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01	Update for the November submission: - Dose assessments: annual dose Stage 3, build-up, short-term and collective dose included. - Details of Stage 1 and Stage 2 annual dose assessments provided in the 1st issue removed to annex 1 and 2.	26.11.08
02	PCER March 2010 update - Complementary information included in sub-chapter 11.1 section 1.1.1.e. and sub-chapter 11.2 section 1 - References format	28.03.10
03	PCER Final Submission - Minor formatting changes and editorial corrections - References listed under each numbered section or sub-section heading numbered [Ref-1], [Ref-2], [Ref-3], etc	23.12.11
04	Consolidated PCER update: - Update of the collective doses in Sub-chapter 11.1 sections 4.1, 4.2, Appendix 6 table A and Sub-chapter 11.5 section 1 - Clarification of text in Sub-chapter 11.1 section 3.2 and Sub-chapter 11.5 section 1	19.06.12

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SUB-CHAPTER 11.1 – RADIOLOGICAL HEALTH IMPACT

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1. ANNUAL DOSES TO THE PUBLIC

This section deals with requirements 2.7 and 2.9 of the Environment Agency (EA) Process and Information (P&I) Document [Ref-1].

The methodology used to carry out an Initial Radiological Assessment (IRA) is provided by the EA [Ref-2] [Ref-3].

The purpose and scope of the initial assessment methodology are to provide a system for undertaking an initial cautious prospective assessment of the dose arising from radioactive waste discharges to the environment, and to identify those discharges for which a more detailed assessment should be undertaken.

The assessment consists of three stages. At the first stage, the IRA is carried out using default data. If the assessed total dose is greater than 20 µSv y^{-1} then a Stage 2 assessment must be carried out. A Stage 2 assessment uses refined data which is more suited to the site in question. Again if assessed total dose is greater than 20 µSv y^{-1} then a Stage 3 assessment must also be carried out using a set of site parameters appropriate for the UK.

The IRA methodology provides a robust and acceptable screening to identify where further resource should be expended to look in more detail at the predicted doses. Simple cautious assumptions are made regarding the behaviour of radionuclides in the environment and the habits of persons possibly exposed. It should be noted that this methodology is generic for any radiological practice.

In the IRA methodology, all discharges are assumed to be continuous, uniform, routine releases. Moreover, it is assumed that discharges continue for 50 years. Effective dose is assessed in the 50^{th} year[1].

The general method used in the IRA methodology to calculate environmental concentrations and doses follows a conventional critical group approach as described in European Commission (EC) guidance document Radiation Protection 72 EUR15760 [Ref-4]. The critical group is intended to be representative of those individuals in the population expected to receive the highest dose.

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1 The uncertainty in calculating activities at 50 years as opposed to 60 is insignificant for the annual dose assessment. See Sub-chapter 11.3.

1.1. STAGE 1 OF THE INITIAL RADIOLOGICAL ASSESSMENT METHODOLOGY

1.1.1. Assessment methodology

The first stage of the IRA methodology consists of a simple and cautious assessment of the critical group dose.

Non-site specific Dose Per Unit Release (DPUR) values (µSv y^{-1} per Bq y^{-1}) are used for different radionuclides, release routes (air and water) and exposure pathways. Four age groups are considered: offspring (including embryo, fetus and newborn child), infant, child or adult. To calculate these DPUR, external dose rates are taken from Federal Guidance Report 12. To calculate exposure from inhalation and ingestion, the effective dose coefficients for intakes by inhalation and ingestion are taken from EC British Safety Standard (BSS) Council Directive 96/29/EURATOM. Dose coefficients for assessing effective dose to the embryo and fetus following intakes of radionuclides by the mother are taken from ICRP 88 [Ref-1].

For all release scenarios defined in the methodology, DPURs are calculated for each radionuclide, each exposure pathway, and each age group using the following formula:

$$DPUR\ p,r,a = CPURr \times Hp,a \times DFr,a$$

Where: *DPUR p,r,a* = the dose per unit release factor for a specific pathway, radionuclide, and age group (µSv y^{-1} per Bq y^{-1});

CPURr = the activity concentration per unit release in a relevant material (Bq kg^{-1}, Bq l^{-1}, or Bq m^{-3} per Bq y^{-1});

Hp,a = the habit data relevant to the pathway considered for a specific age group, either inhalation rate (m^3 y^{-1}), ingestion rate (kg y^{-1}) or occupancy time (h y^{-1}); and

DFr,a = the dose per unit intake by ingestion or inhalation factor (µSv Bq^{-1}) or external dose factor (µSv h^{-1} per Bq kg^{-1}) for each radionuclide and age group.

For each exposure group, the DPURs of all relevant pathways are summed.

For each radionuclide, the DPURs of the different age groups are compared and the worst age DPUR selected. Consequently, the doses assessed in the first stage of the IRA methodology are the doses for the worst age group of offspring, infant, child or adult. These DPUR data are based on key assumptions which are described below.

a) Exposure groups

The critical groups assumed are:

- a **farming family** living 100 m from the discharge point who grows large quantities of their own foods. The farming family consumes all foods at critical rates, 100% of which are grown locally. The receptor point for food production is assumed to be 500 m from the stack;

- a **fishing family**[2] living near to the site, fishing in the local waters, consuming the catches at critical rates, 50% of sea fish caught from the local compartment (remaining 50% from the regional compartment), and 100% of shell fish from the local compartment.

Other habit data for the critical groups are provided in Annex 1 - Table A [Ref-1].

As offspring intakes are dependant on maternal exposures during gestation, adult habit data has been used to estimate offspring exposures.

b) Food intake

Consumptions for each age group are provided in Annex 1 - Table B [Ref-1].

c) Other parameters

For radioactive emissions to air, a single release point is considered, i.e. the stack of the EPR Reactor Building. A ground level release is considered.

For radioactive liquid releases, a single release point is considered, i.e. the pipe discharge. The releases are assumed to take place into a local marine compartment characterised by a volumetric water exchange rate of 100 m^3 s^{-1} with the neighbouring regional compartment.

The following default assumptions and main parameters used in the first Stage of the initial assessment are listed in Annex 1 - Tables C and D [Ref-1].

d) Pathways considered

For releases to air, the gaseous exposure pathways taken into account in the dose assessment are as follows:

- Internal irradiation from inhalation of radionuclides in the effluent plume;

- External irradiation from radionuclides in the effluent plume;

- External irradiation from radionuclides deposited to the ground; and

- Internal irradiation from consumption of terrestrial food incorporating radionuclides deposited to the ground (only nuclides with half-life > 3 hours).

2 As the scope of the study has defined, the EPR unit is assumed to be located near coastline or estuary.

For releases to sea, the liquid exposure pathways taken into account in the dose assessment are as follows:

- External irradiation from radionuclides deposited in shore sediments (spending time on local beaches); and
- Consumption of seafood.

e) Maximum discharges of the EPR unit

The maximum annual aerial and liquid radioactive discharges of the EPR unit, used for the impact analysis, are presented in the table below (Sub-chapter 11.1 - Table 1). As stated in PCER Sub-chapter 6.3, the dose received from discharges of gaseous carbon-14 (C-14) was calculated based on the first estimate of the maximum value (900 GBq y^{-1}) rather than on the reviewed value (700 GBq y^{-1}). Similarly, the initial value for the other gaseous fission and activation products (340 MBq y^{-1}) was used instead of the reviewed value (120 MBq y^{-1}). As such, the dose calculations are expected to represent an overestimate of the dose received. Since gaseous carbon-14 is the main contributor to the overall gaseous dose received from gaseous discharges, it is expected that the overall dose from gaseous discharge will be lower than discussed. Considering the low impact of fission and activation products on the total dose received, it is expected that the reduction of the annual limit for fission and activation products will not have a major impact on the overall dose calculation.

Sub-chapter 11.1 - Table 1: Maximum annual radioactive discharges used for the impact analysis

Category of radionuclides	Maximum annual aerial radioactive discharge	Maximum annual liquid radioactive discharge
Tritium	3 TBq	75 TBq
Carbon-14	900 GBq**	95 GBq
Iodine isotopes – total	400 MBq	50 MBq
Noble gases – total	22.5 TBq	-
FP/AP* – total	340 MBq***	10 GBq

* FP/AP: other fission or activation products emitting beta or gamma radiation.

** Initial value, reviewed value is 700 GBq.

*** Initial value, reviewed value is 120 MBq.

The following spectrums are applied for these radionuclides.

Sub-chapter 11.1 - Table 2: Spectrum of maximum annual radioactive discharges

For maximum annual aerial radioactive discharges

	Radionuclides	Spectrum
Tritium	H-3	100%
Carbon-14	C-14	100%
Iodine isotopes	I-131	45.6%
	I-133	54.4%
Noble gases	Kr-85	13.9%
	Xe-133	63.1%
	Xe-135	19.8%
	Ar-41	2.9%
	Xe-131m	0.3%
FP/AP	Co-58	25.5%
	Co-60	30.1%
	Cs-134	23.4%
	Cs-137	21%

For maximum annual liquid radioactive discharges

	Radionuclides	Spectrum
Tritium	H-3	100%
Carbon-14	C-14	100%
Iodine isotope	I-131	100%
FP/AP	Ag-110m	5.7%
	Co-58	20.7%
	Co-60	30%
	Cs-134	5.6%
	Cs-137	9.45%
	Mn-54	2.7%
	Sb-124	4.9%
	Sb-125	8.15%
	Ni-63	9.6%
	Te-123m	2.6%
	Others[3]	0.6%

The chemical forms of the radionuclides taken into account in the study are the following:

- For gaseous discharges: tritium is considered in the form of atmospheric water vapour. Carbon-14 is in the form of atmospheric carbon, in particulate form - type M. Isotopes of iodine are considered to be in inorganic form (I_2) as this is the most restrictive; and
- For liquid discharges: tritium is considered in the form of tritiated water.

1.1.2. Annual dose to the most exposed members of the public for gaseous discharges

The discharged activities taken into account in the dose assessment calculations and the annual dose due to gaseous discharges are given in Annex 1 - Table E. For each radionuclide, the total DPUR value is the sum of the DPUR for each exposure pathway. The total DPUR values for each age group have been compared and those from the worst age group are presented.

[3] All of the various radionuclides that may be episodically detected. For a 1300 MW(e) plant in France, the 'others' category is represented by chromium-51. The same assumption is taken into account in this study.

As presented in Annex 1 - Table E, the result of the first stage of the IRA methodology is a **total dose for releases to air equal to 72.8 µSv y^{-1}**. The major contributor to the dose is carbon-14 (almost 85%).

1.1.3. Annual dose to the most exposed members of the public for liquid discharges

The discharged activities taken into account in the dose assessment calculations and the annual dose due to liquid discharges are given in Annex 1 - Table F. For each radionuclide, the total DPUR value is the sum of the DPUR for each exposure pathway. The total DPUR values for each age group have been compared and those from the worst age group are presented.

As presented in Annex 1 - Table F, the result of the first stage of the IRA methodology is a **total dose for releases to coastal or estuary water equal to 60 µSv y^{-1}**. The major contributor to the dose is carbon-14 (almost 73%).

1.1.4. Annual dose from direct radiation to the most exposed members of the public

As measurement data is not available in this instance, the dose rate from direct radiation has been estimated.

As the outside of any building of the facility is an undesignated area, the public dose limit of 1 mSv y^{-1} is appropriate for estimating the maximum dose rate at the outside of the buildings.

The dose rate at the site boundary can then be estimated using a 1/r relationship and the direct radiation is calculated as below:

$$\text{Direct Radiation} = \frac{1}{r} \times D \times \left(SF_i \times FT_i + SF_o \times FT_o\right)$$

Where: D = Dose rate (mSv y^{-1}) at 1 m from building surface;

$SF_{i,o}$ = Shielding Factor indoors and outdoors;

$FT_{i,o}$ = Fraction of Time indoors and outdoors; and

r = Distance from Reactor Building to critical group in m.

For the terrestrial critical group adult living 100 m from the Reactor Building with the habit data mentioned in Annex 1 - Table A, the direct radiation is calculated as below:

$$\text{Direct Radiation} = \frac{1}{100} \times 1 \times \left(0.1 \times 0.5 + 1 \times 0.5\right) = 5.5\ \mu Sv\ y^{-1}$$

The annual dose from direct radiation from an EPR station to the critical group assumed to be living 100 m from the Reactor Building is less than 6 µSv y^{-1}.

1.1.5. Annual dose to the critical group for the facility

The critical group is intended to be representative of those individuals in the population expected to receive the highest dose. As it is possible that the fisherman family are also local residents consuming locally grown foodstuffs, it is necessary to sum the doses from all release routes to estimate the critical group dose. The table below (Sub-chapter 11.1 - Table 3) presents the total dose for this critical group.

Sub-chapter 11.1 - Table 3: Summary total dose – Stage 1

Release Routes	Exposure Groups	Total Dose (µSv y^{-1})
Air	Local Resident Family	72.8
Coastal or Estuary Water	Fisherman Family	60.0
Direct Radiation	Local Resident Family	5.5
	Total Critical Group dose µSv y^{-1}	138.3

1.1.6. Conclusions

The annual total dose for the critical group at Stage 1 is 138.3 µSv y^{-1}. The major contributor to this dose is the carbon-14.

