30E-12	3.99E-13	0.00E+00	2.27E-10
Sr-89	2.37E-14	1.59E-14	8.58E-15	2.01E-19	0.00E+00	4.82E-14
Sr-90	2.68E-12	2.77E-13	2.19E-13	3.44E-19	0.00E+00	3.18E-12
Te-123 (Te-123m)	9.77E-26	6.42E-27	1.17E-26	2.53E-30	0.00E+00	1.16E-25
Te-123m	1.04E-13	3.93E-14	4.74E-14	7.82E-18	0.00E+00	1.91E-13
Te-125m (Sb-125)	4.22E-10	3.69E-11	6.71E-11	3.39E-14	0.00E+00	5.26E-10
U-234 (Pu-238)	1.77E-19	1.10E-19	5.98E-19	2.10E-22	0.00E+00	8.85E-19
U-235 (Pu-239)	1.74E-23	1.02E-23	5.48E-23	2.10E-24	0.00E+00	8.44E-23
U-236 (Pu-240)	8.19E-22	4.78E-22	2.58E-21	8.64E-25	0.00E+00	3.88E-21
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	1.64E-18	0.00E+00	1.64E-18
Zn-65	3.99E-10	6.72E-09	4.66E-09	1.31E-12	0.00E+00	1.18E-08
Zr-95	2.29E-14	1.92E-13	4.86E-12	6.70E-13	0.00E+00	5.75E-12
Total	**1.49E-07**	**2.76E-08**	**5.45E-08**	**4.59E-10**	**1.53E-07**	**3.84E-07**

*Includes contribution from progeny of parent radionuclides, i.e. La-140 includes contribution from decay of Ba-140, Nb-95 from decay of Zr-95, Pu-238 from decay of Cm-242, Pu-239 from decay of Cm-243 and Pu-240 from decay of Cm-244.

Brackets indicate a radionuclide progeny of a discharged radionuclide, e.g. U-234 (Pu-238) shows that Pu-238 is the precursor that was discharged and U-234 is the progeny produced during the subsequent radioactive decay.

Table A.38: Collective Dose (man Sv) truncated to 500 years to the EU 12 Population due to Liquid Discharges

Radionuclide	Fish	Crustaceans	Molluscs	Beach sediment gammas	Global circulation	Total
Ag-110m	4.11E-14	1.42E-13	3.22E-13	4.05E-17	0.00E+00	5.05E-13
Am-241	4.10E-16	5.07E-16	2.09E-14	3.46E-18	0.00E+00	2.19E-14
Ba-140	3.75E-14	8.75E-15	1.46E-13	1.94E-16	0.00E+00	1.93E-13
Ce-141	1.89E-14	5.68E-13	9.52E-13	1.93E-14	0.00E+00	1.56E-12
Ce-144	1.09E-12	2.63E-11	4.44E-11	6.65E-13	0.00E+00	7.25E-11
Cm-242	2.06E-17	2.58E-16	1.31E-14	1.19E-19	0.00E+00	1.33E-14
Cm-243	1.83E-18	1.13E-17	6.09E-16	4.14E-19	0.00E+00	6.22E-16
Cm-244	1.07E-16	7.79E-16	4.10E-14	4.34E-20	0.00E+00	4.19E-14
Co-58	8.66E-12	1.03E-10	4.40E-11	9.31E-13	0.00E+00	1.56E-10
Co-60	8.56E-10	6.24E-09	2.76E-09	4.88E-10	0.00E+00	1.03E-08
Cr-51	7.06E-14	2.73E-13	3.69E-13	3.19E-15	0.00E+00	7.16E-13
Cs-134	1.06E-10	7.02E-12	8.77E-12	2.09E-13	0.00E+00	1.22E-10
Cs-137	1.89E-10	8.00E-12	1.15E-11	5.57E-13	0.00E+00	2.09E-10
Fe-55	2.09E-09	1.01E-08	5.75E-08	1.89E-12	0.00E+00	6.97E-08
Fe-59	6.67E-12	8.25E-11	4.24E-10	1.23E-13	0.00E+00	5.14E-10
H-3	3.51E-07	4.89E-08	7.43E-08	0.00E+00	9.24E-07	1.40E-06
I-131	2.12E-12	6.02E-12	5.01E-12	2.78E-17	0.00E+00	1.31E-11
La-140*	2.95E-14	3.45E-13	2.94E-13	9.13E-15	0.00E+00	6.78E-13
Mn-54	2.31E-11	2.71E-11	2.35E-09	1.76E-11	0.00E+00	2.41E-09
Nb-95*	1.72E-13	1.52E-12	6.42E-12	1.59E-12	0.00E+00	9.71E-12
Ni-63	3.73E-10	8.48E-11	1.84E-10	0.00E+00	0.00E+00	6.42E-10
Np-237 (Am-241)	5.64E-20	4.59E-20	3.40E-19	2.04E-22	0.00E+00	4.42E-19
Pu-238*	2.38E-13	1.08E-13	1.74E-12	7.30E-20	0.00E+00	2.09E-12
Pu-239*	7.84E-14	2.41E-14	4.35E-13	4.51E-20	0.00E+00	5.38E-13
Pu-240*	1.23E-13	3.78E-14	6.83E-13	2.36E-18	0.00E+00	8.44E-13
Ru-103	3.11E-14	1.92E-12	3.36E-11	8.58E-16	0.00E+00	3.56E-11
Ru-106	2.06E-12	2.78E-11	6.85E-10	5.76E-15	0.00E+00	7.15E-10
Sb-122	4.35E-15	1.02E-15	6.79E-16	1.47E-19	0.00E+00	6.05E-15
Sb-124	6.39E-11	3.67E-12	2.68E-12	3.43E-14	0.00E+00	7.03E-11
Sb-125	5.07E-10	5.94E-12	6.45E-12	4.60E-13	0.00E+00	5.20E-10
Sr-89	4.70E-14	4.89E-14	2.19E-14	2.14E-19	0.00E+00	1.18E-13
Sr-90	6.53E-12	8.80E-13	6.61E-13	4.10E-19	0.00E+00	8.07E-12
Te-123 (Te-123m)	2.56E-25	2.12E-26	3.90E-26	3.07E-30	0.00E+00	3.16E-25
Te-123m	2.15E-13	1.20E-13	1.21E-13	8.58E-18	0.00E+00	4.57E-13
Te-125m (Sb-125)	9.76E-10	1.17E-10	1.95E-10	3.92E-14	0.00E+00	1.29E-09
U-234 (Pu-238)	4.75E-19	3.68E-19	2.09E-18	2.65E-22	0.00E+00	2.93E-18
U-235 (Pu-239)	4.81E-23	3.47E-23	2.03E-22	2.67E-24	0.00E+00	2.88E-22
U-236 (Pu-240)	2.26E-21	1.63E-21	9.54E-21	1.10E-24	0.00E+00	1.34E-20
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	1.71E-18	0.00E+00	1.71E-18
Zn-65	8.29E-10	2.06E-08	1.20E-08	1.45E-12	0.00E+00	3.34E-08
Zr-95	4.40E-14	5.88E-13	1.24E-11	7.09E-13	0.00E+00	1.37E-11
Total	**3.57E-07**	**8.63E-08**	**1.51E-07**	**5.14E-10**	**9.24E-07**	**1.52E-06**

*Includes contribution from progeny of parent radionuclides, i.e. La-140 includes contribution from decay of Ba-140, Nb-95 from decay of Zr-95, Pu-238 from decay of Cm-242, Pu-239 from decay of Cm-243 and Pu-240 from decay of Cm-244.
Brackets indicate a radionuclide progeny of a discharged radionuclide, e.g. U-234 (Pu-238) shows that Pu-238 is the precursor that was discharged and U-234 is the progeny produced during the subsequent radioactive decay.

Table A.39: Collective Dose (man Sv) truncated to 500 years to the World Population due to Liquid Discharges

Radionuclide	Fish	Crustaceans	Molluscs	Beach sediment gammas	Global circulation	Total
Ag-110m	6.03E-14	1.86E-13	3.50E-13	4.06E-17	0.00E+00	5.96E-13
Am-241	6.08E-16	6.65E-16	2.27E-14	3.46E-18	0.00E+00	2.40E-14
Ba-140	4.99E-14	1.14E-14	1.59E-13	1.94E-16	0.00E+00	2.20E-13
Ce-141	2.52E-14	7.41E-13	1.03E-12	1.93E-14	0.00E+00	1.82E-12
Ce-144	1.46E-12	3.42E-11	4.81E-11	6.65E-13	0.00E+00	8.45E-11
Cm-242	2.76E-17	3.36E-16	1.41E-14	1.19E-19	0.00E+00	1.45E-14
Cm-243	2.52E-18	1.48E-17	6.59E-16	4.14E-19	0.00E+00	6.77E-16
Cm-244	1.46E-16	1.02E-15	4.44E-14	4.34E-20	0.00E+00	4.56E-14
Co-58	1.16E-11	1.34E-10	4.76E-11	9.31E-13	0.00E+00	1.94E-10
Co-60	1.17E-09	8.14E-09	2.99E-09	4.88E-10	0.00E+00	1.28E-08
Cr-51	9.46E-14	3.56E-13	4.00E-13	3.19E-15	0.00E+00	8.54E-13
Cs-134	1.64E-10	9.25E-12	9.54E-12	2.09E-13	0.00E+00	1.83E-10
Cs-137	3.27E-10	1.07E-11	1.27E-11	5.66E-13	0.00E+00	3.51E-10
Fe-55	2.97E-09	1.32E-08	6.23E-08	1.89E-12	0.00E+00	7.85E-08
Fe-59	8.99E-12	1.08E-10	4.60E-10	1.23E-13	0.00E+00	5.77E-10
H-3	6.00E-07	6.57E-08	8.15E-08	0.00E+00	2.57E-05	2.65E-05
I-131	2.82E-12	7.85E-12	5.43E-12	2.78E-17	0.00E+00	1.61E-11
La-140*	3.95E-14	4.51E-13	3.18E-13	9.13E-15	0.00E+00	8.17E-13
Mn-54	3.14E-11	3.54E-11	2.54E-09	1.76E-11	0.00E+00	2.62E-09
Nb-95*	2.30E-13	1.98E-12	6.95E-12	1.59E-12	0.00E+00	1.08E-11
Ni-63	5.69E-10	1.12E-10	2.00E-10	0.00E+00	0.00E+00	8.81E-10
Np-237 (Am-241)	1.08E-19	6.38E-20	3.79E-19	2.07E-22	0.00E+00	5.51E-19
Pu-238*	3.74E-13	1.42E-13	1.90E-12	7.33E-20	0.00E+00	2.41E-12
Pu-239*	1.31E-13	3.21E-14	4.78E-13	4.56E-20	0.00E+00	6.41E-13
Pu-240*	2.05E-13	5.04E-14	7.50E-13	2.39E-18	0.00E+00	1.01E-12
Ru-103	4.20E-14	2.50E-12	3.64E-11	8.58E-16	0.00E+00	3.90E-11
Ru-106	3.10E-12	3.65E-11	7.44E-10	5.77E-15	0.00E+00	7.84E-10
Sb-122	5.79E-15	1.33E-15	7.35E-16	1.47E-19	0.00E+00	7.85E-15
Sb-124	8.71E-11	4.79E-12	2.90E-12	3.43E-14	0.00E+00	9.48E-11
Sb-125	8.08E-10	7.86E-12	7.02E-12	4.61E-13	0.00E+00	8.23E-10
Sr-89	6.38E-14	6.38E-14	2.37E-14	2.14E-19	0.00E+00	1.51E-13
Sr-90	1.14E-11	1.18E-12	7.27E-13	4.18E-19	0.00E+00	1.33E-11
Te-123 (Te-123m)	4.91E-25	2.93E-26	4.35E-26	3.33E-30	0.00E+00	5.64E-25
Te-123m	3.02E-13	1.57E-13	1.32E-13	8.58E-18	0.00E+00	5.91E-13
Te-125m (Sb-125)	1.58E-09	1.56E-10	2.13E-10	3.93E-14	0.00E+00	1.94E-09
U-234 (Pu-238)	9.34E-19	5.15E-19	2.34E-18	2.70E-22	0.00E+00	3.79E-18
U-235 (Pu-239)	9.70E-23	4.92E-23	2.29E-22	2.76E-24	0.00E+00	3.78E-22
U-236 (Pu-240)	4.56E-21	2.31E-21	1.08E-20	1.14E-24	0.00E+00	1.77E-20
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	1.71E-18	0.00E+00	1.71E-18
Zn-65	1.18E-09	2.69E-08	1.30E-08	1.46E-12	0.00E+00	4.11E-08
Zr-95	5.89E-14	7.66E-13	1.34E-11	7.09E-13	0.00E+00	1.50E-11
Total	**6.09E-07**	**1.15E-07**	**1.64E-07**	**5.14E-10**	**2.57E-05**	**2.66E-05**

*Includes contribution from progeny of parent radionuclides, i.e. La-140 includes contribution from decay of Ba-140, Nb-95 from decay of Zr-95, Pu-238 from decay of Cm-242, Pu-239 from decay of Cm-243 and Pu-240 from decay of Cm-244.
Brackets indicate a radionuclide progeny of a discharged radionuclide, e.g. U-234 (Pu-238) shows that Pu-238 is the precursor that was discharged and U-234 is the progeny produced during the subsequent radioactive decay.