As the total critical group dose at Stage 1 is greater than 20 µSv y^{-1}, it is necessary to continue the screening assessment to Stage 2 using refined parameters.

1.2. STAGE 2 OF THE INITIAL RADIOLOGICAL ASSESSMENT METHODOLOGY

1.2.1. Assessment methodology

All assumptions and parameters remain unchanged from the Stage 1 assessment except for two parameters: stack height and local marine compartment volumetric exchange rate.

In Stage 2, an effective stack height of 20 m and a local marine compartment volumetric exchange rate of 130 $m^3 s^{-1}$ have been assumed for the revised calculations.

The EPR Reactor Building is of the order of 60 m high, and the stack protrudes a few metres above the building. As a result of entrainment in the wake of the Reactor Building, the effective height of the release has been conservatively assumed to be reduced to one third of the Reactor Building height. Consequently, the effective stack height is assumed to be 20 m.

Two scaling factors are therefore required to take into account the difference in activity concentration in air and deposited at the receptor point as a result of increasing the effective stack height to 20 m: one for food exposure and another for inhalation and external exposure to atmospheric discharges. According to the IRA methodology, the values for these two factors are 0.31 and 0.04 respectively.

A value of 130 $m^3 s^{-1}$ represents the lowest exchange rate for the existing Nuclear Power Plants in the UK and is therefore realistically conservative.

It is considered that the discharge point for liquid will be close to the site and so it is necessary to combine the results for the two exposure groups as both exposure groups could be exposed to both releases. This represents a conservative assumption.

1.2.2. Annual dose to the most exposed members of the public for gaseous discharges

For each radionuclide considered in the gaseous discharges, the total DPUR values for the worst age group defined which are taken into account in the IRA are used. The Annex 2 - Table A presents the DPUR values for each exposure pathway and the resulting annual total dose.

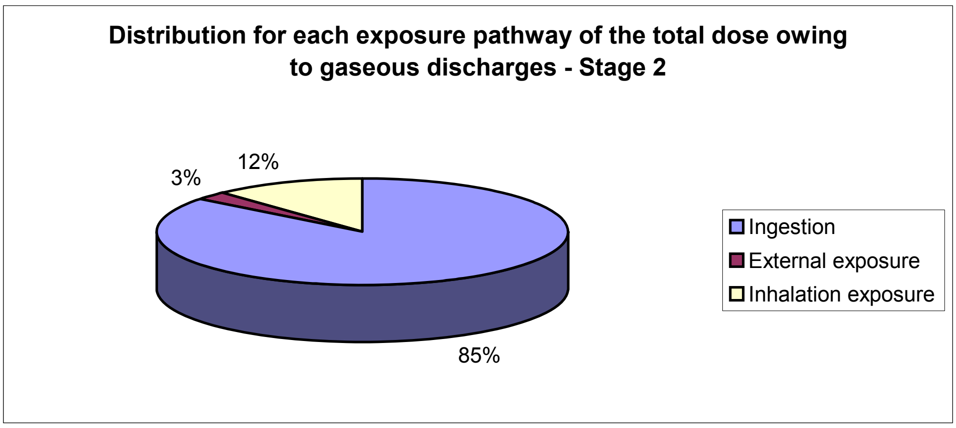
The table below (Sub-chapter 11.1 - Table 4) shows the total doses calculated for each exposure pathway. The values of doses calculated for each radionuclide are given in Annex 2 - Table B.

Sub-chapter 11.1 - Table 4: Releases to air - Doses for each exposure pathway – Stage 2

	Dose owing to food ingestion (µSv y^{-1})	Dose owing to external exposure (µSv y^{-1})	Dose owing to inhalation exposure (µSv y^{-1})	Total dose (µSv y^{-1})
Total Dose for radionuclides (µSv y^{-1})	**9.7**	**0.3**	**1.4**	**11.4**

The distribution for each exposure pathway in the total dose owing to gaseous discharges from the site is presented in the figure below (Sub-chapter 11.1 - Figure 1):

Sub-chapter 11.1 - Figure 1: Distribution for each exposure pathway of total dose owing to gaseous discharges – Stage 2



For gaseous discharges, the most important exposure pathway is ingestion.

1.2.3. Annual dose to the most exposed members of the public for liquid discharges

For each radionuclide considered in the liquid discharges, the total DPUR values for the worst age group defined which are taken into account in the initial radiological assessment are used. The Annex 2 - Table C presents the DPUR values for each exposure pathway and the resulting annual total dose.

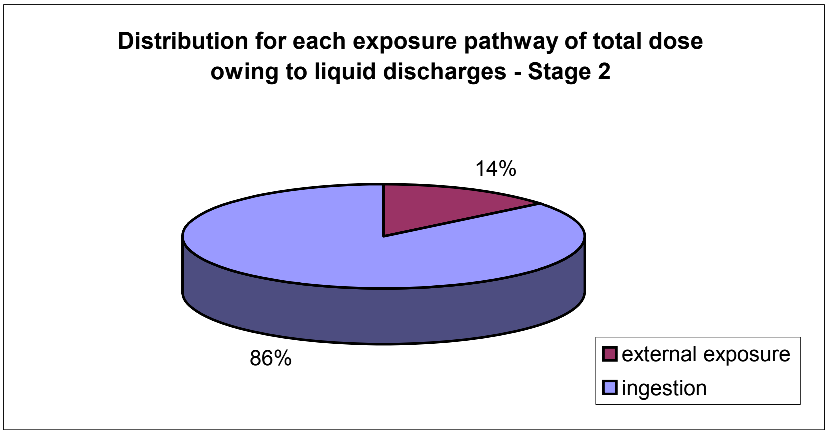
The table below (Sub-chapter 11.1 - Table 5) shows the doses calculated for each exposure pathway. The values of doses calculated for each radionuclide are given in Annex 2 - Table D.

Sub-chapter 11.1 - Table 5: Releases to coastal or estuary water – Doses for each exposure pathway – Stage 2

	Dose owing to external exposure (μSv y^{-1})	Dose owing to the ingestion of seafood (μSv y^{-1})	Total dose (μSv y^{-1})
Total Dose for radionuclides (μSv y^{-1})	**6.6**	**39.5**	**46.1**

The distribution for each exposure pathway of the total dose owing to liquid discharges from the site is presented in the figure below (Sub-chapter 11.1 - Figure 2):

Sub-chapter 11.1 - Figure 2: Distribution for each exposure pathway of total dose owing to liquid discharges – Stage 2



For liquid discharges, the most important exposure pathway is ingestion.

1.2.4. Annual dose from direct radiation to the most exposed members of the public

The annual dose from direct radiation is assessed in the same way as in section 1.1.4.

As a consequence, for the Stage 2, the annual dose from direct radiation from an EPR station to the critical group assumed to be living 100 m from the Reactor Building is less than 6 μSv y^{-1}.

1.2.5. Annual dose to the critical group for the facility

The critical group is intended to be representative of those individuals in the population expected to receive the highest dose. As it is possible that the fisherman family are also local residents consuming locally grown foodstuffs, it is necessary to sum the doses from all release routes to estimate the critical group dose. The table below (Sub-chapter 11.1 - Table 6) presents the total dose for this critical group.

Sub-chapter 11.1 - Table 6: Summary total dose – Stage 2

Release Routes	Exposure Groups	Total Dose ($\mu Sv\ y^{-1}$)
Air	Local Resident Family	11.4
Coastal or Estuary Water	Fisherman Family	46.1
Direct Radiation	Local Resident Family	5.5
	Total Critical Group dose $\mu Sv\ y^{-1}$	63.0

1.2.6. Conclusions

The annual total dose for the critical group at Stage 2 decreases by comparison with the value obtained at Stage 1 because of the refined parameters taken into account in Stage 2 (height of stack and volumetric exchange rate).

The annual total dose for the critical group at Stage 2 is 63.0 $\mu Sv\ y^{-1}$. The major contributor to this dose is carbon-14. This value ensures compliance with the dose limit for members of the public, i.e. 1000 $\mu Sv\ y^{-1}$ and the Government's dose constraint for a single source[4], i.e. 300 $\mu Sv\ y^{-1}$. However, the annual total dose calculated in the Stage 2 is still above the 20 $\mu Sv\ y^{-1}$. It is therefore necessary to carry out a detailed assessment using more refined assumptions.

1.3. STAGE 3 OF THE INITIAL RADIOLOGICAL ASSESSMENT METHODOLOGY

The methodology applied is based on the use of PC CREAM 98 software tool [Ref-1]. PC CREAM comprises a suite of 6 programmes (ASSESSOR, DORIS, PLUME, FARMLAND, RESUS, and GRANIS) for modelling the transfer of radionuclides through the environment and calculating the dose to individuals and the population from exposure to these nuclides.

[4] In its advice on UK application of ICRP's new recommendations on radiological protection, the UK Health Protection Agency (HPA) proposes that for new nuclear power stations this constraint should be reduced to some value less than 150 $\mu Sv\ y^{-1}$. As it is a recommendation and not a regulatory value, the value of 150 $\mu Sv\ y^{-1}$ is only given for information.

All discharges are assumed to be continuous, uniform, routine releases. Moreover, it is assumed that discharges continue for 50 years[5]. The maximum annual gaseous and liquid discharges of the EPR unit and the spectrum applied for the radionuclides are presented in Sub-chapter 11.1 - Tables 1 and 2.

The retained parameters are different from those presented at Stage 1 and 2. For the Stage 3, the parameters are a set of site characteristics which are appropriate for the UK.

1.3.1. Site characteristics

A set of site characteristics needed to carry out impact studies for GDA are presented in Sub-chapter 11.1 - Table 7 below. These site characteristics are defined to be appropriate for the development of an EPR in the UK, i.e.:

- good geographic representation; and
- taking into account coastal and estuarine locations.

The parameters are chosen as they represent the ‘typical data’ of potential sites where a new EPR reactor could be located. These parameters for the dispersion of gaseous and liquid discharges are presented in PCER Chapter 10 and summarised below.

- **Parameters for the dispersion of gaseous discharges**

  The public receptor and food receptor points are selected from the nearest potential property and farmland to a new reactor site. Both points are located 500 m from the release point.

  The effective stack height is assumed to be 20 m as described in section 1.2.1.

  As the site is a typical UK location, an uniform windrose is chosen at 70% Pasquill stability category D which is typical of coastal UK, as shown in NRPB-R91 [Ref-1].

  Standard washout coefficients and deposition velocities are chosen and a surface roughness typical of agricultural areas is selected as given in RP-72 [Ref-2].

- **Parameters for the dispersion of liquid discharges**

  The local waters, known as the local compartment, are defined based on the most restrictive value for each parameter for each of the potential sites. The smallest volume, is combined with the largest depth, longest coastline length, lowest volumetric exchange rate, lowest suspended sediment load and highest sedimentation rate.

  The regional compartment, Cumbrian Waters[6], is selected as this compartment has the lowest flow with other regional compartments and therefore results in the lowest dispersion and highest activity concentration within the waters of interest.

The <u>other data</u> (habit data, food intake, etc.) used to calculate the annual dose are presented for each section below.

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5 The uncertainty in calculating activities at 50 years as opposed to 60 is insignificant for the annual dose assessment. See Sub-chapter 11.3.

6 As the regional compartment selected is Cumbrian Waters, the marine module is Irish Sea.

Sub-chapter 11.1 - Table 7: Parameters of site characteristics – Stage 3

Site characteristics	Parameter Values
Public receptor point aerial discharges (m)	500
Food production receptor point (m)	500
Site boundary (m)	100
Windrose	uniform
Pasquill stability category	70 % D
Deposition velocity (m s^{-1})	1×10^{-3} (others), 1×10^{-2} (Iodine isotopes), 0 (Noble gases)
Washout coefficient (s^{-1})	1×10^{-4}
Surface roughness (m)	0.3
Marine module	Irish Sea
Regional compartment	Cumbrian Waters
Local compartment volume (m^3)	3×10^8
Local compartment depth (m)	20
Local compartment coastline length (m)	3×10^4
Local compartment volumetric exchange rate (m^3 y^{-1})	1.1×10^{10}
Local compartment suspended sediment load (t m^{-3})	5×10^{-6}
Local compartment sediment rate (t m^{-2} y^{-1})	1×10^{-2}
Local compartment sediment density (t m^{-3})	2.6
Local compartment bioturbation rate (m^2 y^{-1})	3.6×10^{-5}
Local compartment diffusion rate (m^2 y^{-1})	3.15×10^{-2}

1.3.2. Annual dose to the most exposed members of the public from gaseous discharges

1.3.2.1. Assessment methodology

a) Exposure group and habit data

The most exposed members are assumed to be a farming family living 500 m from the discharge point. The adults are assumed to spend time each year outdoors working on the land adjacent to the site, the children and infants also spend time outdoors. The habit data of the farming family, as defined in NRPB-W41 [Ref-1], are summarised in the table below (Sub-chapter 11.1 - Table 8).

Sub-chapter 11.1 - Table 8: Habit data for gaseous discharges – Stage 3

Parameters	Adult	Child	Infant
Location factor cloud gamma	0.2	0.2	0.2
Location factor deposited gamma	0.1	0.1	0.1
Occupancy ($h\ y^{-1}$)	8760	8760	8760
Fraction of time indoors	0.5	0.8	0.9
Breathing rate ($m^3\ h^{-1}$)	1.12	0.64	0.22

b) Pathways considered

The pathways of exposure considered in this assessment are:

- Internal irradiation from inhalation of radionuclides in the effluent plume and inhalation of resuspended radionuclides following deposition;
- External irradiation from radionuclides in the effluent plume;
- External irradiation from radionuclides deposited to the ground; and
- Internal irradiation from consumption of terrestrial food incorporating radionuclides deposited to the ground.

The dose coefficients used for all exposure pathways and the chemical forms used are presented in Annex 3 - Table A.

c) Food intake

This farming family consumes the top two foodstuffs at critical rates, and all other terrestrial foods at average rates as defined in NRPB-W41 [Ref-1]. It is assumed that the top two foods are 100% locally sourced, however, all other foods are assumed to be 50% locally sourced and 50% sourced from elsewhere and therefore assumed to be uncontaminated.

The top two foodstuffs are determined by running ASSESSOR considering only the ingestion pathway and using the inputs as described in Sub-chapter 11.1 - Tables 7 and 9.

Here it is assumed that all terrestrial foods (with the exception of grain and milk products which are ignored for this study[7]) are consumed at critical rates. The two food groups with the highest ingestion doses are then assumed to be eaten at critical rates for the assessment proper.

[7] Ingestion of grain is not considered as there is no evidence of grain being grown, milled and consumed on a local scale. Milk products are not considered for the ‘top two’ approach. Indeed, they include milk products (such as cheese) which are not likely to be local products but also milk drinks which are already taken into account in cow milk and sheep milk. If milk products have been taken into account in the ‘top two’ approach, they would have been one of the top two products. Nevertheless, once the top two foodstuffs are determined, milk products are considered at average rates to assess the annual dose from gaseous discharges.

Annex 3 - Figures A, B and C show the dose breakdown for the ingestion of foods at critical rates for each of the three age groups. The doses are dominated by the ingestion of cows milk and root vegetables. These food groups are selected as the 'top two' in terrestrial most exposed members assessments.

Sub-chapter 11.1 - Table 9 below presents the food data as presented in PCER Chapter 10.

Sub-chapter 11.1 - Table 9: Food consumption rates for gaseous discharges – Stage 3

Parameters	Adult	Child	Infant
Fraction of food locally produced – 'top two'	1	1	1
Fraction of food locally produced – all other foods	0.5	0.5	0.5
Ingestion of green vegetables (kg person^{-1} y^{-1}) average rates	35	15	5
Ingestion of root vegetables (kg person^{-1} y^{-1}) average rates	60	50	15
Ingestion of fruit (kg person^{-1} y^{-1}) average rates	20	15	9
Ingestion of sheep meat (kg person^{-1} y^{-1}) average rates	8	4	0.8
Ingestion of offal (kg person^{-1} y^{-1}) average rates	5.5	3	1
Ingestion of cow meat (kg person^{-1} y^{-1}) average rates	15	15	3
Ingestion of milk (kg person^{-1} y^{-1}) average rates	95	110	130
Ingestion of milk products (kg person^{-1} y^{-1}) average rates	20	15	15
Ingestion of green vegetables (kg person^{-1} y^{-1}) critical rates	80	35	15
Ingestion of root vegetables (kg person^{-1} y^{-1}) critical rates	130	95	45
Ingestion of fruit (kg person^{-1} y^{-1}) critical rates	75	50	35
Ingestion of sheep meat (kg person^{-1} y^{-1}) critical rates	25	10	3
Ingestion of offal (kg person^{-1} y^{-1}) critical rates	20	10	5.5
Ingestion of cow meat (kg person^{-1} y^{-1}) critical rates	45	30	10
Ingestion of milk (kg person^{-1} y^{-1}) critical rates	240	240	320

1.3.2.2. Results

The annual dose to the most exposed members of the public from gaseous discharges is assessed using the PLUME and ASSESSOR modules of PC CREAM 98.

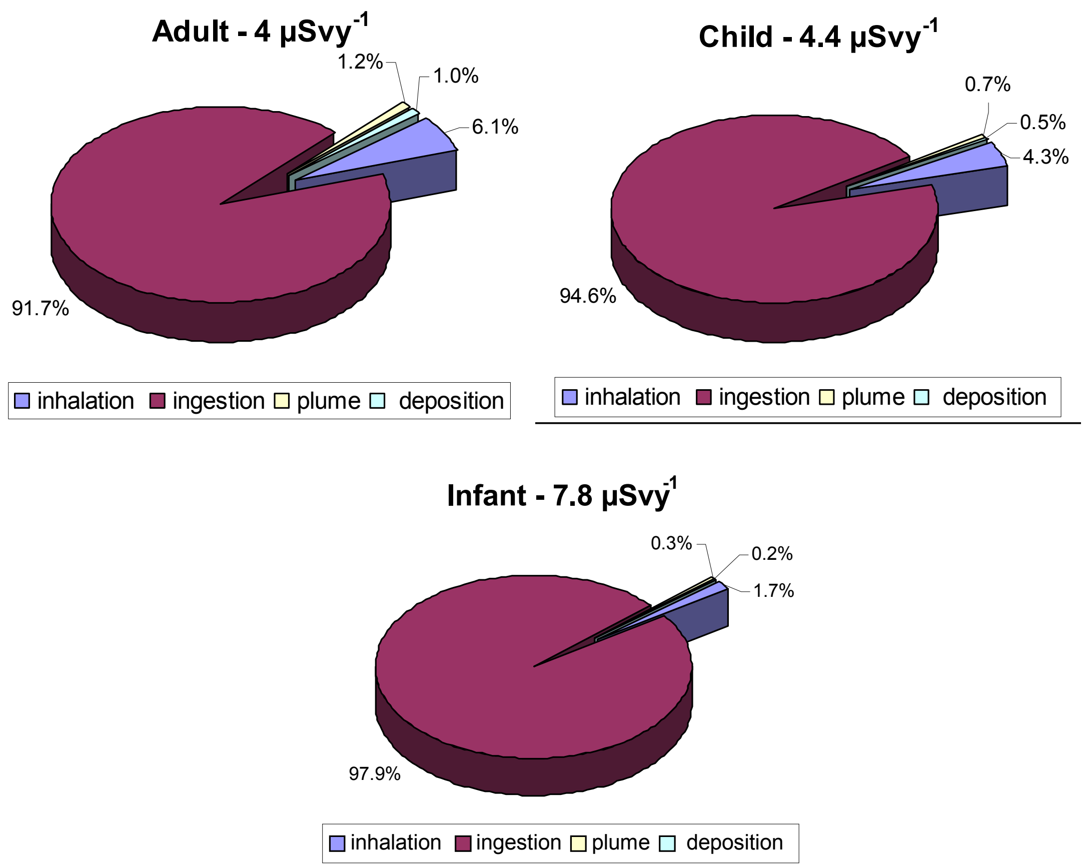
The doses to adults, children and infants from each pathway are presented in the table below (Sub-chapter 11.1 - Table 10) (See Annex 3 - Tables B, C and D for more details: annual dose for all discharged radionuclides from each pathway and each age group).

Sub-chapter 11.1 - Table 10: Annual dose to the farming most exposed members from gaseous discharges (µSv y^{-1}) by exposure pathway – Stage 3

	Inhalation dose (µSv y^{-1})	Ingestion of terrestrial food dose (µSv y^{-1})	External exposure to plume dose (µSv y^{-1})	External exposure to deposited radionuclides dose (µSv y^{-1})	Total dose (µSv y^{-1})
Adult	2.4E-01	3.6E+00	4.7E-02	3.9E-02	4.0E+00
Child	1.9E-01	4.2E+00	3.0E-02	2.0E-02	4.4E+00
Infant	1.3E-01	7.7E+00	2.4E-02	1.3E-02	7.8E+00

The pie charts below (Sub-chapter 11.1 - Figure 3) show the dose to the most exposed members, from gaseous discharges, for each pathway.

Sub-chapter 11.1 - Figure 3: Distribution for each exposure pathway of dose owing to gaseous discharges – Stage 3



For the <u>farming family</u>, the total dose received by each age group is 4.0, 4.4 and 7.8 µSv y^{-1} for adults, children and infants respectively.

For the three age groups, the dose due to the ingestion of terrestrial food is the major contributor pathway.

Infants receive the greatest dose of the three age groups. As shown in Annex 3 - Table D, this is dominated by the ingestion of carbon-14 in milk (62%) and root vegetables (17%).

1.3.3. Annual dose to the most exposed members of the public from liquid discharges

1.3.3.1. Assessment methodology

a) Exposure group and habit data

The most exposed members are assumed to be a fishing family, where the adults spend time fishing near the coast and the children and infants spend time playing on the coast. The habit data of the fishing family, as defined in NRPB-W41 [Ref-1] and ICRP 66 [Ref-2], are summarised in the table below (Sub-chapter 11.1 - Table 11).

Sub-chapter 11.1 - Table 11: Habit data for liquid discharges – Stage 3

Parameters	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 seafood caught in local compartment	1	1	1
Fraction of seafood caught in regional compartment	0	0	0
Beach occupancy ($h\ y^{-1}$)	2000	300	30
Breathing rate marine ($m^3\ h^{-1}$)	1.69	1.12	0.35

b) Pathways considered

The pathways of exposure considered in this assessment are:

- ingestion of sea fish, crustacea and mollusca caught locally;
- inhalation of seaspray when on the coast; and
- external exposure to beach sediments (three age groups) and fishing gear (only for adults).

The dose coefficients used for all exposure pathways and the chemical forms used are presented in Annex 3 - Table A.

c) Food intake

The fishing family consumes sea-foodstuffs at critical rates [Ref-1], as presented in PCER Chapter 10 and summarised in the table below (Sub-chapter 11.1 - Table 12).

Sub-chapter 11.1 - Table 12: Food consumption rates (critical rates) for liquid discharges – Stage 3

Parameters	Adult	Child	Infant
Ingestion of sea fish (kg $person^{-1}$ y^{-1})	100	20	5
Ingestion of crustacea (kg $person^{-1}$ y^{-1})	20	5	0
Ingestion of mollusca (kg $person^{-1}$ y^{-1})	20	5	0

1.3.3.2. Results

The annual dose to the most exposed members of the public from liquid discharges is assessed using the DORIS and ASSESSOR modules of PC CREAM 98.

The doses to adults, children and infants from each pathway are presented in the table below (Sub-chapter 11.1 - Table 13) (See Annex 3 - Tables E, F and G for more details: annual dose for all discharged radionuclides from each pathway and each age group).

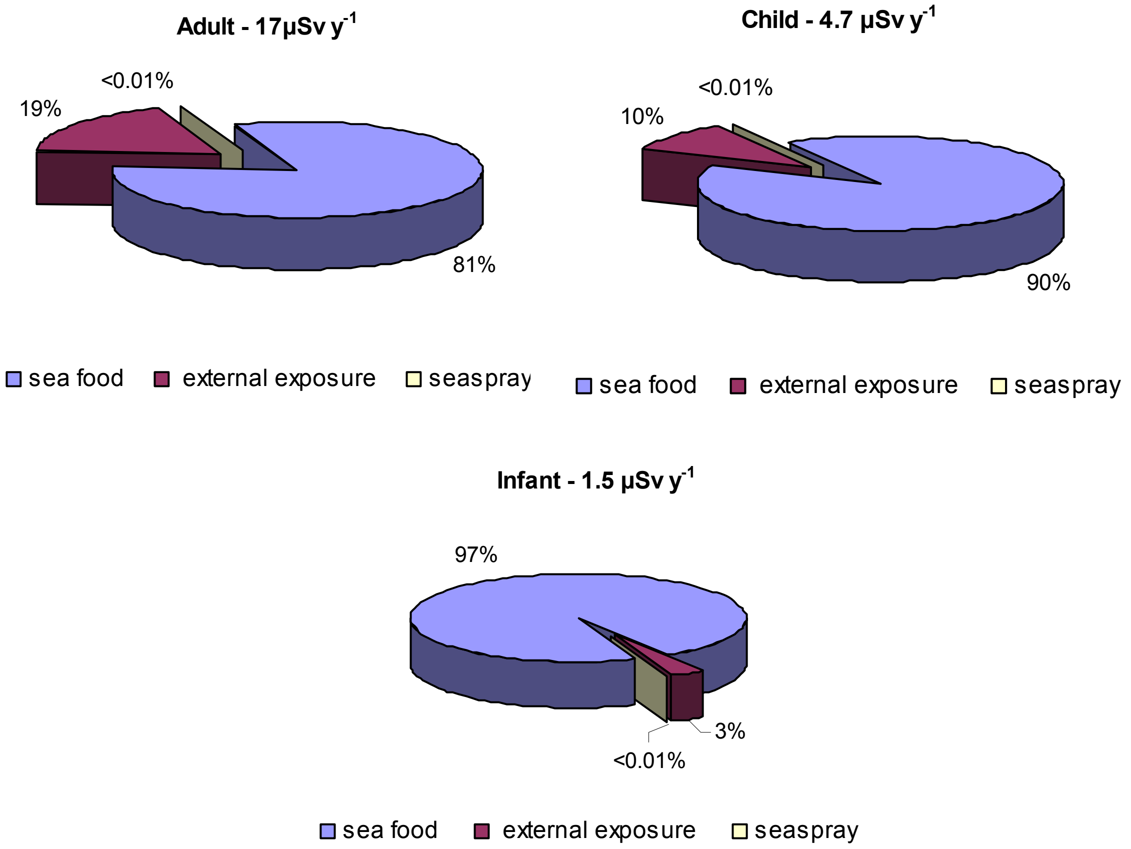
Sub-chapter 11.1 - Table 13: Annual dose to the marine most exposed members from liquid discharges (μSv y^{-1}) by exposure pathway – Stage 3

	Ingestion of seafood dose (μSv y^{-1})	External exposure dose[8] (μSv y^{-1})	Inhalation of seaspray dose (μSv y^{-1})	Total dose (μSv y^{-1})
Adult	1.4E+01	3.2E+00	1.7E-09	1.7E+01
Child	4.2E+00	4.8E-01	2.2E-10	4.7E+00
Infant	1.4E+00	4.8E-02	1.5E-11	1.5E+00

The pie charts below (Sub-chapter 11.1 - Figure 4) show the dose to the most exposed members, for liquid discharges, by pathway.