Table A.40: First Pass Collective Dose (man Sv) to the UK Population truncated to 500 years due to Gaseous Discharges

	Collective Dose (man Sv)															
Radionuclide	Gamma from plume	Beta from plume	Inhalation of plume	Gamma from ground	Beta from ground	Re-suspen sion	Green vegetables	Grain	Root vegetables	Sheep meat	Sheep liver	Cow meat	Cow liver	Cow milk	Cow milk products	Total
Ag-110m	1.38E-14	1.04E-17	8.84E-13	5.54E-12	1.05E-12	7.84E-16	1.19E-13	1.85E-13	3.55E-14	3.01E-14	4.90E-13	3.37E-14	5.46E-13	3.08E-11	0.00E+00	3.97E-11
Am-241	1.56E-21	6.98E-26	8.29E-14	5.51E-18	2.02E-22	1.30E-15	1.31E-16	3.15E-17	3.55E-18	2.12E-18	8.07E-18	4.68E-18	2.30E-17	2.18E-18	0.00E+00	8.44E-14
Am-243 (Cm-243)	5.15E-29	5.20E-34	9.91E-22	1.14E-24	3.21E-26	1.81E-23	1.74E-24	3.69E-25	4.86E-26	1.14E-26	4.35E-26	3.48E-26	1.71E-25	1.77E-26	0.00E+00	1.01E-21
Ar-41	7.38E-05	1.75E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.55E-05
Ba-137m (Cs-137)	4.29E-13	2.73E-15	0.00E+00	1.36E-15	2.41E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.33E-13
Ba-140	7.62E-13	5.93E-14	5.15E-10	2.37E-10	3.63E-11	2.34E-13	3.20E-11	8.40E-16	9.50E-18	8.93E-13	6.59E-14	1.05E-12	5.49E-14	1.20E-10	0.00E+00	9.44E-10
C-14	0.00E+00	7.87E-08	1.62E-02	0.00E+00	0.00E+00	0.00E+00	7.25E-03	1.30E-01	2.89E-02	2.88E-03	1.54E-04	6.06E-03	2.42E-04	5.46E-02	0.00E+00	2.46E-01
Ce-141	4.52E-13	3.43E-14	4.62E-10	2.45E-11	4.66E-11	2.68E-13	2.13E-11	5.96E-14	3.55E-16	3.97E-14	4.81E-13	4.29E-14	3.81E-13	1.39E-11	0.00E+00	5.70E-10
Ce-144	1.07E-13	1.03E-14	4.83E-09	1.21E-10	1.24E-09	4.40E-12	2.18E-10	2.97E-11	4.56E-13	2.09E-12	2.26E-11	2.99E-12	2.42E-11	1.26E-10	0.00E+00	6.63E-09
Cm-242	5.67E-21	0.00E+00	7.60E-12	1.90E-18	3.40E-20	6.19E-15	5.23E-15	4.85E-16	1.43E-19	2.70E-17	1.04E-16	2.46E-17	1.21E-16	1.17E-17	0.00E+00	7.61E-12
Cm-243	7.89E-22	1.54E-23	4.54E-15	3.32E-18	8.83E-20	1.37E-17	7.27E-18	1.61E-18	2.03E-20	1.12E-19	4.26E-19	2.33E-19	1.14E-18	1.08E-19	0.00E+00	4.57E-15
Cm-244	1.96E-22	0.00E+00	5.00E-13	6.81E-19	0.00E+00	1.18E-15	7.34E-16	1.61E-16	1.41E-18	1.10E-17	4.18E-17	2.21E-17	1.09E-16	1.03E-17	0.00E+00	5.03E-13
Co-58	1.86E-11	2.42E-14	7.13E-10	2.29E-09	6.16E-11	4.92E-13	9.08E-11	2.99E-11	2.34E-13	5.08E-13	2.87E-12	5.36E-13	2.25E-12	5.30E-11	0.00E+00	3.26E-09
Co-60	4.88E-11	4.38E-14	4.48E-09	9.86E-08	2.52E-10	6.41E-12	5.54E-10	1.33E-09	1.02E-10	9.51E-12	5.08E-11	1.12E-11	4.50E-11	3.52E-10	0.00E+00	1.06E-07
Cr-51	5.04E-13	0.00E+00	1.41E-11	2.56E-11	5.48E-14	7.90E-15	2.82E-12	3.69E-15	6.96E-18	1.43E-12	8.84E-14	1.50E-12	6.78E-14	1.88E-12	0.00E+00	4.81E-11
Cs-134	1.86E-12	8.30E-15	1.85E-10	1.94E-09	4.84E-11	2.07E-13	2.21E-10	2.92E-09	7.57E-10	1.18E-09	6.30E-11	1.06E-09	4.27E-11	5.51E-09	0.00E+00	1.39E-08
Cs-137	0.00E+00	4.97E-15	7.84E-11	2.29E-09	5.09E-11	2.44E-13	1.09E-10	1.57E-09	4.17E-10	6.10E-10	3.25E-11	5.12E-10	2.05E-11	2.58E-09	0.00E+00	8.27E-09
Fe-59	3.66E-12	1.11E-14	2.63E-10	2.75E-10	1.96E-11	1.64E-13	3.09E-11	3.01E-12	7.59E-15	1.47E-13	2.58E-11	1.58E-13	2.73E-11	9.36E-12	0.00E+00	6.58E-10
H-3	0.00E+00	0.00E+00	1.29E-03	0.00E+00	0.00E+00	0.00E+00	2.48E-04	1.19E-04	9.65E-04	5.75E-05	3.06E-06	1.21E-04	4.83E-06	4.20E-03	0.00E+00	7.01E-03
I-131	5.76E-09	1.17E-10	2.56E-06	6.85E-07	3.76E-07	8.24E-09	4.92E-06	5.21E-13	4.76E-12	1.48E-06	1.32E-07	2.15E-06	1.32E-07	1.75E-04	0.00E+00	1.88E-04
I-132	2.42E-09	3.43E-11	2.75E-09	4.17E-09	1.25E-09	4.35E-13	1.19E-26	0.00E+00	0.00E+00	2.14E-41	8.04E-24	9.16E-38	1.86E-23	3.02E-23	0.00E+00	1.06E-08
I-133	1.63E-09	5.85E-11	9.22E-08	2.18E-08	2.02E-08	1.02E-10	6.61E-10	1.88E-81	6.34E-67	2.05E-12	1.32E-11	1.21E-11	2.65E-11	2.43E-08	0.00E+00	1.61E-07
I-135	1.52E-09	1.91E-11	7.25E-09	7.09E-09	2.08E-09	3.18E-12	2.58E-15	7.99E-240	2.26E-192	2.31E-21	4.46E-16	8.88E-20	1.04E-15	1.86E-13	0.00E+00	1.80E-08
Kr-85	5.50E-10	3.25E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.80E-09
Kr-85m	4.91E-08	4.07E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.32E-08
Kr-87	5.93E-14	8.14E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.74E-14
Kr-88	3.31E-08	3.59E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.34E-08
La-140*	1.18E-11	1.52E-13	1.30E-10	3.38E-11	1.15E-11	5.85E-14	4.73E-12	1.44E-48	1.19E-43	2.76E-14	3.07E-14	4.64E-14	2.54E-14	1.01E-12	0.00E+00	1.93E-10
Mn-54	9.68E-12	0.00E+00	4.03E-10	4.73E-09	6.03E-13	3.74E-13	6.77E-11	1.16E-10	1.45E-11	8.88E-12	1.87E-11	9.15E-12	1.47E-11	1.03E-10	0.00E+00	5.49E-09
Nb-95*	1.08E-11	3.42E-15	4.90E-10	6.65E-10	2.81E-12	3.34E-13	4.91E-11	2.11E-12	2.46E-14	1.07E-15	6.41E-17	1.08E-15	4.75E-17	1.17E-13	0.00E+00	1.22E-09
Nb-95m (Zr-95)	4.49E-14	6.03E-15	1.40E-11	3.37E-12	7.25E-13	3.44E-15	2.79E-13	1.77E-30	1.59E-29	1.20E-19	2.02E-20	2.57E-19	2.69E-20	6.56E-16	0.00E+00	1.84E-11
Np-237 (Am-241)	1.09E-30	2.26E-33	2.58E-23	6.65E-26	1.27E-27	5.91E-20	4.73E-22	2.04E-21	1.04E-21	2.55E-24	9.74E-24	1.26E-23	6.17E-23	5.85E-24	0.00E+00	6.28E-20
Pr-144 (Ce-144)	1.80E-13	4.14E-13	2.32E-12	3.50E-15	1.41E-13	5.30E-18	7.10E-141	0.00E+00	0.00E+00	1.97E-249	1.69E-100	2.81E-224	2.99E-100	3.34E-118	0.00E+00	3.06E-12
Pr-144m (Ce-144)	3.36E-14	0.00E+00	0.00E+00	1.77E-15	2.43E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.54E-14
Pu-238*	8.86E-23	0.00E+00	1.29E-12	2.42E-19	7.95E-22	1.05E-14	2.19E-15	4.99E-16	2.67E-17	3.98E-17	1.52E-16	8.82E-17	4.33E-16	4.10E-17	0.00E+00	1.30E-12
Pu-239*	1.08E-23	0.00E+00	1.79E-13	5.79E-20	4.19E-22	3.94E-15	2.98E-16	6.94E-17	6.09E-18	4.75E-18	1.81E-17	1.03E-17	5.05E-17	4.80E-18	0.00E+00	1.84E-13
Pu-240*	1.91E-23	0.00E+00	2.84E-13	6.38E-20	4.78E-23	6.19E-15	4.72E-16	1.10E-16	9.62E-18	7.52E-18	2.86E-17	1.63E-17	8.01E-17	7.60E-18	0.00E+00	2.91E-13
Rb-87 (Kr-87)	0.00E+00	5.44E-30	4.38E-26	0.00E+00	7.16E-26	1.09E-27	5.20E-25	2.63E-24	2.14E-24	3.75E-25	2.00E-26	6.26E-25	2.51E-26	1.81E-23	0.00E+00	2.46E-23
Rb-88 (Kr-88)	9.58E-09	1.98E-09	5.52E-09	7.55E-10	1.78E-09	5.22E-14	5.11E-133	0.00E+00	0.00E+00	6.18E-235	4.20E-90	2.10E-210	4.77E-90	4.09E-108	0.00E+00	1.96E-08
Sb-122	2.34E-14	1.74E-15	1.25E-12	1.18E-13	2.04E-13	3.28E-16	3.12E-14	3.36E-37	6.20E-35	3.60E-16	8.95E-15	6.06E-16	8.75E-15	3.36E-14	0.00E+00	1.68E-12
Sb-124	1.14E-11	1.28E-13	9.30E-10	1.15E-09	2.41E-10	6.20E-13	9.61E-11	2.21E-11	1.68E-13	1.67E-11	9.53E-11	1.61E-11	6.80E-11	5.70E-11	0.00E+00	2.71E-09
Sb-125	5.18E-13	3.28E-15	1.41E-10	7.00E-10	1.90E-11	1.68E-13	1.14E-11	2.60E-11	1.11E-12	3.07E-12	1.64E-11	2.60E-12	1.04E-11	6.91E-12	0.00E+00	9.38E-10
Sr-89	4.44E-16	1.78E-13	7.41E-10	3.79E-14	3.09E-10	4.75E-13	8.18E-11	1.17E-11	2.62E-13	2.29E-12	1.33E-13	2.87E-12	1.23E-13	3.84E-10	0.00E+00	1.53E-09
Sr-90	0.00E+00	2.88E-15	2.80E-10	1.86E-17	9.82E-11	8.57E-13	3.75E-10	8.59E-10	2.70E-10	7.11E-12	3.79E-13	1.67E-11	6.69E-13	2.01E-09	0.00E+00	3.92E-09
Te-125m (Sb-125)	6.88E-17	6.48E-18	7.59E-13	7.02E-15	2.29E-16	5.70E-14	2.04E-12	3.31E-12	8.52E-13	3.40E-12	3.02E-12	2.00E-12	1.96E-12	5.57E-12	0.00E+00	2.30E-11
U-234 (Pu-238)	8.63E-31	8.55E-33	4.90E-22	5.19E-27	1.91E-29	5.50E-19	3.50E-21	3.46E-20	3.49E-20	7.01E-26	3.73E-27	6.97E-26	2.79E-27	5.94E-24	0.00E+00	6.24E-19