[8] External exposure to beach sediments (three age groups) and fishing gear (adults only).

Sub-chapter 11.1 - Figure 4: Distribution for each exposure pathway of dose owing to liquid discharges – Stage 3



For the <u>fishing family</u>, the total dose received by each age group is 17, 4.7 and 1.5 µSv y^{-1} for adults, children and infants respectively. For the three age groups, the dose due to the ingestion of seafood is the major contributor pathway.

Adults receive the greatest dose of the three age groups. As shown in Annex 3 - Table E, this dose is dominated by the ingestion of carbon-14 in seafood (81%).

1.3.4. Annual dose to the most exposed members of the public from all discharges

In order to determine the most exposed members of the public from all discharges, three scenarios have been considered:

- the terrestrial most exposed members of the public also consuming locally sourced seafoods at average rates;
- the marine most exposed members of the public also consuming locally sourced terrestrial foods at average rates; and
- the local resident: the most exposed members of the public exposed to liquid and atmospheric discharges.

1.3.4.1. Terrestrial members of public also consuming seafood

a) Assessment methodology

It is assumed that the terrestrial members of the public could potentially consume locally sourced seafoods at average rates [Ref-1].

It is assumed that these individuals are not exposed to fishing gear, seaspray or beach sediments.

Their terrestrial habits and doses are as described in section 1.3.2 above.

The dose received from the ingestion of locally caught seafoods are assessed:

- assuming dispersion in the local compartment, as detailed in Sub-chapter 11.1 - Table 7 above;
- assuming a fraction of seafoods caught in local compartment equal to 1; and
- average ingestion rates as presented in PCER Chapter 10 and summarised in the table below (Sub-chapter 11.1 - Table 14).

Sub-chapter 11.1 - Table 14: Food consumption rates (average rates) for liquid discharges – Stage 3

Parameters	Adult	Child	Infant
Ingestion of sea fish (kg person^{-1} y^{-1})	15	6	3.5
Ingestion of crustacea (kg person^{-1} y^{-1})	1.75	1.25	0
Ingestion of mollusca (kg person^{-1} y^{-1})	1.75	1.25	0

b) Results

The dose received from the ingestion of locally caught seafoods is assessed using the DORIS and ASSESSOR modules of PC CREAM 98.

The doses to adults, children and infants from each pathway are presented in the table below (Sub-chapter 11.1 - Table 15) (See Annex 1 - Tables H, I and J for more details: annual doses for all discharged radionuclides from each pathway and each age group).

Sub-chapter 11.1 - Table 15: Annual dose to the terrestrial members of the public also consuming seafood (µSv y^{-1}) – Stage 3

	Ingestion of seafood dose (average rate) (µSv y^{-1})	Terrestrial pathways dose (µSv y^{-1})	Total dose (µSv y^{-1})
Adult	1.9E+00	4.0E+00	5.9E+00
Child	1.2E+00	4.4E+00	5.6E+00
Infant	1.0E+00	7.8E+00	8.8E+00

For the <u>terrestrial members of the public consuming also seafood</u>, the doses to adults, children and infants are respectively 5.9, 5.6 and 8.8 µSv y^{-1}.

Infants receive the greatest dose of the three age groups; this is dominated by the ingestion of carbon-14 in milk (55%), root vegetables (15%) and fish (11%), as shown in Annex 3 - Table J.

1.3.4.2. Marine members of public also consuming terrestrial foodstuffs

a) Assessment methodology

It is considered that the marine members of the public could potentially consume locally grown products. It is assumed that up to 50% of the terrestrial foods consumed is locally sourced, and that all foods are ingested at average rates [Ref-1].

It is assumed that these individuals are not exposed to the plume (inhalation and external exposition) and to the deposited radionuclides from atmospheric discharges.

Their marine habits and doses are as described in section 1.3.3 above.

The dose received from the ingestion of locally produced terrestrial foods is assessed:

- assuming dispersion, as detailed in the Sub-chapter 11.1 - Table 7 above;
- assuming a fraction of food locally produced equal to 0.5; and
- average ingestion rates as detailed in the Sub-chapter 11.1 - Table 9 above.

b) Results

The doses received from the ingestion of locally produced terrestrial foods are assessed using the PLUME and ASSESSOR modules of PC CREAM 98.

The doses to adults, children and infants from each pathway are presented in the table below (Sub-chapter 11.1 - Table 16) (See Annex 3 - Tables K, L and M for more details: annual doses for all discharged radionuclides from each pathway and each age group).

Sub-chapter 11.1 - Table 16: Annual dose to the marine members of the public also consuming terrestrial food (µSv y^{-1}) – Stage 3

	Ingestion of terrestrial food dose (average rate) (µSv y^{-1})	Marine pathways dose (µSv y^{-1})	Total dose (µSv y^{-1})
Adult	1.4E+00	1.7E+01	1.8E+01
Child	1.6E+00	4.7E+00	6.3E+00
Infant	2.3E+00	1.5E+00	3.8E+00

For the <u>marine members of the public consuming also terrestrial food</u>, the doses to adults, children and infants are respectively 18, 6.3 and 3.8 µSv y^{-1}.

Adults receive the greatest dose of the three age groups; this is dominated by the ingestion of carbon-14 in fish (55%) crustacea (11%), and mollusca (11%), as shown in Annex 3 - Tables E and K.

1.3.4.3. Local resident

It is assumed that a family (adults, children and infants) living in the nearest habitation (500 m) is exposed to atmospheric discharges and to liquid discharges in the marine environment. So, the dose to the most exposed members of the public from aerial discharges is summed together with the dose to the most exposed members of the public from liquid discharges. It is a conservative assumption. The inputs to this section are the results from sections 1.3.2 and 1.3.3 above.

The doses to adults, children and infants from all pathways and radionuclides are presented in the table below (Sub-chapter 11.1 Table 17).

Sub-chapter 11.1 - Table 17: Annual dose to the local resident (µSv y^{-1}) – Stage 3

	Fishing family (µSv y^{-1})	Farming family (µSv y^{-1})	Local resident (µSv y^{-1})
Adult	1.7E+01	4.0E+00	2.1E+01
Child	4.7E+00	4.4E+00	9.1E+00
Infant	1.5E+00	7.8E+00	9.3E+00

For the <u>local resident</u>, the doses to adults, children and infants are respectively 21, 9.1 and 9.3 µSv y^{-1}.

1.3.5. Annual dose from direct radiation to the most exposed members of the public

1.3.5.1. Methodology and inputs

Direct exposure to radiation from the Reactor Building for members of the public will be negligible, as the shielding present will ensure contact dose rates with the building are below limits of detection, and would definitely not be measurable at the site boundary. Exposure to direct radiation from waste stores will give the greatest direct radiation dose for a member of the public. 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 members of the public to determine the annual dose for this person.

As measurement data is not available in this instance, it is proposed that a basic assessment is carried out with a source term based on expected building shielding and an estimated building to site boundary distance to determine the likely dose rate at the receptor point.

The receptor point which is considered corresponds to the most exposed member's location which is located 500 m from the site. This location corresponds to the most exposed persons for atmospheric discharges location. As these members live in the vicinity of the site (500 m), they will be exposed to direct radiation.

As the outside of any building of the facility is an undesignated area, the public dose limit of 1 mSv y^{-1} is appropriate for estimating the maximum dose rate at the outside of the buildings. As this dose limit is based on a 2000 hour working year, this equates to a dose rate of 0.5 µSv h^{-1} [9]. For simplicity, this dose rate is assumed to be at a distance of 1 m from the outer wall of a building. The dose rate at a receptor point can be estimated using a 1/r relationship[10].

The outdoors dose rate at the terrestrial most exposed members location is equal to 0.001 µSv h^{-1} as detailed below:

$$D = \frac{0.5\mu Svh^{-1}}{500m} = 0.001\mu Sv\ h^{-1}$$

In order to calculate any direct radiation dose to these persons, an assessment of the shielding effect of their homes from external radiation would need to be carried out. For this assessment, it is reasonable to use characteristic location factors for typical UK housing. A location factor is the ratio between the dose rate measurable indoors to outdoors. As recommended in the IRA methodology ([Ref-1] - Table D1), a location factor of 0.1 is appropriate in this situation[11].

The total 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.

$$Dose = D \times \left(LF_i \times O_i + LF_o \times O_o \right)$$

Where: D = the dose rate at the terrestrial most exposed members location (µSv h^{-1});

$LF_{i,o}$ = the indoors and outdoors location factor;

O_i = the indoors occupancy (h y^{-1}); and

O_o = the outdoors occupancy (h y^{-1}).

The indoors (respectively outdoors) occupancy are determined by multiplying the fraction of time indoors (respectively outdoors) with the occupancy. These parameters are presented in Sub-chapter 11.1 - Table 8. The fraction of time indoors depends on the age group which is considered (adult, child and infant).

9 This approach enables to give more conservative results than the approach presented in the Stage 1 which is based on a maximum dose rate at the outside of the building of 1 mSv y^{-1}.

10 A $1/r^2$ relationship could also be used. The 1/r relationship is more conservative.

11 According to RP72, the gamma dose rate indoors from deposited activity is estimated to be about 0.1 of the dose rate outdoors in a rural environment for the same deposition density on soil.

1.3.5.2. Results

Assuming that the nearest habitation is 500 m from the building, the predicted doses from direct radiation for the terrestrial critical members are as follows:

- For adult

  According to Sub-chapter 11.1 - Table 8, adults are assumed to spend 50% of their time each year outdoors working on the land adjacent to the site. The predicted dose is equal to 4.8 µSv y^{-1} as described below:

$$Dose = D \times \left(LF_i \times O_i + LF_o \times O_o\right) = 0.001 \times \left(0.1 \times 4380 + 1 \times 4380\right) = 4.8 \mu Sv\ y^{-1}$$

- For child

  According to Sub-chapter 11.1 - Table 8, children are assumed to spend 20% of their time outdoors. The predicted dose is equal to 2.5 µSv y^{-1} as described below:

$$Dose = D \times \left(LF_i \times O_i + LF_o \times O_o\right) = 0.001 \times \left(0.1 \times 7008 + 1 \times 1752\right) = 2.5 \mu Sv\ y^{-1}$$

- For infant

  According to Sub-chapter 11.1 - Table 8, infants are assumed to spend 10% of their time outdoors. The predicted dose is equal to 1.7 µSv y^{-1} as described below:

$$Dose = D \times \left(LF_i \times O_i + LF_o \times O_o\right) = 0.001 \times \left(0.1 \times 7884 + 1 \times 876\right) = 1.7 \mu Sv\ y^{-1}$$

  The results are summarised in the following table (Sub-chapter 11.1 - Table 18):

Sub-chapter 11.1 - Table 18: Direct radiation (µSv y^{-1}) – Stage 3

	Adult	Child	Infant
Annual dose to the most exposed members from direct radiation (µSv y^{-1})	4.8	2.5	1.7

1.3.5.3. Discussion

The maximum predicted exposure due to direct radiation is about 5 µSv y^{-1} incurred by a critical group Adult living 500 m from building. This may be compared with the typical background radiation of about 700 µSv y^{-1} from natural cosmic and terrestrial sources [Ref-1].