	Collective Dose (man Sv)														
Radionuclide	**Gamma from plume**	**Beta from plume**	**Inhalation of plume**	**Gamma from ground**	**Beta from ground**	**Re-suspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
U-235 (Pu-239)	3.97E-32	4.35E-35	1.92E-26	2.45E-28	2.13E-30	5.63E-23	2.87E-25	2.87E-24	2.89E-24	2.98E-30	1.59E-31	2.97E-30	1.19E-31	2.53E-28	0.00E+00	6.23E-23
U-236 (Pu-240)	1.23E-33	1.17E-35	9.46E-25	3.26E-30	5.10E-33	2.73E-21	1.35E-23	1.35E-22	1.37E-22	1.42E-28	7.56E-30	1.41E-28	5.65E-30	1.20E-26	0.00E+00	3.01E-21
Xe-131m	3.80E-09	2.09E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.89E-09
Xe-133	1.24E-06	9.50E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-06
Xe-133m	9.07E-11	2.65E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E-10
Xe-135 (I-135)	1.95E-10	1.21E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E-10
Xe-135m (I-135)	3.63E-10	4.36E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.67E-10
Y-90 (Sr-90)	2.17E-21	2.82E-15	1.72E-12	1.18E-20	2.11E-13	3.70E-16	4.83E-14	2.26E-37	4.87E-35	2.92E-19	7.40E-19	6.90E-19	1.01E-18	6.05E-15	0.00E+00	1.99E-12
Zn-65	3.08E-12	3.42E-16	1.96E-10	1.18E-09	1.60E-12	1.73E-13	2.43E-10	4.37E-10	1.24E-10	7.34E-11	3.98E-12	1.34E-10	5.44E-12	1.25E-08	0.00E+00	1.49E-08
Zr-95	4.98E-12	2.34E-14	7.55E-10	1.12E-09	5.43E-11	5.10E-13	4.01E-11	1.06E-11	2.64E-14	8.34E-16	4.75E-17	7.76E-16	3.28E-17	1.40E-13	0.00E+00	1.99E-09
Total	**7.51E-05**	**1.94E-06**	**1.75E-02**	**8.34E-07**	**4.04E-07**	**8.36E-09**	**7.50E-03**	**1.30E-01**	**2.99E-02**	**2.94E-03**	**1.57E-04**	**6.18E-03**	**2.47E-04**	**5.90E-02**	**0.00E+00**	**2.53E-01**

*Includes contribution from progeny of parent radionuclides, i.e. La-140 includes contribution from decay of Ba-140, Nb-95 from decay of Zr-95, Pu-238 from decay of Cm-242, Pu-239 from decay of Cm-243 and Pu-240 from decay of Cm-244.
Brackets indicate a radionuclide progeny of a discharged radionuclide, e.g. U-234 (Pu-238) shows that Pu-238 is the discharged precursor and U-234 is the progeny produced during subsequent radioactive decay.

Table A.41: First Pass Collective Dose (man Sv) truncated to 500 years due to Gaseous Discharges to the EU Population

	Collective Dose (man Sv)															
Radionuclide	Gamma from plume	Beta from plume	Inhalation of plume	Gamma from ground	Beta from ground	Re-suspen sion	Green vegetables	Grain	Root vegetables	Sheep meat	Sheep liver	Cow meat	Cow liver	Cow milk	Cow milk products	Total
Ag-110m	2.71E-14	1.91E-17	1.63E-12	9.18E-12	1.74E-12	1.30E-15	3.12E-13	6.54E-13	9.70E-14	3.21E-14	5.21E-13	6.56E-14	8.99E-13	2.04E-11	1.69E-10	2.04E-10
Am-241	2.95E-21	1.29E-25	1.53E-13	9.17E-18	3.36E-22	2.16E-15	3.47E-16	1.12E-16	9.75E-18	2.26E-18	8.58E-18	9.15E-18	3.78E-17	1.45E-18	1.54E-17	1.56E-13
Am-243 (Cm-243)	2.58E-28	2.51E-33	4.78E-21	5.16E-24	1.45E-25	8.18E-23	1.49E-23	4.80E-24	4.37E-25	2.26E-26	9.22E-26	2.17E-25	8.21E-25	3.04E-26	2.81E-25	4.89E-21
Ar-41	6.60E-05	1.40E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.74E-05
Ba-137m (Cs-137)	8.49E-13	5.13E-15	0.00E+00	2.30E-15	4.06E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.56E-13
Ba-140	1.41E-12	1.04E-13	9.05E-10	3.76E-10	5.77E-11	3.72E-13	7.79E-11	2.75E-15	2.43E-17	9.41E-13	6.91E-14	1.96E-12	8.71E-14	7.71E-11	6.17E-12	1.51E-09
C-14	0.00E+00	2.11E-07	4.35E-02	0.00E+00	0.00E+00	0.00E+00	3.45E-02	8.95E-01	1.45E-01	3.79E-03	2.06E-04	2.10E-02	6.61E-04	5.53E-02	3.03E-01	1.50E+00
Ce-141	8.48E-13	6.21E-14	8.38E-10	3.99E-11	7.60E-11	4.38E-13	5.45E-11	2.05E-13	9.46E-16	4.21E-14	5.08E-13	8.23E-14	6.19E-13	9.09E-12	1.42E-11	1.03E-09
Ce-144	2.03E-13	1.90E-14	8.93E-09	2.01E-10	2.06E-09	7.30E-12	5.72E-10	1.05E-10	1.25E-12	2.23E-12	2.40E-11	5.83E-12	3.99E-11	8.36E-11	7.15E-10	1.27E-08
Cm-242	1.06E-20	0.00E+00	1.40E-11	3.15E-18	5.63E-20	1.03E-14	1.37E-14	1.71E-15	3.90E-19	2.88E-17	1.10E-16	4.79E-17	1.98E-16	7.75E-18	5.63E-17	1.40E-11
Cm-243	1.52E-21	2.86E-23	8.41E-15	5.53E-18	1.47E-19	2.28E-17	1.92E-17	5.72E-18	5.56E-20	1.19E-19	4.52E-19	4.55E-19	1.88E-18	7.18E-20	7.60E-19	8.46E-15
Cm-244	3.79E-22	0.00E+00	9.26E-13	1.13E-18	0.00E+00	1.96E-15	1.94E-15	5.72E-16	3.85E-18	1.17E-17	4.45E-17	4.33E-17	1.79E-16	6.84E-18	7.20E-17	9.31E-13
Co-58	3.63E-11	4.45E-14	1.31E-09	3.77E-09	1.02E-10	8.10E-13	2.36E-10	1.05E-10	6.32E-13	5.40E-13	3.04E-12	1.04E-12	3.69E-12	3.49E-11	1.54E-10	5.75E-09
Co-60	9.69E-11	8.11E-14	8.30E-09	1.64E-07	4.19E-10	1.07E-11	1.46E-09	4.71E-09	2.80E-10	1.01E-11	5.40E-11	2.19E-11	7.41E-11	2.33E-10	2.40E-09	1.82E-07
Cr-51	9.54E-13	0.00E+00	2.55E-11	4.16E-11	8.91E-14	1.29E-14	7.16E-12	1.26E-14	1.85E-17	1.51E-12	9.33E-14	2.86E-12	1.10E-13	1.23E-12	1.38E-12	8.25E-11
Cs-134	3.66E-12	1.54E-14	3.43E-10	3.23E-09	8.05E-11	3.43E-13	5.82E-10	1.04E-08	2.07E-09	1.25E-09	6.70E-11	2.07E-09	7.03E-11	3.65E-09	3.57E-08	5.95E-08
Cs-137	0.00E+00	9.21E-15	1.45E-10	3.82E-09	8.46E-11	4.06E-13	2.87E-10	5.58E-09	1.14E-09	6.51E-10	3.46E-11	1.00E-09	3.37E-11	1.71E-09	1.81E-08	3.25E-08
Fe-59	7.15E-12	2.01E-14	4.79E-10	4.52E-10	3.22E-11	2.69E-13	7.95E-11	1.04E-11	2.03E-14	1.57E-13	2.73E-11	3.05E-13	4.46E-11	6.14E-12	1.62E-11	1.16E-09
H-3	0.00E+00	0.00E+00	3.45E-03	0.00E+00	0.00E+00	0.00E+00	1.18E-03	8.23E-04	4.85E-03	7.55E-05	4.11E-06	4.18E-04	1.32E-05	4.25E-03	1.68E-03	1.67E-02
I-131	7.09E-09	1.38E-10	3.04E-06	8.05E-07	4.42E-07	9.68E-09	7.16E-06	9.20E-13	7.64E-12	1.43E-06	1.26E-07	3.01E-06	1.65E-07	9.20E-05	4.35E-07	1.09E-04
I-132	2.12E-09	2.67E-11	2.14E-09	3.30E-09	9.85E-10	3.45E-13	1.10E-26	0.00E+00	0.00E+00	1.85E-41	6.98E-24	8.27E-38	1.66E-23	1.31E-23	0.00E+00	8.57E-09
I-133	1.81E-09	6.21E-11	9.79E-08	2.30E-08	2.13E-08	1.08E-10	7.97E-10	2.60E-81	8.41E-67	1.93E-12	1.24E-11	1.48E-11	2.99E-11	1.20E-08	7.26E-39	1.57E-07
I-135	1.55E-09	1.80E-11	6.83E-09	6.69E-09	1.96E-09	3.00E-12	2.64E-15	8.73E-240	2.53E-192	2.11E-21	4.06E-16	9.34E-20	1.05E-15	8.66E-14	3.95E-111	1.71E-08
Kr-85	1.49E-09	8.70E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-08
Kr-85m	4.99E-08	3.98E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.39E-08
Kr-87	4.94E-14	5.96E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.54E-14
Kr-88	3.22E-08	3.21E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.25E-08
La-140*	2.21E-11	2.67E-13	2.27E-10	5.36E-11	1.83E-11	9.28E-14	1.15E-11	4.71E-48	3.03E-43	2.90E-14	3.22E-14	8.68E-14	4.02E-14	6.50E-13	4.97E-28	3.33E-10
Mn-54	1.90E-11	0.00E+00	7.44E-10	7.84E-09	1.00E-12	6.20E-13	1.78E-10	4.09E-10	3.98E-11	9.46E-12	1.99E-11	1.78E-11	2.41E-11	6.82E-11	5.94E-10	9.97E-09
Nb-95*	2.10E-11	6.27E-15	8.97E-10	1.10E-09	4.63E-12	5.49E-13	1.28E-10	7.39E-12	6.66E-14	1.14E-15	6.80E-17	2.09E-15	7.77E-17	7.67E-14	1.39E-13	2.15E-09
Nb-95m (Zr-95)	1.89E-13	2.38E-14	5.51E-11	1.25E-11	2.69E-12	1.27E-14	1.87E-12	1.82E-29	1.15E-28	2.05E-19	3.62E-20	1.34E-18	1.08E-19	9.31E-16	2.77E-22	7.24E-11
Np-237 (Am-241)	5.48E-30	1.09E-32	1.25E-22	3.01E-25	5.74E-27	9.84E-20	1.25E-21	7.26E-21	2.84E-21	2.72E-24	1.04E-23	2.46E-23	1.02E-22	3.88E-24	4.13E-23	1.10E-19
Pr-144 (Ce-144)	3.65E-13	7.88E-13	4.41E-12	6.01E-15	2.43E-13	9.12E-18	1.88E-140	0.00E+00	0.00E+00	2.20E-249	1.88E-100	5.94E-224	5.27E-100	2.30E-118	0.00E+00	5.82E-12
Pr-144m (Ce-144)	6.46E-14	0.00E+00	0.00E+00	3.02E-15	4.14E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.76E-14
Pu-238*	1.65E-22	0.00E+00	2.39E-12	4.04E-19	1.32E-21	1.74E-14	5.78E-15	1.77E-15	7.33E-17	4.24E-17	1.61E-16	1.72E-16	7.13E-16	2.72E-17	2.88E-16	2.43E-12
Pu-239*	2.05E-23	0.00E+00	3.32E-13	9.64E-20	6.97E-22	6.56E-15	7.86E-16	2.47E-16	1.67E-17	5.06E-18	1.92E-17	2.01E-17	8.33E-17	3.18E-18	3.38E-17	3.40E-13
Pu-240*	3.58E-23	0.00E+00	5.26E-13	1.06E-19	7.95E-23	1.03E-14	1.24E-15	3.90E-16	2.64E-17	8.02E-18	3.04E-17	3.19E-17	1.32E-16	5.04E-18	5.37E-17	5.38E-13
Rb-87 (Kr-87)	0.00E+00	1.05E-29	8.45E-26	0.00E+00	1.22E-25	1.85E-27	1.31E-24	1.03E-23	5.79E-24	4.34E-25	2.30E-26	1.38E-24	4.61E-26	1.26E-23	1.33E-22	1.65E-22
Rb-88 (Kr-88)	1.00E-08	2.04E-09	5.70E-09	8.07E-10	1.90E-09	5.58E-14	4.96E-133	0.00E+00	0.00E+00	6.32E-235	4.25E-90	2.57E-210	5.54E-90	2.07E-108	0.00E+00	2.05E-08
Sb-122	3.71E-14	2.65E-15	1.89E-12	1.65E-13	2.85E-13	4.57E-16	6.04E-14	8.60E-37	1.29E-34	3.69E-16	9.09E-15	1.00E-15	1.25E-14	1.97E-14	1.98E-23	2.49E-12
Sb-124	2.23E-11	2.33E-13	1.70E-09	1.89E-09	3.97E-10	1.02E-12	2.49E-10	7.71E-11	4.54E-13	1.77E-11	1.01E-10	3.11E-11	1.11E-10	3.75E-11	1.42E-10	4.78E-09
Sb-125	1.01E-12	6.07E-15	2.60E-10	1.16E-09	3.15E-11	2.80E-13	3.00E-11	9.23E-11	3.05E-12	3.28E-12	1.75E-11	5.07E-12	1.72E-11	4.58E-12	4.58E-11	1.67E-09
Sr-89	8.64E-16	3.24E-13	1.35E-09	6.23E-14	5.07E-10	7.81E-13	2.11E-10	4.07E-11	7.05E-13	2.44E-12	1.41E-13	5.54E-12	2.01E-13	2.53E-10	7.83E-10	3.16E-09
Sr-90	0.00E+00	5.33E-15	5.18E-10	3.09E-17	1.63E-10	1.42E-12	9.88E-10	3.05E-09	7.41E-10	7.58E-12	4.03E-13	3.27E-11	1.10E-12	1.33E-09	1.41E-08	2.09E-08
Te-125m (Sb-125)	3.29E-16	3.08E-17	3.60E-12	3.13E-14	1.02E-15	9.60E-14	5.75E-12	1.23E-11	2.48E-12	3.64E-12	3.21E-12	4.00E-12	3.23E-12	3.80E-12	1.37E-11	5.59E-11
U-234 (Pu-238)	4.34E-30	4.12E-32	2.36E-21	2.35E-26	8.63E-29	9.15E-19	9.25E-21	1.23E-19	9.57E-20	1.39E-25	7.93E-27	4.34E-25	1.34E-26	1.02E-23	9.42E-23	1.14E-18
U-235 (Pu-239)	2.08E-31	2.10E-34	9.28E-26	1.11E-27	9.63E-30	9.36E-23	7.59E-25	1.02E-23	7.94E-24	5.91E-30	3.37E-31	1.85E-29	5.72E-31	4.34E-28	4.01E-27	1.12E-22

	Collective Dose (man Sv)														
Radionuclide	**Gamma from plume**	**Beta from plume**	**Inhalation of plume**	**Gamma from ground**	**Beta from ground**	**Re-suspen sion**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
U-236 (Pu-240)	6.09E-33	5.66E-35	4.56E-24	1.48E-29	2.31E-32	4.54E-21	3.57E-23	4.80E-22	3.74E-22	2.81E-28	1.60E-29	8.79E-28	2.72E-29	2.07E-26	1.91E-25	5.43E-21
Xe-131m	8.97E-09	4.89E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-08
Xe-133	2.56E-06	1.94E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.75E-06
Xe-133m	1.63E-10	4.66E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E-10
Xe-135 (I-135)	2.45E-10	1.52E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.61E-10
Xe-135m (I-135)	3.91E-10	4.64E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.96E-10
Y-90 (Sr-90)	8.24E-21	1.07E-14	6.52E-12	4.20E-20	7.54E-13	1.32E-15	3.08E-13	2.21E-36	3.36E-34	4.88E-19	1.29E-18	3.46E-18	3.92E-18	8.28E-15	5.55E-24	7.60E-12
Zn-65	6.09E-12	6.32E-16	3.61E-10	1.96E-09	2.66E-12	2.86E-13	6.39E-10	1.55E-09	3.39E-10	7.82E-11	4.23E-12	2.61E-10	8.95E-12	8.29E-09	6.83E-08	8.18E-08
Zr-95	9.70E-12	4.29E-14	1.38E-09	1.85E-09	8.95E-11	8.40E-13	1.04E-10	3.71E-11	7.13E-14	8.87E-16	5.03E-17	1.50E-15	5.36E-17	9.23E-14	3.71E-13	3.47E-09
Total	**6.87E-05**	**1.83E-06**	**4.70E-02**	**1.03E-06**	**4.72E-07**	**9.82E-09**	**3.57E-02**	**8.96E-01**	**1.50E-01**	**3.87E-03**	**2.10E-04**	**2.14E-02**	**6.74E-04**	**5.96E-02**	**3.05E-01**	**1.52E+00**

*Includes contribution from progeny of parent radionuclides, i.e. La-140 includes contribution from decay of Ba-140, Nb-95 from decay of Zr-95, Pu-238 from decay of Cm-242, Pu-239 from decay of Cm-243 and Pu-240 from decay of Cm-244.
Brackets indicate a radionuclide progeny of a discharged radionuclide, e.g. U-234 (Pu-238) shows that Pu-238 is the discharged precursor and U-234 is the progeny produced during subsequent radioactive decay.

Table A.42: Global Circulation Collective Dose (man Sv) truncated to 500 years due to Gaseous Discharges

	Collective dose (man Sv)			
Radionuclide	**UK**	**EU12**	**EU25**	**World**
C-14	1.78E-01	1.08E+00	1.36E+00	2.99E+01
H-3	1.95E-05	1.18E-04	1.49E-04	3.27E-03
Kr-85	2.00E-09	1.21E-08	1.53E-08	3.29E-07
Total	**1.78E-01**	**1.08E+00**	**1.37E+00**	**2.99E+01**

Appendix B - Definition of Input Data for Stage 3 Assessment Using PC-CREAM08®

This Appendix describes the input data and parameters that were entered into PC-CREAM 08® for the Stage 3 assessment.

The following tables are presented in this Appendix:
Table B.4.1-1: Local Compartment Default Data
Table B.4.2-1: Representative Persons High Food Consumption Rates
Table B.4.2-2: Representative Persons Mean Food Consumption Rates
Table B.4.2-3: Summary of Marine Plant Consumption Rates
Table B.4.2-4: Inhalation and External Pathway Data
Table B.5.2-1: Representative Person Consumption Rates
Table B.5.2-2: Mean Consumption Rate
Table B.5.2-3: Occupancy and Inhalation Rates

1. Introduction

This note defines the input data for use in PC-CREAM 08® to determine the Stage 3 prospective dose assessment due to liquid and gaseous discharges.

2. Method

The data has been broken down into a series of steps:

- Identification of source terms;
- Definition of input data for assessment of the consequences of liquid discharges;
- Definition of input data for assessment of the consequences of gaseous discharges.

3. Source Terms

The annual liquid discharge to the environment at the proposed annual discharge limit is given in Table 6.3-3.

The annual gaseous discharge to the environment at the proposed annual discharge limit is given in Table 6.3-4.

4. Definition of Input Data for Assessment of the Consequences of Liquid Discharges

The radiological consequences of routine discharges of liquid radioactive wastes are to be calculated using PC-CREAM 08® v1.5.1.85 database version 2.0.0.

The radiological consequences to the representative person are to be calculated. For liquid discharges this representative person is a member of the Fisherman family who also consumes locally sourced terrestrial foods at an average rate. Doses are calculated for Adult, Child and Infant member of this group.

The assessment is undertaken in two stages:

i. A DORIS model is initially generated. This DORIS module calculates the concentration of radionuclides defined for a unit annual release rates of the radionuclides of interest;

ii. The DORIS module is called up in the ASSESSOR marine individual dose module. The annual discharge rates and exposure routes are then defined and the individual doses calculated.

4.1 Input Data

The following input data is defined for the assessment:

- Site: Reference Site (Wylfa is used as the software requires a specific site to be defined);
- Discharge information: Isotopes as defined in Table 6.3-3. Note unit annual discharge rate is used;
- Element dependent parameters: Default;
- Local compartment details: Default, as outlined in Table B.4.1-1:

Table B.4.1-1: Local Compartment Default Data

Item	Unit	Detailed site value
Marine Module	-	Reference Site (Wylfa)
Regional compartment	-	Irish sea west
Local compartment volumetric exchange rate	m^3/y	4×10^{10}
Local compartment volume	m^3	2×10^{9}
Local compartment depth	m	20
Local compartment coastline length	m	10^{4}
Local compartment suspended sediment load	t/m^3	10^{-5}
Local compartment sediment rate	$t/m^2/y$	5×10^{-3}
Local compartment sediment density	t/m^3	2.6
Local compartment diffusion rate	m^2/y	3.15×10^{-2}

Regional Model details: Default;
Volumetric exchange rates: Default;
Output materials: All;
Output times: Add 60 years.

4.2 ASSESSOR Input

Using the ASSESSOR and the marine individual dose module, the assessments are undertaken using the following input data.

Site name: Reference site (Wylfa is defined as the software requires a specific site to be identified)
Times: select 1, 50, 60 & 500 years

Discharges: as per Table 6.3-3

Ingestion pathways: as per the representative person consumption rates and fraction caught in the local compartment given below:

Table B.4.2-1: Representative Persons High Food Consumption Rates

Item	Unit	Value used for detailed site assessment	Reference
Fish:	kg/y		[Ref-B.1]
Fraction local compartment		0.5	
Adult		100	
Child		20	
Infant		5	
Crustaceans:	kg/y		[Ref-B.1]
Fraction local compartment		1.0	
Adult		20	
Child		5	
Infant		0	
Molluscs:	kg/y		[Ref-B.1]
Fraction local compartment		1.0	
Adult		20	
Child		5	
Infant		0	
Seaweed:	kg/y		Section 4.2.1 in Appendix B
Fraction local compartment		1.0	
Adult		2.3	
Child		0.5	
Infant		0	

The mean consumption rates to be used to determine the marine contribution to the terrestrial member of the public are given below:

Table B.4.2-2: Representative Persons Mean Food Consumption Rates

Item	Unit	Value used for detailed site assessment	Reference
Fish: fraction local compartment Adult Child Infant	kg/y	 0.5 15 6 3.5	[Ref-B.2]
Crustaceans: fraction local compartment Adult Child Infant	kg/y	 1.0 1.75* 1.25* 0	[Ref-B.2]
Molluscs: fraction local compartment Adult Child Infant	kg/y	 1.0 1.75* 1.25* 0	[Ref-B.2]
Seaweed: fraction local compartment Adult Child Infant	kg/y	 1.0 0.8 0 0	Section 4.2.1 in Appendix B

* Note specific values are not given for crustacea or molluscs in [Ref-B.2]. A value is given for shellfish and this has been divided equally between the two food groups.

4.2.1 Marine Plant Consumption Rate

Table B.4.2-3 below presents a summary of the CEFAS habit data surveys for marine plant consumption rates at nuclear power plant in England and Wales.