1.3.6. Annual dose to the critical group for the facility

It is assumed that the most exposed members of the public from all discharges are also exposed to the direct radiation. The conservative assessment is obtained by summing the dose to the local resident with the direct radiation. Therefore the inputs to this section are the results from sections 1.3.4.3 and 1.3.5 above.

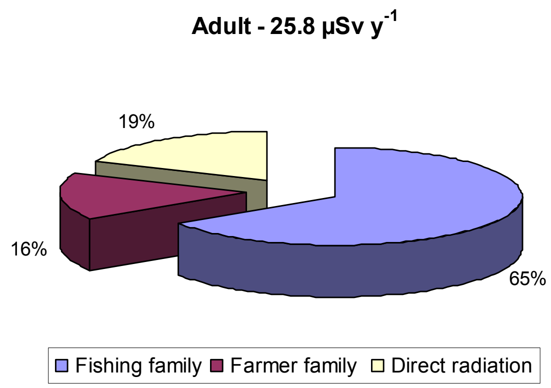
The doses to adults, children and infants from all pathways and radionuclides are presented in the table below (Sub-chapter 11.1 - Table 19).

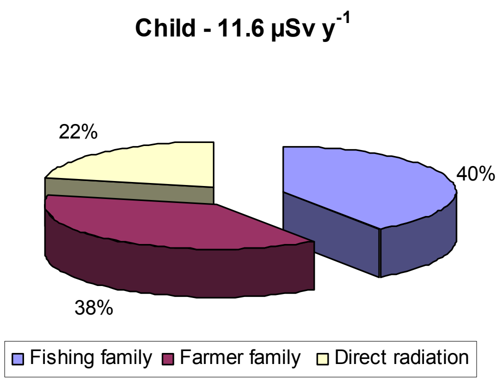
Sub-chapter 11.1 - Table 19: Annual dose to the critical group (μSv y^{-1}) – Stage 3

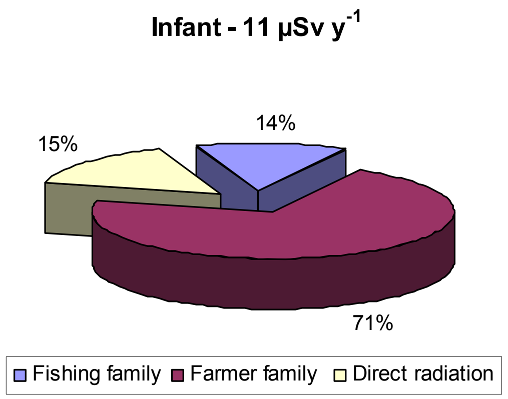
	Local resident (μSv y^{-1})	Direct radiation (μSv y^{-1})	Critical group (μSv y^{-1})
Adult	2.1E+01	4.8E+00	2.58E+01
Child	9.1E+00	2.5E+00	1.16E+01
Infant	9.3E+00	1.7E+00	1.10E+01

The pie charts below (Sub-chapter 11.1 - Figure 5) show the dose to the critical group by pathway.

Sub-chapter 11.1 - Figure 5: Distribution for each exposure pathway of total dose to the critical group – Stage 3







For the critical group, the doses to adults, children and infants are 25.8, 11.6 and 11 μSv y^{-1} respectively.

The food intake of the adult critical group with critical ingestion rates for seafood, milk and root vegetables is highly conservative and improbable. Moreover the parameters used for this assessment are often conservative for potential EPR UK sites which lead to a total dose slightly higher than the threshold of 20 μSv y^{-1}.

1.3.7. Conclusion

The highest total dose is 25.8 μSv y^{-1} to an adult of the critical group. As presented previously, this dose is only a little higher than the threshold of 20 μSv y^{-1}, because most of the parameters used for this assessment are conservative. The results above demonstrate that the limits proposed will ensure compliance with the dose limit for members of public (1000 μSv y^{-1}) and the government's dose constraint[12] (300 μSv y^{-1}). It should be remembered that we are all exposed to an average radiation dose of 2700 μSv y^{-1} [Ref-1].

[12] In its advice on UK application of ICRP's new recommendations on radiological protection, the UK Health Protection Agency (HPA) proposes that for new nuclear power stations this constraint should be reduced to some value less than 150 μSv y^{-1}. As this document is currently a consultation draft, the value of 150 μSv y^{-1} is only given for information.

2. POTENTIAL SHORT-TERM DOSES

This section deals with requirements 2.7 and 2.9 of the EA P&I Document [Ref-1].

The potential short-term doses are only assessed for gaseous discharges. Indeed, liquids are stored in holding tanks prior to being discharged at certain times in the water. Liquid discharges are thus regular short-term discharges which occur repeatedly through the year and are modelled as continuous releases.

For the radiological impact assessment of gaseous discharges, it is normally assumed that discharges occur continuously and uniformly over a year. However, during normal operations, short-term gaseous discharges can occur during, for example, outages and start-up or when purging the cooling system. It is possible that such short-term discharges may lead to doses that are higher (or indeed, lower) than would be expected if it were assumed that the discharges are continuous over a year. The IRA methodology based on DPUR values, and PC CREAM are not appropriate for short-term elevated discharges because these methods are simplified for continuous releases.

2.1. ASSESSMENT METHODOLOGY

Potential short-term doses, including via the food chain are calculated for a local critical group based on the methods described in NRPB W54 [Ref-1]. ADMS [Ref-2] is used to model the dispersion of the aerial discharges assuming a single weather stability category and calculating dispersion assuming either no rain or rain showers.

The dynamic food chain models described in FARMLAND (NRPB R-273) [Ref-3] and RP-72 [Ref-4] are used to determine doses from the ingestion of foodstuffs in the year following the release for all radionuclides except for tritium (H-3) and carbon-14 (C-14) (see section 2.5.1), the fruit model is described in NRPB-W46 [Ref-5]. The compartment modelling software ModelMaker4 (Modelkinetix) is used to replicate the FARMLAND models. Transfer and intake rates for animals and crops are taken from RP-72.

The pathways of exposure and the exposure times which are considered to assess the short-term impact are the following:

- Ingestion of foodstuffs: the associated dose is calculated in the year following the short-term release;
- Inhalation and external irradiation from the plume: the associated doses are calculated for the period of the passage of the plume; and
- External irradiation from deposited radionuclides: the associated dose is calculated for the year following the release.

2.2. SHORT-TERM RELEASE CONSIDERED

The activities considered for the calculation of short-term doses are based on the maximal monthly discharge values from the EPR in normal operation including contingencies.

The activities released during the short-term discharge are the following (Sub-chapter 11.1 - Table 20):

Sub-chapter 11.1 - Table 20: Activity released for the short-term assessment – Potential short-term

Radionuclides	Activity released (Bq)
H-3	3.00E+11
C-14	1.00E+11
Kr-85	6.95E+11
Xe-133	3.16E+12
Xe-135	9.90E+11
Ar-41	1.45E+11
Xe-131m	1.50E+10
I-131	1.82E+08
I-133	2.18E+08
Co-58	4.34E+07
Co-60	5.12E+07
Cs-134	3.98E+07
Cs-137	3.57E+07

A 24 hour release scenario for the discharge of these activities is chosen as it is considered to be conservative enough and to provide bounding estimates for the calculation of short-term doses.

The release rates during the 24 hour discharge are the following (Sub-chapter 11.1 - Table 21):

Sub-chapter 11.1 - Table 21: Release rates for the short-term assessment – Potential short-term

Radionuclides	Release rates ($Bq\ s^{-1}$)
H-3	3.47E+06
C-14	1.16E+06
Kr-85	8.04E+06
Xe-133	3.65E+07
Xe-135	1.15E+07
Ar-41	1.68E+06
Xe-131m	1.74E+05
I-131	2.11E+03
I-133	2.52E+03
Co-58	5.02E+02
Co-60	5.92E+02
Cs-134	4.60E+02
Cs-137	4.13E+02

2.3. DEFINITION OF REPRESENTATIVE SITE PARAMETERS FOR SHORT-TERM DISCHARGE

The representative site parameters which are retained for the short-term doses assessment are presented in the three following tables:

- Sub-chapter 11.1 - Table 22 presents the parameters which are the same as the ones used for the annual doses assessment.

Sub-chapter 11.1 - Table 22: Principal parameters – Potential short-term

Parameters	Values
Receptor point (m)	500
Deposition velocity (m s^{-1})	1 x 10^{-3} (others), 1 x 10^{-2} (Iodine isotopes), 0 (Noble gases)
Washout coefficient (s^{-1}) for rain assessment	1 x 10^{-4}
Surface roughness (m)	0.3
Location factor cloud gamma– indoors occupancy	0.2
Location factor cloud gamma– outdoors occupancy	1
Location factor deposited gamma – indoors occupancy	0.1
Location factor deposited gamma – outdoors occupancy	1
Fraction of food locally produced	0.5, 1 for 'Top Two'
Occupancy terrestrial adult (h y^{-1})	8760
Occupancy terrestrial child (h y^{-1})	8760
Occupancy terrestrial infant (h y^{-1})	8760
Fraction of time indoors terrestrial adult – outdoor worker	0.5
Fraction of time indoors terrestrial child – 5-10 y old	0.8
Fraction of time indoors terrestrial infant	0.9
Ingestion rates	As given in Sub-chapter 11.1 - Table 9

- Sub-chapter 11.1 - Table 23 presents the parameters representative for an EPR unit.

Sub-chapter 11.1 - Table 23: Representative parameters for an EPR unit – Potential short-term

Parameters	Values
Stack height (m)	60
Building dimensions (m)	60 x 60 x 60
Exit velocity (m s^{-1})	7
Exit temperature of plume	ambient
Stack diameter (m)	2.5

The stack height assumed is 60 m. Indeed, ADMS is used to characterise the atmospheric dispersion. As ADMS enables to take into account the buildings, the Reactor Building is specified in ADMS. The effect of this building upon the height of the plume is consequently evaluated by ADMS.

- Sub-chapter 11.1 - Table 24 presents the parameters which are specific to a short-term dose assessment.

Sub-chapter 11.1 - Table 24: Specific short-term dose parameters – Potential short-term

Parameters	Values
Date of release	1st July
Discharge period (h)	24
Pasquill stability category	D
Wind speed (m s^{-1})	5 (measured at 10 m)
Boundary layer depth (m)	800
Windrose	towards receptor
Wind angle	σ_θ
Breathing rate terrestrial adult m^3 h^{-1} – indoors	0.48
Breathing rate terrestrial child m^3 h^{-1} – indoors	0.58
Breathing rate terrestrial infant m^3 h^{-1} – indoors	0.21
Breathing rate terrestrial adult m^3 h^{-1} – outdoors	1.75
Breathing rate terrestrial child m^3 h^{-1} – outdoors	0.87
Breathing rate terrestrial infant m^3 h^{-1} – outdoors	0.31

The release is assumed to occur on 1st July. Indeed, time of year is especially important for the ingestion pathway because agricultural practices change depending on the season, and the foods that are available also differ. For example, potatoes are either early crop varieties that are immediately consumed, or main crop varieties which are both immediately consumed or stored for later consumption. For a third of the year, there are no potatoes in the ground to be contaminated. To take these factors into account, the methodology will model a summer release assumed to occur on 1st July, as this will be the most conservative for all foodstuffs.

The breathing rates are issued from NRPB W41 [Ref-1] and ICRP 66 [Ref-2]. For each age group, they are calculated as explained below:

- For the adult

  An adult spends 12 hours per day outdoors (which is based on the indoors fraction of 0.5). For 2 hours per day, the adult breathes at the heavy work breathing rate of 3 m^3 h^{-1}, and for the remaining 10 hours outdoors per day, he breathes at the light work breathing rate of 1.5 m^3 h^{-1}. Therefore, the average outdoors breathing rate is 1.75 m^3 h^{-1}.

An adult spends 12 hours per day indoors. For 4 hours per day, the adult is indoors at rest with a resting breathing rate of 0.54 $m^3 h^{-1}$, and for the remaining 8 hours per day, he sleeps with a sleeping breathing rate of 0.45 $m^3 h^{-1}$. Therefore, the average indoors breathing rate is 0.48 $m^3 h^{-1}$.

- For the child

  A child spends 4.8 hours per day outdoors (which is based on the indoors fraction of 0.8). For 4.8 hours per day, the child breathes at the general breathing rate of 0.87 $m^3 h^{-1}$.

  A child spends 19.2 hours per day indoors. For 9.2 hours per day, the child breathes at the child general breathing rate of 0.87 $m^3 h^{-1}$ and for the remaining 10 hours per day, he sleeps at the sleeping breathing rate of 0.31 $m^3 h^{-1}$. Therefore, the average indoors breathing rate is 0.58 $m^3 h^{-1}$.

- For the infant

  An infant spends 2.4 hours per day outdoors (which is based on the indoors fraction of 0.9). For 2.4 hours per day, the infant breathes at the infant general breathing rate of 0.31 $m^3 h^{-1}$.

  An infant spends 21.6 hours per day indoors. For 7.6 hours per day, the infant breathes at the infant general breathing rate of 0.31 $m^3 h^{-1}$ and for the remaining 14 hours per day, he sleeps at the infant sleeping breathing rate of 0.15 $m^3 h^{-1}$. Therefore, the average indoors breathing rate is 0.21 $m^3 h^{-1}$.