Table B.4.2-3: Summary of Marine Plant Consumption Rates

Nuclear power station site (England & Wales)	Year of habit survey	Reference	Number in the 97.5th percentile (high rate) group	Maximum consumption rate (kg/y)	Mean consumption rate for the high-rate group (kg/y)	Predominant species
Hartlepool	2008	[Ref-B.3]	1	0.2	0.2	Samphire
Heysham	2011	[Ref-B.4]	7	2.3	1.6	Samphire
Hinkley Point	2010	[Ref-B.5]	7	0.9	0.7	Samphire & Porphyra
Sizewell	2010	[Ref-B.6]	4	1.0	0.9	Samphire
Wylfa	2009	[Ref-B.7]	1	0.5	0.5	Porphyra
Average	-	-	-	1.0	0.8	-

It is proposed to use a consumption rate of 2.3 kg/y for the Adult representative person consumption rate and a value of 0.8 kg/y for the mean Adult consumption rate.

Data on the consumption of marine plants by Child and Infant age groups is very sparse. Two high-rate Child consumers of marine plants were identified at Sizewell, each with a consumption rate of 0.5 kg/y. Although a very limited set of data it is proposed to assign a representative person consumption rate of 0.5

kg/y and a zero kg/y mean consumption rate for the Child age group.

No consumption of marine plans was identified for the Infant age group therefore zero kg/y high and mean consumption rates are assigned to this age groups.

The following data was defined for the inhalation and external pathways:

Table B.4.2-4: Inhalation and External Pathway Data

Item	Unit	Value used for detailed site assessment	Reference
Inhalation rate:	m^3/h		[Ref-B.1]
Adult		0.92	
Child		0.64	
Infant		0.22	
Handling Fisherman gear:	h/y		[Ref-B.2]
Adult		2000	
Child		0	
Infant		0	
Distance from sea:	m		[Ref-B.8]
Adult		100	
Child		100	
Infant		100	
Beach occupancy:	h/y		[Ref-B.1]
Adult		2000	
Child		300	
Infant		30	

Note: inhalation of sea spray is the sum of beach occupancy and time spent handling fishing gear

5. Definition of Input Data for Assessment of the Consequences of Gaseous Discharges

The radiological consequences of routine discharges of liquid radioactive wastes are to be calculated using PC-CREAM 08® v1.5.1.85 database version 2.0.0.

The radiological consequences to the Representative Person are to be calculated. For gaseous discharges this Representative Person will be a member of the Local Resident family, who also consumes locally sourced seafoods at average rates. Doses are to be calculated for Adult, Child and Infant member of this group.

The assessment is undertaken in two stages:

i. PLUME, GRANIS, FARMLAND and RESUS models are produced to calculate the concentration of radionuclides in the atmosphere, ground, foodstuffs and re-suspension for unit annual release rates of the radionuclides of interest.

ii. The PLUME module is then called up in the ASSESSOR atmospheric individual dose module. This is where the annual discharge rates and exposure routes are defined and the individual doses calculated.

5.1 Input Data

The following input data is defined:

PLUME module

Discharges:	Isotopes as defined in Table 6.3-4
Distances:	Default values
Release heights:	Add 19m (see section 16.2.1)
Roughness length:	0.3m [Ref-B.1]
Met sampling scheme:	Default (Hosker-Smith)

GRANIS module

Discharges:	Isotopes as defined in Table 6.3-4. Note unit annual discharge rate is to be used
Soil model composition:	Undisturbed, generic wet soil
Output times:	Add 60 years

FARMLAND module

Models:	Default
Nuclides:	Isotopes as defined in Table 6.3-4. Note unit annual discharge rate is to be used
Plant-dependent model parameters:	Default
Animal-dependent model parameters:	Default
Concentration ratios:	Default
Animal equilibrium concentration ratios:	Default
Other element dependent parameters:	Default
Output times:	Add 60 years

RESUS module

Nuclides:	Isotopes as defined in Table 6.3-4.
Output times:	Add 60 years, remove 10^8 years:

5.2 ASSESSOR Input

Using the ASSESSOR and the Atmospheric individual dose module the assessment is undertaken using the following input data.

Stack:	A release height of 19m
Stack discharges:	Isotopes as defined in Table 6.3-4
Receptor points:	270 m taken as the closest approach from generic site plot plan [Ref-B.10] 500 m taken as location of food production [Ref-B.1] as defined in the IRAT methodology
Ingestion data:	The representative person consumption rates in Table B.5.2-1 based on the 'top two' methodology (see Appendix D) were used

Table B.5.2-1: Representative Person Consumption Rates

	Consumption rate (kg/y)		
Foodstuff	**Adult (16 to 64 years)**	**Child (10 to 11 years)**	**Infant**
Green vegetables	35	15	5
Root vegetables	130	50	15
Fruit	20	15	9
Sheep meat	8	4	0.8
Sheep liver*	2.75	1.5	0.5
Cow meat	15	15	3
Cow liver*	2.75	1.5	0.5
Milk	95	240	320
Milk products	60	45	45

* Note specific values are not given for cow liver or sheep liver in [Ref-B.2]. A value is given for offal and this has been divided equally between the two food groups.
Highlighted values are those consumed at the high rate

Note: The consumption of locally produced grain and grain products is taken to be zero. Grain is bulked and combined with other grain at regional millers and so will be significantly diluted prior to entry into the consumer market. In addition, the delay time for grain is significant: HPA-RPD-043 [Ref-B.9] suggests a value of 210 days. The fraction of other terrestrial food grown locally is 1.

The mean consumption data to be used to determine the terrestrial contribution to the marine member of the public have been taken from [Ref-B.2] and are given below:

Table B.5.2-2: Mean Consumption Rate

	Consumption rate (kg/y)		
Foodstuff	**Adult (16 to 64 years)**	**Child (10 to 11 years)**	**Infant**
Green vegetables	35	15	5
Root vegetable	60	50	15
Fruit	20	15	9
Sheep meat	8	4	0.8
Sheep liver*	2.75	1.5	0.5
Cow meat	15	15	3
Cow liver*	2.75	1.5	0.5
Milk	95	110	130
Milk products	20	15	15

* Note specific values are not given for cow liver or sheep liver in [Ref-B.2]. A value is given for offal and this has been divided equally between the two food groups.

Occupancy and inhalation rates: The following data was used

Table B.5.2-3: Occupancy and Inhalation Rates

Item	Unit	Value used for detailed site assessment	Reference
Inhalation rate Adult Child Infant	m^3/h	 0.92 0.64 0.22	[Ref-B.1]
Occupancy at Habitation Adult Child Infant	h/y	 8,760 8,760 8,760	[Ref-B.1]
Fraction of time spent indoors Adult Child Infant	-	 0.5 0.8 0.9	[Ref-B.1]
Cloud shielding factor	-	0.2	[Ref-B.1]
Shielding factor for deposited radionuclides	-	0.1	[Ref-B.1]

Delay times: Default (note report by HPA-RPD-043 - Delay Times between Harvesting or Collection of Food Products and Consumption for Use in Radiological Assessments [Ref-B.9] reports on delay times. However, it is considered that, as the majority of the default delay times are zero, no amendment to the default values is required).

Met data: 70% cat D with 10% rain in C and D. based on Figure 11 of NRPB-R91 which shows that 70% cat D is appropriate for a site on the North Wales coast.

6. Assessments

There are a total of 4 PC-CREAM 08® assessments to be undertaken.

- A marine assessment with high consumption rates;
- A marine assessment with mean consumption rates;
- An atmospheric assessment with top two consumption rates; and,
- An atmospheric assessment with mean consumption rates.

The results from the Stage 3 assessment are to be used to estimate the annual dose to the representative person.

Two scenarios are considered:

i. The terrestrial member of the public for gaseous discharges also consuming locally sourced seafood at average rate.

In this case the dose to each age group is the sum of:

- Inhalation, gamma and beta from plume, gamma and beta from ground and re-suspension at a receptor distance of 270m;
- ‘Top two’ foodstuffs produced at a distance of 500m;

- o Marine ingestion pathway doses at the mean consumption rate;
- o Direct radiation contribution at the site boundary.

ii. The marine member of the public for liquid discharges also consuming locally sourced terrestrial foods at average rate.

In this case the dose to each age group is the sum of:

- o All marine pathways including seafood consumption at the high consumption rate;
- o Doses due to consumption of mean terrestrial foodstuffs produced at a distance of 500m.

7. Appendix B References

[Ref-B.1] Environment Agency, “Initial Radiological Assessment Methodology – Part 2 Methods and Input Data Science Report”, SC030162/SR2, May 2006.

[Ref-B.2] National Radiological Protection Board, “Generalised habit data for radiological assessment”, K R Smith and A L Jones. NRPB-W41 May 2003.

[Ref-B.3] The Centre for Environment, Fisheries & Aquaculture Science, “Radiological Habits Survey: Hartlepool”,2008. (http://www.cefas.defra.gov.uk/publications/environment/Hartlepool-2008-Report-Final.pdf.)

[Ref-B.4] The Centre for Environment, Fisheries & Aquaculture Science, “Radiological Habits Survey: Heysham”, 2011. (http://www.cefas.defra.gov.uk/publications/environment/Heysham-2011.pdf)

[Ref-B.5] The Centre for Environment, Fisheries & Aquaculture Science, “Radiological Habits Survey: Hinkey Point”, 2010. (http://www.cefas.defra.gov.uk/publications/environment/Hinkley-Point-2010-Report.pdf)

[Ref-B.6] The Centre for Environment, Fisheries & Aquaculture Science, “Radiological Habits Survey: Sizewell”, 2010. (http://www.cefas.defra.gov.uk/publications/environment/Sizewell-2010-Complete-Report.pdf)

[Ref-B.7] The Centre for Environment, Fisheries & Aquaculture Science, “Radiological Habits Survey: Wylfa”, 2013. (http://www.cefas.defra.gov.uk/publications/environment/Wylfa2013.pdf.)

[Ref-B.8] Health Protection Agency, “The methodology for assessing the radiological consequences of routine releases of radionuclides into the environment used in PC-CREAM 08”, HPA-RPD-058, November 2009.

[Ref-B.9] Health Protection Agency, “Delay Times between Harvesting or Collection of Food Products and Consumption for Use in Radiological Assessments”, HPA-RPD-043, Jones and Sherwood, 2008.

[Ref-B.10] Hitachi-GE Nuclear Energy Ltd., “Generic Site Description”, GA91-9901-0020-00001, XE-GD-0095, Rev. E, February 2016.

Appendix C - Derivation of Noble Gas DPUR Values

This Appendix describes the calculation and results for noble gas Dose Per Unit Release values for noble gas isotopes of interest that are not included in the published IRAT reports.

The following tables are presented in this Appendix:
Table C.2.1-1: Noble Gases Discharges from the ABWR
Table C.2.1-2: Default Atmospheric DPUR Values
Table C.2.1-3: DPUR and DCFPAK Values for Discharged Noble Gases
Table C.3.1-1: Calculated DPUR Values μSv/h per Bq/y Discharged
Table C.4-1: Calculated DPUR Values

1. Introduction

Due to the significant contribution of noble gases to the gaseous discharge it was considered that isotope specific Dose Per Unit Release (DPUR) values would be required.

This appendix presents the data, method and results of the calculation of DPUR values for noble gases released.

2. Method

The calculation has been broken down into the following steps:

- Identification of noble gas release rates;
- Calculation of external dose rate;
- Calculation of DPUR values.

2.1 Noble Gases Release Rate

The ABWR will release noble gases into the environment. These are identified in Table C.2.1-1 below [Ref-C.1].

Table C.2.1-1: Noble Gases Discharges from the ABWR

Radionuclide	Half life	DPUR available in IRAT
Kr-83m	1.83h	×
Kr-85m	4.48h	✓
Kr-85	10.72y	✓
Kr-87	76.3m	×
Kr-88	2.84h	×
Kr-89	3m	×
Kr-90	32.3 s	×
Xe-131m	11.84d	×
Xe-133m	2.19d	×
Xe-133	5.24d	✓
Xe-135m	15.6m	×
Xe-135	9.11h	×
Xe-137	3.83m	×
Xe-138	14.13m	×
Xe-139	39.7 s	×

Table C.2.1-1 also identifies radionuclides that are included in the atmospheric release scenario and for which DPUR values are given as described in [Ref-C.2].

Where DPUR values are not available, the recommendation in the IRAT methodology is to use default DPUR values. These default values are dependent on the half-life of the radionuclides being assessed and, for releases of beta/gamma emitters to atmosphere, are shown in Table C.2.1-2.

Table C.2.1-2: Default Atmospheric DPUR Values

Half life	Default radionuclide	Exposure Pathway (µSv/y per Bq/y discharge)				Age group
		Food consumption	External irradiation	Inhalation	Total	
$T_{1/2}$<1day	Am-242	1.90E-14	6.40E-14	3.80E-10	3.80E-10	Adult
$T_{1/2}$ <10day	I-131	4.10E-09	3.80E-11	3.90E-10	4.50E-09	Infant
$T_{1/2}$>10day	Pb-210	5.70E-09	3.20E-12	2.30E-08	2.90E-08	Child

For noble gases it is considered that the use of the default radionuclide DPUR values are not appropriate, since the use of the default radionuclides will lead to estimates of inhalation and ingestion doses that are not viable exposure pathways for noble gases.

DPUR values that are available for noble gases are shown in Table C.2.1-3.

Table C.2.1-3: DPUR and DCFPAK Values for Discharged Noble Gases

Radionuclide	Half life	External irradiation DPUR µSv/y per Bq/y discharge	DCFPAK immersion in air effective dose (Sv/s per Bq/m^3)
Kr-83m	1.83h	×	1.20E-18
Kr-85m	4.48h	3.6E-13	6.87E-15
Kr-85	10.72y	1.3E-14	2.40E-16
Kr-87	76.3m	×	3.97E-14
Kr-88	2.84h	×	9.71E-14
Kr-89	3m	×	-
Kr-90	32.3s	×	-
Xe-131m	11.84d	×	3.49E-16
Xe-133m	2.19d	×	1.28E-15
Xe-133	5.24d	7.0E-14	1.33E-15
Xe-135m	15.6m	×	1.90E-14
Xe-135	9.11h	×	1.10E-14
Xe-137	3.83m	×	-
Xe-138	14.13	×	5.48E-14
Xe-139	39.7s	×	-

By inspection of the data in Table C.2.1-3 it can be seen that using the existing DPUR values as surrogates for the other noble gases is likely to lead to an underestimate of the external dose.

For example, using the DPUR value for Kr-85m as a surrogate for Kr-88 and comparing the DCFPAK [Ref-C.3] is likely to lead to an underestimate of about one order of magnitude in the estimate of the external dose due to the discharge of Kr-88.

It is therefore considered that it is appropriate to derive isotope specific DPUR values for the noble gases discharges to atmosphere.

3. Calculation of DPUR Values

3.1 Determination of External Dose Rate

DPUR values have been calculated for individual noble gas isotopes based on the methodology presented in section D.4.3 of [Ref-C.4], where:

DR_{ext_cloud} = $DR_{ext\_cloud(u)} \times A_{air}$

Where
$DR_{ext\_cloud(u)}$ = external dose rate per unit air concentration (μSv/h per Bq/m^3)
A_{air} = activity concentration in air at 100m per unit release (Bq/m^3 per Bq/y)

$DR_{ext\_cloud(u)}$ are derived from the values presented in Table C.2.1-3 above.
$DR_{ext\_cloud(u)}$ = DCFPAK (Sv/s per Bq/m^3) × 3600 seconds/hour × 1E+06 μSv per Sv
= DCFPAK × 3.6E+09

The airborne activity concentration at 100m is given in Table D3 of [Ref-C.4].

For an annual release rate of 1 Bq/y the air concentration at 100m is given as 2.8E-12 Bq/m^3.

Therefore,

DR_{ext_cloud} = DCFPAK × 3.6E+09 (μSv/h per Bq/m^3) × 2.8E-12 (Bq/m^3 per Bq/y)

Table C.3.1-1 below presents the calculated DPUR values.

Table C.3.1-1: Calculated DPUR Values µSv/h per Bq/y Discharged

Radionuclide	Calculated DPUR values (µSv/h per Bq/y discharge)
Kr-83m	1.21E-20
Kr-85m	6.92E-17
Kr-85	2.42E-18
Kr-87	4.00E-16
Kr-88	9.79E-16
Kr-89	N/A
Kr-90	N/A
Xe-131m	3.52E-18
Xe-133m	1.29E-17
Xe-133	1.34E-17
Xe-135m	1.92E-16
Xe-135	1.11E-16
Xe-137	N/A
Xe-138	5.52E-16
Xe-139	N/A

N/A indicates that the submersion value was not available in DCFPAK

3.2 Calculation of DPUR Values

The method for calculation of DPUR factors for external exposure is given in section D.6 of [Ref-C.4].

The DPUR factors for external exposure pathways for each age group were calculated as follows:
$DPUR_{ext} = DR_{ext\_cloud(u)} \times H_{occ,a} (F_{ind,a} \times T_{ind} + F_{out,a} \times T_{out})$

Where:

$DPUR_{ext}$ is dose per unit release factor from external exposure to activity in the air for the age group considered (µSv/y per Bq/y)
$DR_{ext\_cloud(u)}$ is external dose rate from either activity in air (µSv/h per Bq/y)
$H_{occ,a}$ is total occupancy for the age group considered (h/y)
= 8,760 hours/year
$F_{ind,a}$ is fraction spent indoors for the age group considered
= 0.5 for Adult
= 0.8 for Child
= 0.9 for Infant
T_{ind} is indoor shielding factor for cloud shine = 0.2
$F_{out,a}$ is fraction spent outdoors for age group considered = 1– $F_{ind,a}$
= 0.5 for Adult
= 0.2 for Child
= 0.1 for Infant
T_{out} is outdoor shielding factor for cloud (no shielding assumed so set to 1).

4. Results

The results of the calculations of DPUR are summarised in Table C.4-1 below

Table C.4-1: Calculated DPUR Values

Radionuclide	DPUR Adult (µSv/y per Bq/y)	DPUR Child (µSv/y per Bq/y)	DPUR Infant (µSv/y per Bq/y)
Kr-83m	6.4E-17	3.8E-17	3.0E-17
Kr-85m	3.6E-13	2.2E-13	1.7E-13
Kr-85	1.3E-14	7.6E-15	5.9E-15
Kr-87	2.1E-12	1.3E-12	9.8E-13
Kr-88	5.1E-12	3.1E-12	2.4E-12
Kr-89	N/A	N/A	N/A
Kr-90	N/A	N/A	N/A
Xe-131m	1.8E-14	1.1E-14	8.6E-15
Xe-133m	6.8E-14	4.1E-14	3.2E-14
Xe-133	7.0E-14	4.2E-14	3.3E-14
Xe-135m	1.0E-12	6.0E-13	4.7E-13
Xe-135	5.8E-13	3.5E-13	2.7E-13
Xe-137	N/A	N/A	N/A
Xe-138	2.9E-12	1.7E-12	1.4E-12
Xe-139	N/A	N/A	N/A

N/A indicates that the submersion value was not available in DCFPAK. For the purposes of the IRAT stage 1 dose estimate the largest DPUR value for Kr-88 of 5.1E-12 was used as a surrogate value.

5. Appendix C References

[Ref-C.1] Hitachi-GE Nuclear Energy Ltd., “Quantification of Discharges and Limits”, GA91-9901-0025-00001, HE-GD-0004, Rev. F, July 2016.

[Ref-C.2] Environment Agency, “Initial Radiological Assessment Methodology – Part 1 User Report Science Report”, SC030162/SR1, May 2006.

[Ref-C.3] Oak Ridge National Laboratory, “DCFPAK: Dose Coefficient File Package for Sandia National Laboratory Eckerman”, K F and Leggett, R W Dosimetry Research Group, 2002.

[Ref-C.4] Environment Agency, “Initial Radiological Assessment Methodology – Part 2 Methods and Input Data Science Report”, SC030162/SR2, May 2006.

Appendix D - Derivation of Consumption Rates for Stage 3 Assessment

This Appendix describes the data, method and results of the calculation of the 'top two' consumption rates for use in the Stage 3 prospective dose assessment.

The following tables are presented in this Appendix:
Table D.4-1: High Ingestion Rates for Assessed Foodstuffs
Table D.5-1: Top Two Foodstuffs
Table D.6-1: Overall Foodstuffs Consumption Rates

1. Introduction

The P&ID identifies the requirement for a prospective radiological assessment at the proposed limits for discharges.

This calculation note presents the data, method and results of the calculation of the ‘top two’ consumption rates for use in the Stage 3 prospective dose assessment.

2. Method

The calculation has been broken down into a series of steps:

- Identification of foodstuffs and high consumption rates;
- Calculation of the dose contribution of each foodstuff;
- Identification of the top two foodstuffs;
- Compilation of the overall foodstuffs consumption rates.

3. Identification of Foodstuffs and High Consumption Rates

The use of the ‘top two’ approach for generic dose assessments is used where no site-specific habits data are available but a detailed site-specific assessment is still required. [Ref-D.1]. This is the circumstance for the detailed Stage 3 prospective dose assessment being undertaken in support of the GDA for the UK ABWR and as such the ‘top two’ method will be adopted.

For terrestrial foods contaminated by atmospheric releases the assessment generally uses generic data for the UK [Ref-D.2] as the basis for the assessment.

The assessment is initially made with all the relevant habits data (mainly food intakes) set to ‘high levels’ (95th or 97.5th percentile). The assessment results identify the two habits that give rise to the highest doses (‘top two’). These habits are retained at ‘high levels’, whereas the other habits are reduced to 50th percentile levels and the assessment is repeated. This adjustment to the assessment ensures that the calorific intake is not unreasonably high.

The 97.5th percentile consumption rate is to be used for each age group (Adult, Child and Infant).

All foodstuff production is assumed to take place at 500m from the release location.

4. Calculation of the Dose Contribution of Each Foodstuff

The dose due to the ingestion of contaminated foodstuffs is undertaken using PC-CREAM 08®. The following input data is defined for the assessment

The annual gaseous discharge to the environment for the proposed annual discharge limit is given in Table 6.3-4.

The PLUME module in PC-CREAM 08® was used to determine the air concentration and deposition rates for the above radionuclides (and daughters) at a distance of 500m. Default parameters were used in all input screens with the exception of:

- Radionuclides: all those listed in Table 6.3-4;

- Release height: 19m.
- Ensure the Hosker-Smith met scheme is used.

The FARMLAND module was used to determine the concentrations in foodstuffs. Default parameters were used in all input screens with the exception of:

- Radionuclides: all those listed in Table 6.3-4;
- Output times:
  - Added 60 years
  - Removed 10^8 years.

For completeness, data was entered for the GRANIS and RESUS modules.
For GRANIS Default parameters were used in all input screens with the exception of:

- Radionuclides: all those listed in Table 6.3-4;
- Soil model composition: undisturbed generic wet soil
- Output times:
  - Added 60 years
  - Removed 10^8 years.

For RESUS parameters used in all input screens were:

- Radionuclides: all those listed in Table 6.3-4;
- Output times:
  - Added 60 years
  - Removed 10^8 years.

The high ingestion rates (97.5th percentile) for the foodstuffs considered [Ref-D.2] are:

Table D.4-1: High Ingestion Rates for Assessed Foodstuffs

	Consumption rate (kg/y)		
Foodstuff	**Adult (16-64 years)**	**Child (10-11 years)**	**Infant**
Green vegetables	80	35	15
Root vegetables	130	95	45
Fruit	75	50	35
Sheep meat	25	10	3
Sheep liver*	10	5	2.75
Cow meat	45	30	10
Cow liver*	10	5	2.75
Milk	240	240	320
Milk products	60	45	45
Grain†	0	0	0

* Offal value divided by 2, i.e. even split between cow liver and sheep liver
† Grain has been excluded from the assessment as it is considered that locally produced grain is not consumed locally and so is not a viable pathway. Grain is bulked and combined with other grain at regional millers and so will be significantly diluted prior to entry into the consumer market.