The meteorological parameters required by ADMS to characterise the dispersion of the plume (wind speed, boundary layer depth, windrose and wind angle) are justified below.

2.4. ATMOSPHERIC DISPERSION

2.4.1. Parameters

The ADMS 4 model is used to model the dispersion of this short-term release assuming a single weather stability category D during the 24 hour short-term release. This assumption is acceptable as the category D is the stability category for much of coastal UK for 70% of the year. This weather condition is characterised by a wind speed of 5 m s^{-1} (measured at 10 m) and a boundary layer depth of 800 m[13].

Moreover, for a 24 hour short-term release, the wind direction could reasonably vary considerably. In order to take into account this variation in the wind direction and also the turbulence phenomena which happen during short-term releases, a wind angle (which corresponds to σ_θ) is calculated and entered in the meteorological condition in ADMS[14]. It is assumed that this wind angle is sufficient to characterise the meandering effects explained above. The calculation of this parameter is explained in Annex 4 and its value for a 24 hour release is 21.7 degrees.

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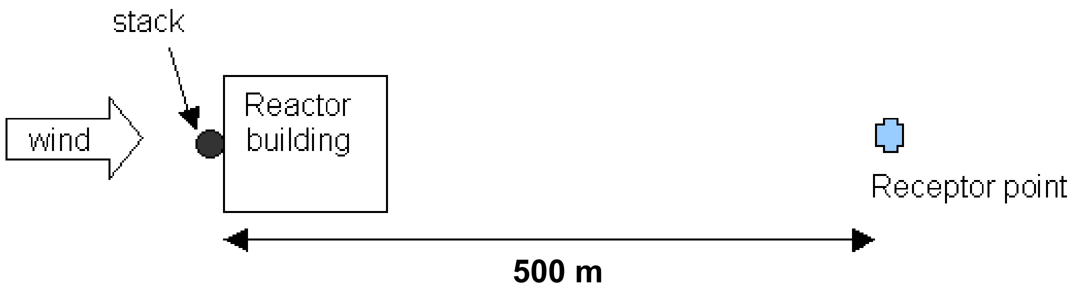
[13] See table 2 in NRPB-R91.

[14] Only one meteorological condition is entered in ADMS and the integration time considered for the calculation is equal to one hour.

The stack height taken into account is 60 m. The stack is assumed to be on the side of the Reactor Building, and the receptor location in line with this is 500 m from the stack (see Sub-chapter 11.1 - Figure 6). Activity concentrations, at a receptor location of 500 m from the release point, are calculated for unit releases for a stack located upwind and downwind of the Reactor Building. It is determined that air and ground level concentrations are marginally higher for an upwind stack. Building effects are also taken into account within ADMS. Building effects increase the plume width.

Sub-chapter 11.1 - Figure 6: Position of the stack and receptor point in relation to the Reactor Building – Potential short-term



2.4.2. Results

The airborne and ground concentrations at 500 m upwind for a 24 hour short-term release at 1 Bq s^{-1} for each radionuclide are presented below (see Sub-chapter 11.1 - Table 25).

Sub-chapter 11.1 - Table 25: Airborne and ground concentrations results – Potential short-term

Radionuclides	Air concentration (Bq m^{-3})	Ground Concentration – Dry deposition (Bq m^{-2} s^{-1})	Ground Concentration – Wet deposition (Bq m^{-2} s^{-1})	Ground Concentration – Total deposition (Bq m^{-2} s^{-1})
Ar-41	2.26×10^{-6}	0.00×10^{0}	0.00×10^{0}	0.00×10^{0}
C-14	2.26×10^{-6}	0.00×10^{0}	0.00×10^{0}	0.00×10^{0}
Co-58	2.25×10^{-6}	2.25×10^{-9}	2.58×10^{-8}	2.81×10^{-8}
Co-60	2.25×10^{-6}	2.25×10^{-9}	2.58×10^{-8}	2.81×10^{-8}
Cs-134	2.25×10^{-6}	2.25×10^{-9}	2.58×10^{-8}	2.81×10^{-8}
Cs-137	2.25×10^{-6}	2.25×10^{-9}	2.58×10^{-8}	2.81×10^{-8}
H-3	2.26×10^{-6}	0.00×10^{0}	0.00×10^{0}	0.00×10^{0}
I-131	2.15×10^{-6}	2.15×10^{-8}	2.58×10^{-8}	4.73×10^{-8}
I-133	2.15×10^{-6}	2.15×10^{-8}	2.58×10^{-8}	4.73×10^{-8}
Kr-85	2.26×10^{-6}	0.00×10^{0}	0.00×10^{0}	0.00×10^{0}
Xe-131m	2.26×10^{-6}	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$
Xe-133	2.26×10^{-6}	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$
Xe-135	2.26×10^{-6}	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$

As it is not possible to have 100% wet deposition together with 100% dry deposition, the ground concentration which is considered in the short-term calculations is the one linked to the limited deposition pathway which is the wet deposition.

2.5. INGESTION DOSE MODELLING

2.5.1. Methodology

Dose to the critical group from ingestion of contaminated foodstuffs is considered from 1st July – 30th June following a release on 1st July. The following assumptions are made:

- Cow models

  For the cow model three periods are considered:

  - Graze pasture 1st July – 31st October;
  - Eat contaminated silage or hay 1st November – 15th April; and
  - Graze pasture 15th April – 30th June.

  When a deposit occurs in July, the peak concentration in milk will occur a few days after the deposit and then the concentrations decline owing to the loss of surface contamination on the pasture.

  Cows leave the pasture for winter and are fed with contaminated hay or silage (harvested throughout the summer). During this time the concentration in the milk increases to just below the peak activity as a result of eating feed contaminated to a higher level than that remaining on the ground. The cows return to pasture in April and the concentration in the milk decreases again until July. The influence of winter feed is more marked when deposition occurs during the summer as the grass is cut soon after deposition. Due to this effect the concentration in the milk over the year is taken to be equal to the peak concentration (that occurs days after deposition) for the entire year, taking into account radioactive decay.

  For meat, similar features in the concentration as a function of time can be seen. Peak concentration is assumed to remain constant for the remainder of the year, except for radioactive decay. The meat is consumed over this time with an activity concentration of the meat, averaged over this period.

  For caesium, iodine and cobalt isotopes, the cow model is used to determine the peak activity concentration in the meat due to the two intake pathways: inhalation of the plume and consumption of contaminated pasture. The time integrated concentration is found from:

$$TIC = \frac{AC\,x\,(1-e^{-\lambda t})}{\lambda}$$

  Where: AC = activity concentration Bq kg^{-1};

  λ = radioactive decay constant s^{-1}; and

  t = integration time.

  The time integrated concentration in milk is found by summation of the model output over 365 days. The time integrated concentration is used in the calculation of dose as described in section 2.6.

  A factor to represent the fraction of activity that remains in the foodstuff after processing and preparation is also applied. In the case of milk and cow meat this preparation factor is 1, i.e. no losses due to food processing or preparation are assumed.

Similarly a factor representing the 'top two' approach is applied. For milk this factor is 1, i.e. all milk consumed is assumed to be locally produced. For cow meat a factor of 0.5 is used, i.e. 50% of the cow meat is assumed to be produced locally.

- Green vegetable models

Green vegetables are assumed to be continuously harvested throughout the year. As the growth periods of vegetables vary, the concentration at time of cropping is assumed for a vegetable growing at time of deposition, with uptake from soil and losses to soil and decay for the period since deposition.

For caesium, iodine and cobalt isotopes, the green vegetable model is used to determine the time integrated concentration in green vegetables as a result of deposition of activity from the plume. The time integrated concentration is used in the calculation of dose as described in section 2.6.

A factor to represent the fraction of activity that remains in the foodstuff after processing and preparation is also applied. In the case of green vegetables this preparation factor is 0.2, i.e. 80% of the initial activity is lost due to food processing or preparation [Ref-1].

Similarly a factor representing the 'top two' approach is applied. For green vegetables this factor is 0.5, i.e. 50% of the green vegetables are assumed to be produced locally.

- Root vegetable models

The root vegetable is taken to be potatoes as these are the most consumed root vegetable, the activity concentration in all root vegetables consumed will thus be that calculated for potatoes.

For the root vegetables model four periods are considered:

- o Harvesting for consumption 1st July – 1st August;
- o Harvesting for consumption and storage 1st August – 15th November;
- o Planted 1st February; and
- o Harvested for consumption 15th June – 30th June.

For modelling purposes the model is run for 32 days. During the 32 days (1st July – 1st August) some potato products are harvested and consumed, having a concentration equal to that of a potato growing at the time of deposition, with uptake from the soil and losses to the soil and decay for the period since deposition.

The concentration at day 32 (1st August) is recorded and any potatoes consumed from 1st August – 14th June (day 348) have this activity minus losses as a result of radioactive decay.

The activity in soil on 1st February (day 216) is noted. The model is then re-run with soil input activity equal to this value (no external plant contamination as a result of deposition) and results for days 349 – 365 (corresponding to 5th June – 30th June) taken to be the activity concentration in the second potato crop. The activity concentration in the tubers is taken for the ingestion dose assessment, i.e. the activity in the remainder of the plant is ignored once the crop is harvested.

For caesium, iodine and cobalt isotopes, the root vegetable model is used to determine the time integrated concentration in root vegetables as a result of deposition of activity from the plume. The time integrated concentration is used in the calculation of dose as described in section 2.6.

A factor to represent the fraction of activity that remains in the foodstuff after processing and preparation is also applied. In the case of root vegetables this preparation factor is 1.0, i.e. no losses of the initial activity due to food processing or preparation are assumed [Ref-1].

Similarly a factor representing the ‘top two’ approach is applied. For root vegetables this factor is 1.0, i.e. all of the root vegetables are assumed to be produced locally.

- Fruit model

The fruit is assumed to be apples as woody trees are dominant in UK fruit production and these fruits are in the growth stage at the time of the discharge.

For the fruit model four periods are considered:

  - Growing 1st July – 15th September;
  - Harvest 15th September;
  - No fruit 15th September – 15th April; and
  - Growing 15th April – 30th June.

Deposition occurs during the fruit growing season. The concentration in the fruit at day 77 (15th September) is recorded. This value is the concentration assumed for the remainder of the year (15th September – 30th June) taking into account radioactive decay (assuming apples are made into apple products or frozen, therefore eaten all year round). No preparation losses are taken into account.

For caesium, iodine and cobalt isotopes, the fruit model is used to determine the time integrated concentration in fruit as a result of deposition of activity from the plume. The time integrated concentration is used in the calculation of dose as described in section 2.6.

Similarly a factor representing the ‘top two’ approach is applied. For fruit this factor is 0.5, i.e. 50% of the fruit consumed is assumed to be produced locally.

- Sheep model

For sheep model, it is considered that sheep graze all year round.

The activity in meat is averaged over the period between the peak concentration and 30th June to allow for slaughter and consumption at any time in the first year.

For caesium, iodine and cobalt isotopes, the sheep model is used to determine the time integrated concentration in sheep meat as a result of inhalation of the plume and ingestion of contaminated pasture in a similar manner as described for cow meat, above. The time integrated concentration is used in the calculation of dose as described in section 2.6.

A factor to represent the fraction of activity that remains in the foodstuff after processing and preparation is also applied. In the case of sheep meat this preparation factor is 1, i.e. no losses due to food processing or preparation are assumed.

Similarly a factor representing the ‘top two’ approach is applied. For sheep meat a factor of 0.5 is used, i.e. 50% of the sheep meat is assumed to be produced locally.

- Tritium and carbon-14

  For tritium (H-3) and carbon-14 (C-14), a specific activity approach is adopted for calculating the activity concentrations in foodstuffs. It is assumed that all foodstuffs come into rapid equilibrium with atmospheric tritium and carbon-14. The specific activity of each element in the food is equal to the atmospheric concentration. The concentration in food is therefore calculated using the following formula:

$$C_{food} = C_{plume} \times F$$

  Where F is a conversion factor (in Bq kg^{-1} per Bq m^{-3}) relating the airborne concentration of the radionuclide in the plume at the point of interest to the concentration of the radionuclide in foodstuffs produced at that point. These factors are given in the EA Initial Radiological Assessment Methodology Part 2 [Ref-2] (see Sub-chapter 11.1 - Table 26).

Sub-chapter 11.1 - Table 26: Conversion factors for foodstuffs for H-3 and C-14 – Potential short-term

Foodstuffs	Conversion factor (Bq kg^{-1} per Bq m^{-3})	
	H-3	C-14
Green vegetables	112.5	267
Root vegetables	100	533
Fruit	100	533
Cow milk	112.5	267
Cow and sheep meat	87.5	800

The conversion factor F is for calculation of activity in foodstuffs due to a continuous release where the foodstuffs is in equilibrium with the activity in the air. Therefore to account for the short transient duration of the release a time factor is applied to modify the concentration factor F. The Time Factor, TF, is the release duration divided by the number of hours per year, i.e. 24/8766 = 2.74 x 10^{-3}.