The assessment of the annual dose was calculated using the ASSESSOR module for the atmospheric individual dose. The input parameters were the default parameters with the exception of the following:

i. **Supporting models screen**
   - Site: Reference Site (Wylfa is used as the software requires a specific site to be defined)
   - Appropriate model for each exposure pathway

ii. **Stack details**
   - Stack 1 release height 19m

iii. **Stack discharge**
   - As per Table 6.3-4

iv. **Receptor points**
   - Receptor 1: 100m
   - Receptor 2: 500m

v. **Ingestion data:**
   - All high (except grain = 0)

vi. **Occupancy and inhalation rates**
   - Occupancy time spent indoors [Ref-D.3]
     - Adult 50%
     - Child 80%
     - Infant 90%
   - Inhalation rates
     - Adult 0.92 m^3/h
     - Child 0.64 m^3/h
     - Infant 0.22 m^3/h
   - Met data
     - Pasquill category: 70% D with 10% rain in category C and D
     - Wind rose: uniform
     - Number of sectors: 12

5. Identification of the Top Two Foodstuffs

The results of the PC-CREAM 08® calculations, at 500m, after 60 years continuous discharge, using the input data defined in section 4 above were:

Table D.5-1: Top Two Foodstuffs

	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green vegetables	Root vegetables	Sheep liver	Sheep meat
Adult	3.30E-01	1.48E+00	2.82E+00	4.00E+00	1.67E+00	1.79E+00	2.89E+00	3.30E-01	8.23E-01
Child	2.27E-01	1.36E+00	3.91E+00	4.21E+00	1.54E+00	1.08E+00	2.91E+00	2.28E-01	4.54E-01
Infant	3.30E-01	1.48E+00	2.82E+00	4.00E+00	1.67E+00	1.79E+00	2.89E+00	3.30E-01	8.23E-01

It can be seen that the "top two" foodstuffs are Milk Products and Root Vegetables for the Adult age group and Milk and Milk Products for both the Child and Infant age groups

6. Compilation of the Overall Foodstuffs Consumption Rates

The overall foodstuffs consumption rates using the 'top two' method are:

Table D.6-1: Overall Foodstuffs Consumption Rates

	Consumption rate (kg/y)		
Foodstuff	**Adult (16-64 years)**	**Child (10-11 years)**	**Infant**
Green veg	35	15	5
Root veg	130	50	15
Fruit	20	15	9
Sheep meat	8	4	0.8
Sheep liver*	2.75	1.5	0.5
Cow meat	15	15	3
Cow liver*	2.75	1.5	0.5
Milk	95	240	320
Milk products	60	45	45

* Offal value divided by 2, i.e. even split between cow liver and sheep liver

7. Appendix D References

[Ref-D.1] National Dose Assessment Working Group, "Acquisition and Use of Habits Data for Prospective Assessments", NDAWG/2/2009.

[Ref-D.2] National Radiological Protection Board, "Generalised habit data for radiological assessment", K R Smith and A L Jones. NRPB-W41 May 2003.

[Ref-D.3] Environment Agency, "Initial Radiological Assessment Methodology – Part 2 Methods and Input Data Science Report", SC030162/SR2, May 2006.

Appendix E - Specific Activity Model for H-3 and C-14 for Gaseous Discharges

This Appendix presents the data, method and results of the calculation of the build-up of H-3 and C-14 in soil following 60 years of gaseous discharges at the proposed annual discharge limit.

The following tables are presented in this Appendix:
Table E.3-1: Annual Gaseous Discharge for the ABWR
Table E.4.2-1: Typical Elemental Composition of Soil

1. Introduction

This calculation note presents the data, method and results of the calculation of the build-up of H-3 and C-14 in soil following 60 years of gaseous discharges at the proposed annual discharge limit.

2. Method

The calculation has been broken down into a series of steps:

- Air concentration at 100m for a ground level release (Stage 1 assessment parameters)
- Calculation of the concentration in soil based on a specific activity model.
- Results

3. Air Concentration

The annual gaseous discharge to the environment at the proposed annual discharge limit is given in Table 6.3-4 and is given in Table E.3-1 below.

Table E.3-1: Annual Gaseous Discharge for the ABWR

Radionuclide	Half life	Annual release (Bq/y)
C-14	5,730 y	1.7E+12
H-3	12.35 y	1.0E+13

For consistency with the Stage 1 IRAT methodology [Ref-E.1] the following parameters were specified:

Pasquill category:	50% D with 10% rain in category C and D.
Wind rose:	Uniform
Number of sectors:	12
Receptor location:	100m from point of release
Release height:	Ground level

The PLUME module in PC-CREAM 08® [Ref-E.2] was used to determine the air concentration for a non-depositing gas at a distance of 100m.

4. Specific Activity Model

The specific activity (SA) model provides an alternative approach for long-lived isotopes of biologically regulated, essential elements that are highly mobile in the environment. In the simplest application of the SA model, as used here, the radioisotope mixes physically and chemically with its corresponding stable element within some compartment of the environment, resulting in a certain specific activity.

The reference [Ref-E.3] for the following sections is: International Atomic Energy Agency "Specific Activity Models And Parameter Values For H-3, C-14 And Cl-36. IAEA-TECDOC-1616 Quantification of Radionuclide Transfer in Terrestrial and Freshwater Environments for Radiological Assessments", 2009.

Following traditional usage, the SA model for H-3 is formulated in terms of the H-3 concentration in water rather than the ratio of H-3 activity to the mass of hydrogen in a given compartment.

4.1 Tritium (H-3)

H-3 is transferred from air to soil through wet and dry deposition from the airborne plume. Concentrations in soil water are lower than those in air moisture, partly because precipitation is less contaminated than air moisture, and partly because soil water concentrations are diluted by uncontaminated precipitation that falls when the plume is not present. Here, the soil water concentration (C_{sw}, Bq/l) is assumed to be proportional to the concentration in air moisture (C_{am}, Bq/l), with a proportionality constant CR_s:

$C_{sw} = CR_s \times C_{am}$ (equation 2, p551 of [Ref-E.3])

CR_s: TECDOC-1616 proposes a default value of 0.3
C_{am} $= C_{air}/H_a$ (equation 3, p552 of [Ref-E.3])

Where:
C_{air} = concentration of H-3 in air, Bq/m^3 and,
H_a = absolute humidity (kg/m^3). A value of 0.008 kg/m^3 is given in section D.5.3 of [Ref-E.1].

Therefore, for an air concentration of 1 Bq/m^3:

C_{sw} = 0.3/0.008 =37.5 Bq/kg

The amount of soil water present in soil can be estimated by comparing the wet density and dry density of the reference soil in the PC-CREAM 08® module GRANIS [Ref-E.2].

Density of wet soil	=1.50 g/cm^3
Density of dry soil	= 1.25 g/cm^3
Mass of water in 1 cm^3 wet soil	= 0.25 g

Therefore, the amount of soil water present in 1kg of wet soil can be found from:

1000 g / (1.50 g/cm^3) $\times$ 0.25 g = 167 g/kg or 0.167 kg soil water/kg soil

The activity concentration in soil for a H-3 in-air concentration of 1 Bq/m^3 is therefore,

= 37.5 $\times$ 0.167 = 6.3 Bq/kg soil.

4.2 Carbon-14

To quote from [Ref-E.3] "the assumption of full SA equilibrium throughout the terrestrial environment is completely satisfactory for C-14 releases to the atmosphere if, as is usual, the C-14 is emitted as CO_2. This is the only form that is readily taken up by plants, so that active carbon is incorporated into the plant dry matter via photosynthesis at the same rate as stable carbon. Moreover, the organic components of the soil are made up of decayed plant matter and so will reflect the SA ratio of the plants".

Therefore, using a similar approach as that described in the equation 26, p564 of [Ref-E.3] but substituting S_p, which is described in the equation 26, with S_sO_s to derive the amount of organic carbon in the soil:

$$C_s = \frac{C_{air} S_s O_s}{S_{air}}$$

Where:
C_s = C-14 concentration in soil Bq/kg
C_{air} = C-14 concentration in air, Bq/m^3
S_s = concentration of stable Carbon in soil gC/kg

O_s = fraction organic carbon in soil
S_{air} = concentration stable carbon in air gC/m^3

The concentration of stable carbon in soil is taken from the composition of wet soil in the PC-CREAM 08® module GRANIS. The composition is given as:

Table E.4.2-1: Typical Elemental Composition of Soil

Element	Fraction(-)
H	0.04
C	0.07
O	0.60
Al	0.03
Si	0.25
Fe	0.01

GRANIS gives the fraction elemental composition and, although is not defined, is understood to be the mass fraction. Therefore the value of S_s is 70 gC/kg soil.

The concentration of stable carbon in air is given in section D.5.3 of [Ref-E.1] and is 0.15gC/m^3.

The fraction of carbon in soil present as organic matter has been taken as equivalent to the fraction associated with the loss on ignition. The Natural Environment Research Council (NERC) soil mapping portal indicates a value of 10% loss on ignition is reasonable for the North Wales coastal environment. The link to the NERC soil mapping portal is given in [Ref-E.4].

Therefore for a unit concentration of C-14 in air then,
C_s (Bq/kg) = 1 Bq/m^3 $\times$ 70 gC/kg $\times$ 0.1/(0.15 gC/m^3)
= 47 Bq/kg

5. Results

5.1 Air Concentration

The plume module within PC-CREAM 08® gives an air concentration of 1.90E-12 Bq/m^3 per 1Bq/y at a distance of 100m for the meteorological conditions specified above.

Therefore for an annual discharge of:

1.0E+13 Bq/y of H-3 the air concentration at 100m is 19.0 Bq/m^3.

1.7E+12 Bq/y of C-14 the air concentration at 100m is 3.23 Bq/m^3.

5.2 Soil Concentration at 100m from a Ground Level Release (Stage 1 Parameters)

5.2.1 Tritium (H-3)

The soil concentration at 100m from a ground level release (Stage 1 parameters), based on an air concentration of 19.0 Bq/m^3 and the SA model value derived above of 6.3 Bq/kg per Bq/m^3 is 120 Bq/kg.

5.2.2 Carbon-14

The soil concentration at 100m from a ground level release (stage 1 parameters), based on an air concentration of 3.23 Bq/m^3 and the SA model value derived above of 47 Bq/kg per Bq/m^3 is 151.8 Bq/kg.

6. Appendix E References

[Ref-E.1] Environment Agency, "Initial Radiological Assessment Methodology – Part 2 Methods and Input Data Science Report", SC030162/SR2, May 2006.

[Ref-E.2] Health Protection Agency, "The methodology for assessing the radiological consequences of routine releases of radionuclides into the environment used in PC-CREAM 08®", HPA-RPD-058, November 2009.

[Ref-E.3] International Atomic Energy Agency, "Specific Activity Models And Parameter Values For Tritium, C14 And Cl36. IAEA-TECDOC-1616 Quantification of Radionuclide Transfer in Terrestrial and Freshwater Environments for Radiological Assessments", 2009.

[Ref-E.4] Natural Environment Research Council, "UK soil observatory map viewer" (http://mapapps2.bgs.ac.uk/ukso/home.html)

Appendix F - Short-term Atmospheric Dispersion

This Appendix presents the justification of meteorological parameters used in the modelling of a short-term gaseous discharge from the UK ABWR. It also presents the results of a sensitivity study on the effect of cloud cover on short-term atmospheric dispersion.

The following tables are presented in this Appendix:
Table F.6-1: ADMS Pasquill Approximations
Table F.7-1: ADMS Calculation Results

1. Introduction

The dispersion of short-term gaseous releases to the atmosphere is dependent on numerous factors including release height, temperature and velocity of the discharge, and meteorological conditions at the time of the discharge. Unstable, neutral and stable meteorological conditions affect the shape of the plume with the plume becoming less dispersed, hence the plume center line concentration increases, as the meteorological conditions become more stable. This Appendix presents the justification of meteorological parameters used in the modelling of a short-term gaseous discharge from the UK ABWR. It also presents the results of a sensitivity study on the effect of cloud cover on short-term atmospheric dispersion.

2. Lateral Spread

It is considered reasonable to assume that the wind blows in a single direction for a short duration. However, for a 24 hour duration, the wind direction could reasonably vary considerably. It has been cautiously assumed that accounting for the lateral spread is sufficient to determine the broadening of the plume over a period of 24 hours.
Dispersion of the plume in the horizontal plane is determined by the release period. A standard equation for calculating the standard deviation (σ_y) in the horizontal plane in the short-term is given by [Ref-F.4]:

$$\sigma_y{}^2 = \sigma_{y_t}{}^2 + \sigma_{y_w}{}^2$$

Where:
σ_{yt} is the turbulent diffusion component and

σ_{yw} is the component due to fluctuations in wind direction : $0.065\ x\sqrt{\frac{7}{u}T}$

Where x is the downwind distance (m)
u is the windspeed at 10m above ground level (m/s) and
T is the release duration (h)

At downwind distances of 270m and 500m the turbulent diffusion standard deviation in the cross wind direction under Pasquill category D conditions are 20m and 35m, respectively [figure 10 of [Ref-F.1]].

At downwind distances of 270m and 500m the component due to fluctuations in wind direction are 131m and 243m for a wind speed of 3m/s.

Therefore the values of σ_y at 270m and at 500m are 132.5m and 245.5m, respectively.

The lateral spread (as used in ADMS5) is therefore calculated from the standard deviation and distance:

$$\sigma_\theta = 2\tan^{-1}\left(\frac{0.5\sigma_y}{x}\right)$$

This gives a lateral spread of 27.6 degrees for a 24 hour release.

3. Justification of Atmospheric Dispersion Modelling Parameters.

This note presents a summary of the justification for the use of Category D conditions (or more specifically, the ADMS equivalent parameters) for modelling the dispersion of short-term gaseous releases to the atmosphere, prepared as part of the GDA GEP submission for the UK ABWR. The short-term releases modelling was based on the methodology described in NRPB-W54 [Ref-F.1] and recommended by the National Dose Assessment Working Group (NDAWG) [Ref-F.2]. This same approach was used by the Environment Agency in their validation and verification of the GDA submissions made by the requesting parties for the UK EPR and AP1000 reactor designs.

NRPB-W54 Methodology (this also forms the basis of the 2011 NDAWG Guidance)
The NRPB (now Public Health England) report [Ref-F.1] provides a '*realistically cautious, rather than exceedingly cautious'* methodology for assessing doses to members of the public due to short-term releases to the atmosphere.

Some of the key provisions of [Ref-F.1] that informed the choice of the Category D meteorological conditions are presented below.

- Regarding the suitability of Category D meteorological conditions, the NRPB-W54 states that *"the range of possible meteorological conditions is represented by atmospheric stability category D, wind speed 3m/s, boundary layer height 800m and a continuous rainfall rate of 0.1mm/hr"*. These meteorological conditions are described as being 'realistically cautious'. That is the context in which Category D was used in the assessment: a broad representation of possible meteorological conditions over a 24 hour period.
- Regarding the effects of diurnal variations in insolation, NRPB-W54 contends that *"no change in approach is required for night time releases because, on average, the differences observed between both activity concentrations in air and deposition rates at night and during the day are within the uncertainties of the model and input data"*. This was corroborated by a study (described in Appendix C of [Ref-F.1]) of the frequency of occurrence of meteorological conditions (Pasquill categories A to F) at two locations (an inland and a coastal location) over 24hour periods during each of the four seasons of the year. The study demonstrates that the effect of diurnal variations in stability categories effectively 'evens out' over a 24 hour period.

4. Consideration of NDAWG Guidance

The NDAWG has published [Ref-F.2] a guidance note on the assessment of short-term releases to the atmosphere. The document categorically states that *"…assessments should be realistic… Cautious assumptions may be used for the purposes of an initial assessment. Pessimistic assumptions should be avoided for the purpose of authorising discharges of radioactive substances*".

A number of conservative assumptions were embedded in the UK ABWR prospective short-term dose assessment. For instance:

- Release duration – it is conservatively assumed that short-term releases occur uniformly over a 24hr period. In reality, for the UK ABWR, short-term releases are associated with fuel pin failure and releases occur over several days (estimated to be around 14 days from the start of the discharge to the isolation of defective pin and cessation of discharge). Strictly speaking, discharges that occur over a period of a few days should not be considered to be short-term.
- Summer releases – this corresponds to the peak growing season, when livestock graze on contaminated land and members of the public spend longer periods of time outdoors (and therefore have a relatively higher exposure rates/duration).

The introduction of further conservatism, *vis-a-vis* stable (rather than neutral) meteorological conditions, would result in an overly pessimistic assessment outcome, contradictory to NDAWG guidance.

5. Parameters Used for the Short-term Assessment

The following meteorological and physical parameters were defined in ADMS to determine the dispersion for the duration of the release. These conditions are considered to be consistent with the guidance given in [Ref-F.1]:

Meteorological parameters: Category D conditions (0 surface heat flux), wind speed 3 m/s and boundary layer height of 800m. A lateral spread 27.6° was also entered to correct for a 24 hour release period.

Physical parameters: effective stack height 19m, stack diameter 1m, efflux velocity 0 (zero) m/s.

The stack diameter was set to 1m (ADMS default value) and the efflux velocity was set to 0 (zero) m/s. An efflux velocity of zero effectively switches off plume rise modelling in ADMS and is considered to result in a conservative estimate of dispersion.

The effective stack height used was 19m. This was based on the lowest physical stack height of the Japanese ABWRs of 57m as explained in section 5.2.2.2 of this document and application of the " 1/3rd rule" to account for full entrainment in the building wake.

6. Sensitivity Study

The weather conditions that may occur during a release are variable. In the summer months the atmospheric conditions may vary from unstable to neutral during the day (Pasquill category A to D) and from neutral to stable (Pasquill Category D to G) at night. The atmospheric stability and boundary layer height is dependent on a number of factors, principally the heat input and the wind speed. The heat input will depend on the time of day and the amount of cloud cover [Ref-F.4].

The release rate was assumed to be constant over a period of 24 hours commencing at 12:00 on the 1st July. Summer months are the most conservative of all months as many foodstuffs (including animal feeds) are growing and are harvested at this time and would therefore give the highest impact.

To calculate the dispersion coefficient for the short-term (24 hour) release ADMS was used. ADMS does not define metrological conditions on the basis of Pasquill category but instead describes boundary layer meteorology in terms of boundary layer height and the Monin-Obukov length. The Monin-Obukov length is a measure of atmospheric stability. There is no direct equivalent of the Monin-Obukov length and Pasquill Category. However ADMS gives approximations to the Pasquill category which are presented below [Ref-F.4]:

Table F.6-1: ADMS Pasquill Approximations

Pasquill category	Wind speed (m/s)	Surface heat flux (W/m^2)	Boundary layer height (m)
A	1	146	1300
B	2	105	900
C	5	890	850
D	5	0	800
E	3	-12	400
F	2	-7	100
G	1	-0.8	100

To gain an understanding of the sensitivity of the effect of cloud cover a series of AMDS calculations were undertaken. The parameters were defined as follows:

Radionuclide: Kr-85 (representative of noble gases)
Wind speed: 5 m/s for daylight hours, 2 m/s for night-time hours
Wind angle: 270°
Year: 2015

Julian day number: 182 for times 12:00 to 23:00, 183 for times 00:00 to 11:00
Local time: start 12:00 end 11:00 in 1 hourly intervals
Lateral spread: As appropriate for the meteorological conditions and release period (see below)
Cloud cover: 0 oktas
The boundary layer height was undefined.

ADMS was used to determine to dispersion coefficient for each hour of the 24 hour release of the meteorological conditions and the average coefficient for the 24 hour period calculated. The ADMS calculations were repeated for 4 or 8 oktas cloud cover.

The above parameters approximate to the following stability categories over the 24 hour period.

- With zero oktas cloud cover during daylight hours and 5m/s wind speed cat B occurs between 10:00 and 14:00, Cat C between 07:00 to 10:00 and 14:00 to 17:00 and Cat D for the remaining time. For night time hours and 2 m/s wind speed Category g conditions prevail. The corresponding lateral spreads are 12.8°, 12.9°, 11.6° and 15.6°.

- With 4 oktas cloud cover during daylight hours and 5 m/s wind speed Cat C occurs between 07:00 to 17:00 and Cat D for the remaining time. For night-time hours and 2 m/s wind speed category F conditions exist. The corresponding lateral spreads are 15.59°, 11.56° and 19.26°.

- With 8 oktas cloud cover during daylight hours and 5 m/s wind speed Cat D condition occur at all times. During night-time hours and 2 m/s wind speed Category D conditions exist. The corresponding lateral spreads are 18.0° and 20.0°.

7. Results

The results of the ADMS calculations are presented Table F.7-1below:

Table F.7-1: ADMS Calculation Results

	Dispersion coefficient (s/m^3)			
Distance (m)	**0 oktas**	**4 oktas**	**8 oktas**	**E8 (W54)**
100	3.83E-05	3.63E-05	4.48E-05	4.88E-05
200	2.25E-05	2.13E-05	3.96E-05	3.30E-05
270	**1.47E-05**	**1.42E-05**	**2.86E-05**	**2.25E-05**
300	1.25E-05	1.23E-05	2.50E-05	1.93E-05
400	7.99E-06	8.68E-06	1.67E-05	1.24E-05
500	5.85E-06	7.11E-06	1.19E-05	8.66E-06
600	4.83E-06	6.29E-06	8.97E-06	6.38E-06
700	4.33E-06	5.75E-06	7.02E-06	4.90E-06
800	4.06E-06	5.33E-06	5.66E-06	3.88E-06
900	3.91E-06	4.96E-06	4.67E-06	3.16E-06
1000	3.80E-06	4.64E-06	3.93E-06	2.62E-06

These results are also presented in Figure F.7-1 below:

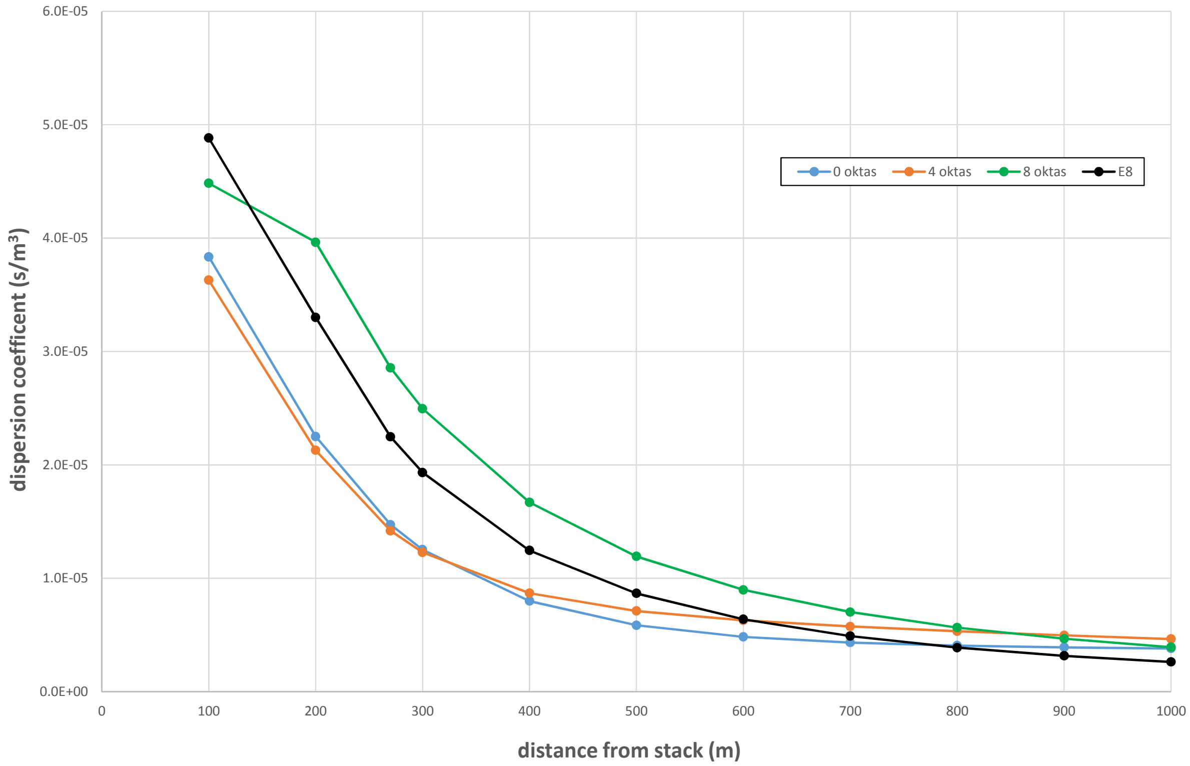

Figure F.7-1: Average Dispersion Coefficient for a 24 Hour Release for a Range of Cloud Cover

It can be seen that the dispersion coefficients based on the guidance published in NRPB-W54 are approximately 1/3rd lower than the average values for 8 oktas cloud cover, and about a factor of two higher than the dispersion coefficients calculated for 0(zero) and 4 oktas cloud cover at 270m.

It is concluded that the use of the NRPB-W54 "realistically cautious" meteorological conditions may introduce a degree of conservatism of no more than about a factor of about 2.

8. Appendix F References

[Ref-F.1] National Radiological Protection Board, "A methodology for assessing doses from short-term planned discharges to the atmosphere", J G Smith, P Bedwell, C Walsh and S M Heywood, NRPB-W54, March 2004.

[Ref-F.2] National Dose Assessment Working Group, "Short-term releases to the atmosphere", NDAWG/2/2011.

[Ref-F.3] Cambridge Environmental Research Consultants, "Atmospheric Dispersion Modelling System, Version 5", CERC 2012.

[Ref-F.4] National Radiological Protection Board, "A model for short and medium range dispersion of radionuclides released to the atmosphere", NRPB-R91, September 1979.