2.5.2. Results

The time integrated activity concentration in each of the foodstuffs is calculated from the ModelMaker4 outputs based on the information discussed above together with data on product yields per area of land.

The ModelMaker results are presented in Annex 4 - Table A. For animals foodstuffs, the model is run twice, for ingestion of activity by the animal and inhalation of activity. Two time integrated activity concentrations are thus calculated for milk, cow meat and sheep meat.

2.6. DOSE CALCULATIONS

The formula used to assess short-term doses is presented below. Most of the parameters are those described in the section 2.3, ADMS results are also used in these formulas.

The dose coefficients for inhalation and ingestion are the same as the ones used for the annual dose assessment (see Annex 3 - Table A). The dose coefficients for the external exposure are presented in Annex 4 - Table B.

- Ingestion

For cobalt, iodine and caesium isotopes in the atmosphere, the dose due to ingestion of a foodstuff is calculated using the following formula:

$$Dose_{ing_n} = C_n \, x TIC_f \times PF_f \times ING_f \times DC_n$$

Where: C_n = the atmospheric concentration of radionuclide n, Bq m^{-3}: this data is a result from ADMS;

TIC_f = the time integrated activity concentration in the foodstuff f (Bq kg^{-1} y per Bq m^{-3});

PF_f = the preparation factor for foodstuff f;

ING_f = is the ingestion rate of foodstuff f (kg y^{-1} or l y^{-1}); and

DC_n = the dose coefficient for ingestion for radionuclide n (Sv Bq^{-1}).

For cobalt, iodine and caesium isotopes deposited on the ground, the dose due to ingestion of a foodstuff is calculated using the following formula:

$$Dose_{ing_n} = SC_n \, x TIC_f \times PF_f \times ING_f \times DC_n$$

Where: SC_n = the surface contamination of radionuclide n, Bq m^{-2}, this data is a result from ADMS;

TIC_f = the time integrated activity concentration in the foodstuff f (Bq kg^{-1} y per Bq m^{-2});

PF_f = the preparation factor for foodstuff f;

ING_f = the ingestion rate of foodstuff f (kg y^{-1} or l y^{-1}); and

DC_n = the dose coefficient for ingestion for radionuclide n (Sv Bq^{-1}).

For tritium and carbon-14, the dose from ingestion of a foodstuff is calculated using the following formula:

$$Dose_{ing_n} = AC \times PF \times ING \times DC_n$$

Where: AC = the activity concentration in the foodstuff (Bq kg^{-1} or Bq l^{-1});

PF = the preparation factor;

ING = the ingestion rate (kg y^{-1} or l y^{-1}); and

DC_n = the dose coefficient for ingestion for radionuclide n (Sv Bq^{-1}).

- Inhalation

Whilst the critical group are indoors, the building will provide a degree of protection from the inhalation of depositing radionuclides. The indoor occupancy reduction factor (RF) is 0.5 for depositing radionuclides. There is no reduction for non-depositing radionuclides. Iodine, cobalt and caesium isotopes are depositing radionuclides. Tritium, carbon-14 and noble gases are not assumed to deposit.

Inhalation dose is calculated using the following formula:

$$Dose_{inh_n} = AirC \times DC_{inh_n} \times \left(\left(INH_{in} \times T_{in} \times RF \right) + \left(INH_{out} \times T_{out} \right) \right)$$

Where: AirC = the activity concentration in air during passage of the cloud (Bq m^{-3}) (this data is a result from ADMS);

$INH_{in,out}$ = the indoors or outdoors breathing rate (m^3 h^{-1});

$T_{in,out}$ = the indoors or outdoors exposure time (h);

DC_{inhn} = the dose coefficient for inhalation for radionuclide n (Sv Bq^{-1}); and

RF = the indoor occupancy reduction factor.

- External dose from the plume

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

$$Dose_{cloud\,n} = AirC \times T \times DC_{cloud} \times (LF_{cloud_i} \times O_i + LF_{cloud\,o} \times O_o)$$

Where: T = the exposure time (24 h);

DC_{cloud} = the dose coefficient for submersion in a plume of radionuclides n (Sv s^{-1} per Bq m^{-3});

$LF_{cloud\ i,o}$ = the location factor for plume radioactivity for indoors and outdoors occupancy; and

$O_{i,o}$ = the occupancy factor for indoors and outdoors occupancy.

- External dose from deposited radioactivity

External dose from exposure to deposited radioactivity during the year following the short-term release is calculated using the following formula:

$$Dose_{dep\,n} = \left(\frac{1 - e^{-\lambda_n t}}{\lambda_n} \right) GC \times DC_{dep} \times (LF_i \times O_i + LF_o \times O_o)$$

Where: GC = the ground concentration following deposition (Bq m^{-2}) (this data is a result from ADMS);

DC_{dep} = the dose coefficient for ground deposition of radionuclide n (Sv s^{-1}per Bq m^{-2});

λ_n = the radioactive decay constant for radionuclide n (s^{-1});

t = the exposure time for deposited radiation (s);

$LF_{i,o}$ = the location factor for deposited radioactivity for indoors and outdoors occupancy; and

$O_{i,o}$ = the occupancy factor for indoors and outdoors occupancy.

2.7. RESULTS

The airborne and deposited activity concentrations as calculated by ADMS for a 24 hour release at 1 Bq s^{-1} for each radionuclide at a distance of 500 m from the stack are presented in section 2.4.2 – Sub-chapter 11.1 - Table 25. These results are multiplied by the actual short-term release rates which are presented in the Sub-chapter 11.1 - Table 21. This enables us to obtain the actual airborne and deposited activity concentrations which are used to assess the short-term doses.

The dose to adults, children and infants from all pathways and radionuclides as a result of a single short-term discharge are presented in Annex 4 - Tables C, D and E respectively. The total dose received by each age group is calculated to be 0.86, 0.89 and 1.46 µSv in the year following the release for adults, children and infants respectively assuming all radionuclides are discharged together in the same release.

For the short-term discharges considered here the most important route of exposure for all age groups is ingestion of contaminated foodstuffs, where the ingestion dose contributes 81%, 89% and 95% of the total dose for adults, children and infants respectively. Carbon-14 is the dominant radionuclide for these exposure groups.

The table below (Sub-chapter 11.1 - Table 27) shows for each age group, the contribution to the total short-term dose of each group of radionuclides, and enables a comparison of these short-term results to the total continuous release dose presented in the section 1.3.2 above. Regarding the total short-term impact following a 24 hour release, despite the conservative assumption used which is that all radionuclides are discharged together in the same release, the total short-term dose is less than the total continuous release dose. Moreover, if a specific release scenario is considered for a short-term discharge and results in the release of just one or two groups of radionuclides, it can be seen in the table below (Sub-chapter 11.1 - Table 27), that for all three age groups, multiple short-term releases of the fission and activation products, iodine isotopes, noble gases, or tritium, would produce a dose below the continuous release dose.

Sub-chapter 11.1 - Table 27: Potential short-term doses

	Radionuclide Group	**Effective Dose per discharge (µSv)**		
		24 hour scenario		
		Adult	**Child**	**Infant**
Short-term dose	Fission and activation products	0.144	0.079	0.059
	Iodine isotopes	0.009	0.011	0.023
	Noble gases	0.033	0.020	0.015
	Tritium	0.020	0.022	0.044
	Carbon-14	0.659	0.758	1.32
	Total short-term dose	0.864	0.889	1.46
Annual dose	Total annual dose	4.0	4.4	7.8

3. POTENTIAL BUILD-UP OF RADIONUCLIDES IN THE ENVIRONMENT

3.1. ASSESSMENT METHODOLOGY

This section deals with requirements 2.7 and 2.9 of the EA P&I Document [Ref-1].

At the end of life of the power station, it is necessary to assess the potential build-up of radionuclides, in the local environment of the facility, which might have the potential to prejudice legitimate users or uses of the land and the sea.

The doses associated with this potential build-up can be assessed using the methodology described in NRPB W36 together with contamination levels calculated using PC CREAM 98:

- HPA-RPD report NRPB-W36 [Ref-2] provides a methodology for estimating doses to members of the public from future use of land previously contaminated with radioactivity. This report includes tables of doses per unit contamination for a number of possible use scenarios for the land for a range of radionuclides. Some of these tables will be used to assess the doses associated with the potential build-up of radionuclides by multiplying theses doses per unit contamination with the activity concentrations in soil and seabed sediments.
- Activity concentrations are determined using PC CREAM 98 [Ref-3] after 60 years[15] (60 years of aerial and liquid continuous discharges). The maximum annual gaseous and liquid radioactive discharges of the EPR unit and the spectrums applied for the radionuclides are presented in the Sub-chapter 11.1 - Tables 1 and 2. The programmes DORIS and FARMLAND are used to model the build-up of radionuclides in the environment.

The doses are calculated using the tables of dose per unit contamination of NRPB-W36 and activity concentrations in land and seabed sediments.

The potential build-up of radionuclides in land and seabed sediments are described below.

- Build-up of radionuclides in land

  Regarding the potential build-up of radionuclides in land, activity concentrations in soil only exist for the radionuclides which are likely to be deposited on the soil, which mean: Co-58, Co-60, Cs-134, Cs-137, I-131 and I-133. Activity concentrations in soil are firstly estimated using the FARMLAND model from PC CREAM 98 at year 60. This program calculates activity concentrations based on a unit deposition rate of 1 Bq m^{-2} s^{-1}.

  To obtain the actual activity concentrations in soil, these FARMLAND results must be multiplied by the effective deposition rates which depend on activity concentrations in air. The parameters which are considered to characterise the dispersion in air are those retained for the definition of the site characteristics and described in Sub-chapter 11.1 - Table 7.

[15] The lifetime of the EPR unit considered is 60 years.

The PLUME model cannot be used to determine activity concentrations in air at distances less than 300 m from the discharge point. However, NRPB-R91 ([Ref-4], figure 38), shows that the activity concentration in air at ground level, for an effective stack height of 20 m and 70% category D meteorological conditions, peaks at approximately 200 m. Therefore, the activity concentration in air is determined using NRPB-R91 and has a maximum value at 200 m of 2.5 x 10^{-6} Bq s m^{-3} per unit release. This value can then be multiplied by the actual EPR activity releases rates (Bq s^{-1}) and the deposition velocity of each radionuclide (see Sub-chapter 11.1 - Table 7) to obtain the actual deposition rate for each radionuclide in Bq m^{-2} s^{-1}.

These values can then be multiplied by the FARMLAND results to obtain the actual activity concentrations in soil.

For these radionuclides (which are likely to be deposited on the soil, i.e.: Co-58, Co-60, Cs-134, Cs-137, I-131 and I-133), the dominant scenario for public exposures is construction work during the development of a contaminated site (NRPB-W36, table 47).

- Build-up of radionuclides in seabed sediments

  NRPB-W36 proposes two recreational scenarios relating to the use of water:

  - ‘The swimmer’: someone who swims or has a boat on a lake (external exposure from suspended radionuclides in the water and inadvertent ingestion of water containing suspended radionuclides).

  - ‘The fisherman and his family’: someone who sits on a lakebank that contains contaminated material, and fishes (external exposure from the lakebank and from contaminated soil on the skin, inhalation of contaminated dust, ingestion of fish caught in the contaminated water and ingestion of contaminated soil). The ingestion of fish is also considered for a child and an infant, representing the fisherman’s family.

  These two scenarios are not directly applicable to the situation studied here (radiological liquid discharges into sea) because they consider that a recreational lake has been formed on the contaminated land. Nevertheless, for information, the doses associated with these two scenarios will be presented for the build-up assessment.

To assess the activity concentrations in seabed sediments at year 60, the supporting program DORIS is used. Input data for the parameters (marine module, regional and local compartments) are as defined in Sub-chapter 11.1 - Table 7.

3.2. RESULTS

The potential build-up of radionuclides and dose associated, in land and seabed sediments are described below.

- Build-up of radionuclides in land

  Regarding the potential build-up of radionuclides in land for the radionuclides which are likely to be deposited on the soil, as precised above, activity concentrations in soil are determined using the FARMLAND results and the effective deposition rates:

  - The FARMLAND results, soil concentrations at year 60 for a unit deposition rate, are presented in Annex 5 - Table A; and

- The effective deposition rates are presented in Annex 5 - Table B.

The calculated soil concentrations for the radionuclides Co-58, Co-60, Cs-134, Cs-137, I-131 and I-133 are presented in Annex 5 - Table C.

For the radionuclides which are not likely to be deposited on the soil, the activity concentrations in air are presented in Annex 5 - Table D.

Regarding the doses associated to the potential build-up in land, among the six radionuclides which are considered above, Co-60, Cs-134 and Cs-137 are the only radionuclides included in the NRPB-W36 report. The other three depositing radionuclides, Co-58, I-131 and I-133, are not considered in W36 as their half-lives are short in comparison with the timescales of interest, and can therefore be neglected. These three radionuclides will have decayed within a year. For the three remaining radionuclides, the dominant scenario for public exposures is construction work during the development of a contaminated site (NRPB-W36, table 47).

The doses per unit contamination are evaluated in the NRPB-W36 report for the radionuclides Co-60, Cs-134 and Cs-137, assuming that the contamination is exposed in a uniform spatial distribution.

The dose per unit contamination is then multiplied with the relevant activity concentration in soil at year 60 assessed above. The doses associated to this potential build-up are presented in Annex 5 - Table E.

❖ Build-up of radionuclides in seabed sediments

The doses per unit contamination are evaluated in the NRPB-W36, Table 15 (‘Fisherman and his family’) and Table 17 (‘Swimmers’) for the radionuclides Co-60, Cs-134, Cs-137, H-3, and Ni-63, assuming that the contamination is exposed in a uniform spatial distribution[16].

Co-58, Cr-51, I-131 and Sb-124 are not considered given that their half-lives are short in comparison with the timescales of interest, and can therefore be neglected.

For the others radionuclides (Ag-110m, C-14, Mn-54, Sb-125, Te-123, Te-123m and Te-125), the dose per unit contamination which are considered corresponds to the maximum value presented in the NRPB-W36 report for these two scenarios among all the radionuclides (Co-60).

For each of the radionuclides, the dose per unit contamination is then multiplied with the relevant activity concentration in seabed sediments at year 60. The doses associated to this potential build-up are presented in Annex 5 - Tables F and G.

❖ Dose associated to the build-up of radionuclides in land and seabed sediments

The doses for the future use of the land and, for information, of the local coast are presented in the table below (Sub-chapter 11.1 - Table 28).

[16] It is a conservative hypothesis.

Sub-chapter 11.1 - Table 28: Doses for the future use of the land and of the local coast – Build-up

Scenario	Land	Local coast	
Dose (Sv y^{-1})	8.4E-09	'Swimmers'	'Fisherman and his family'
		1.7E-07	9.1E-06

NRPB-W36 recommends, in its advice on radiological protection objectives for contaminated land, that it is unlikely that significant expenditure to reduce the excess risk to a member of the critical group of site occupants below about 10^{-6} y^{-1} would be warranted on radiological protection grounds. This risk corresponds to a dose of about 20 µSv y^{-1}. This guidance value is a suitable value to use for this application.

The total associated dose are equal to 8.4×10^{-3} µSv y^{-1} for land, 1.7×10^{-1} µSv y^{-1} ('Swimmer') and 9.1 µSv y^{-1} ('Fisherman and his family') for seabed sediments which are far lower than 20 µSv y^{-1} which broadly corresponds to the risk value of 10^{-6} y^{-1}. Consequently, there would be no radiological protection reasons to restrict future use of the land and of the local coast.

4. COLLECTIVE DOSES TO POPULATIONS FOR DISCHARGES FROM THE FACILITY

This section deals with requirements 2.8 and 2.9 of the EA P&I Document [Ref-1].

4.1. ASSESSMENT METHODOLOGY

Collective doses to the populations of UK, Europe and the World, truncated at 500 years, are to be estimated. The collective dose is a measure of the radiation exposure in a population. In simple terms, it is the sum of effective doses from a given practice or situation to all affected individuals, now and in the future. The UK regulatory guidance [Ref-1] states that collective doses should be truncated at 500 years, this approach has been used in this assessment.

The standard method as described in [Ref-2]) is applied by using the PC-CREAM model. Calculations are performed for one year discharge. For the UK and EU collective dose assessments, distances up to respectively 1500 km and 3000 km must be considered in order to cover the geographical areas of interest. In the proposed approach to assess collective doses, EC report Radiation Protection 72 EUR15760 [Ref-2] makes the assumptions that the magnitude of the population of the EC remains constant over the time period of interest, that habits remain the same and that the whole population are adults.

The collective dose contains two contributions: the first pass and the global circulation. The collective dose due to the first pass represents the dose due to exposure to the original discharge: this exposure can continue for many years following its deposition onto the ground or dispersion in the marine environment even after the discharge has stopped. Beyond this first pass, the global circulation contributes to the collective dose. Some radionuclides, due to their high radioactive half-lives and their behaviour in the environment, can also become globally dispersed and act as a long-term source of exposure to both regional and world population. It is possible to distinguish the collective dose due to the initial discharge (the first pass dose) and due to global circulation. The first pass dose is particularly important for UK population while for world population, it only makes a small contribution except in the first few years after the discharges. The contribution from the global circulation of long-lived radionuclides continues to increase for all times considered.

As the site location is an important factor for estimating the dose to the UK population, it is necessary to make some assumptions about the power station location. Among the potential sites where a new EPR reactor could be located, the site which presents the maximum collective dose is presented here. A uniform windrose with a 70% category D (neutral) Pasquill stability distribution is considered as a typical representation of coastal UK sites. Population and agricultural production distribution are provided by the inbuilt database for each site on the PC CREAM 98 database. This provides data on total annual food production in each annular segment of a polar grid centred on the site of interest and extending to cover the area of interest. Individual external and inhalation doses in each annular segment of the polar grid are scaled by the population in that segment. Collective doses from the ingestion of terrestrial foods are calculated as the product of activity concentration in the food, annual production of the food in the element of a grid and the dose coefficient for ingestion, summed over radionuclides and grid elements. It is assumed that someone eats the food, but no information is available on who eats which food. Collective dose is then obtained by summing over all segments.

For the site selected, the dispersion parameters for the liquid and gaseous discharges are described below (Sub-chapter 11.1 - Table 29).

Sub-chapter 11.1 - Table 29: Dispersion parameters for collective dose to UK, European and World populations

Parameters	Values
Collective dose truncated at year	500
Populations of interest	UK, Europe, World
Effective release height (m)	20
Windrose	uniform
Pasquill stability category	70% D
Deposition velocity (m s^{-1})	1×10^{-3} (others), 1×10^{-2} (Iodine isotopes)
Washout coefficient (s^{-1})	1×10^{-4}
Surface roughness (m)	0.3
Marine module	North Sea
Regional compartment	North Sea SW
Local compartment volume (m^3)	3×10^{8}
Local compartment depth (m)	10
Local compartment coastline length (m)	1×10^{4}
Local compartment volumetric exchange rate (m^3 y^{-1})	1.1×10^{10}
Local compartment suspended sediment load (t m^{-3})	8×10^{-5}
Local compartment sediment rate (t m^{-2} y^{-1})	1×10^{-4}
Local compartment sediment density (t m^{-3})	2.6
Local compartment Bioturbation rate (m^2 y^{-1})	3.6×10^{-5}
Local compartment diffusion rate (m^2 y^{-1})	3.15×10^{-2}
Beach occupancy (manh y^{-1} m^{-1})	50

4.2. RESULTS

Collective dose assessments are carried out using the program PC CREAM 98.

The dose to UK, European and World populations from atmospheric and liquid discharges from an EPR site is presented in the table below (Sub-chapter 11.1 - Table 30) (See Annex 6 - Tables A and B for more details: for all discharged radionuclides).

It is possible to obtain an estimation of individual per caput dose from the collective dose, in order to link this calculation with design considerations. The Health Protection Agency (formerly the National Radiological Protection Board) has stated that discharges giving rise to per caput doses of less than a few nanosieverts per year of discharge can be regarded as trivial [Ref-1]. In that case, the design is considered optimised. The population data for UK, Europe and World are assumed to be 55 million, 700 million and 10 billion respectively.

Sub-chapter 11.1 - Table 30: Collective dose to UK, European and World populations

		UK	Europe	World
Dose collective (man Sv)	**Atmospheric discharges**	0.29	2.31	15.80
	Liquid discharges	0.02	0.15	1.10
	Total	0.31	2.46	16.90
Average per caput dose (nSv)		5.6	3.5	1.7

These results based on the 70% Pasquill category D uniform windrose, considered as typical for coastal UK sites, may not represent a bounding assessment but nevertheless gives a reasonable estimate of the collective dose resulting from the discharges from the UK EPR. Note that the non-uniform nature of site-specific meteorological data could lead to higher UK and EU collective doses since the population distribution is not uniform as a function of angular sector around a given site.

The collective dose is the sum of effective doses from a given practice or situation to all affected individuals, now and in the future. Consequently, the collective dose for World is larger than the collective dose for Europe, which in turn is larger than the collective dose for UK.

There is no legal dose limit on collective doses. However, the International Atomic Energy Agency 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. This criterion is that collective dose should be less than about 1 man Sv [Ref-1].

As can be seen in the table above (Sub-chapter 11.1 - Table 30), the collective dose to the UK population, truncated at 500 years from all discharges is much less than 1 man Sv and the collective dose to the European population is around 2 man Sv.

The results in the table above (Sub-chapter 11.1 - Table 30) show that atmospheric discharges are the major contributor to the total dose. As shown in Annex 6 - Tables A and B, the collective dose from atmospheric and liquid discharges is dominated by releases of carbon-14, accounting for almost 100% of the dose for all populations considered. The collective dose to UK (0.31 man Sv), European (2.46 man Sv) and World (16.90 man Sv) populations are much lower than the collective dose from natural carbon-14 to the UK population, estimated as about 480 man Sv [Ref-2].

As can be seen, these results show that the per caput doses are a few nanosieverts. Therefore design could be considered as optimised.

ANNEX 1 – ANNUAL DOSES – STAGE 1

Table A: Farming and Fishing Family Habit Data

	Infant	Child	Adult
Occupancy at habitation (h y^{-1})*	8760	8760	8760
Fraction of time indoors	0.9	0.8	0.5
Cloud gamma shielding factor	0.2	0.2	0.2
Deposited gamma shielding factor	0.1	0.1	0.1
Breathing rates (m^3 y^{-1})	1927.2	5606.4	8059.2
Breathing rates (m^3 h^{-1})	0.22	0.64	0.92
Beach occupancy (h y^{-1})	30	300	2000

* People are assumed to remain at the same location.

Table B: Food Consumption Rates

Food consumption rates (kg y^{-1})	Adult (16-64 years)	Child (10-11 years)	Infant (6-12 months)
Green vegetables	80	35	15
Root vegetables	130	95	45
Fruit	75	50	35
Sheep meat	25	10	3
Offal	20	10	5.5
Cow meat	45	30	10
Milk	240	240	320
Milk products	60	45	45
Eggs	25	20	15
Fish	100	20	5
Crustacea	20	5	0
Mollusca	20	5	0

Table C: Atmospheric dispersion parameters

Parameters	Values
Weather data	uniform windrose 50% Pasquill Stability Category D average wind speed of 4.2 m s^{-1}
Level release	Ground level release
Deposition velocity (m s^{-1})	1 x 10^{-3} (others), 1 x 10^{-2} (Iodine isotopes), 0 (Noble gases)
Washout coefficient (s^{-1})	1 x 10^{-4}, 0 (Noble gases)
Surface roughness factor (m)	0.3 (typical of agricultural and urban areas)
Design nominal flow rate (m^3 h^{-1})	244,290

Table D: Local compartment parameters

Parameters	Values
Volume (m^3)	1 x 10^8
Depth (m)	10
Coastline length (m)	1 x 10^4
Suspended Sediment Load (t m^{-3})	1 x 10^{-5}
Sedimentation rate (t m^{-2} y^{-1})	5 x 10^{-3}
Sediment density (t m^{-3})	2.6
Bioturbation rate (m^2 y^{-1})	3.6 x 10^{-5}
Diffusion rate (m^2 y^{-1})	3.15 x 10^{-2}

Table E: Releases to air – Stage 1

Radionuclides	Discharge (Bq y^{-1})	Total DPUR (µSv y^{-1}per Bq y^{-1})	Dose (µSv y^{-1})	Contribution (%)
H-3	3.00E+12	9.60E-13	2.88E+00	4.0%
C-14	9.00E+11	6.80E-11	6.12E+01	84.1%
Kr-85	3.13E+12	1.30E-14	4.07E-02	0.1%
Xe-133	1.42E+13	*7.00E-14*	9.94E-01	1.4%
Xe-135	4.46E+12	*5.90E-13*	*2.63E+00*	3.6%
Ar-41	6.53E+11	3.20E-12	2.09E+00	2.9%
Xe-131m	6.75E+10	*5.90E-13*	*3.98E-02*	0.1%
I-131	1.82E+08	4.50E-09	8.21E-01	1.1%
I-133	2.18E+08	1.80E-10	3.92E-02	0.1%
Co-58	8.67E+07	3.10E-10	2.69E-02	*
Co-60	1.02E+08	1.20E-08	1.23E+00	1.7%
Cs-134	7.96E+07	4.20E-09	3.34E-01	0.5%
Cs-137	7.14E+07	7.00E-09	5.00E-01	0.7%
		Total Dose (µSv y^{-1})	**72.8**	**100%**

* negligible contribution (< 0.04%)

In the IRA methodology, the DPUR values are not available for Xe-135 and Xe-131m (noble gases). Doses for these two noble gases are estimated by considering the maximum DPUR value among the noble gases which are considered in the initial assessment methodology and which belong to the same radiotoxicity group.

Xe-135 and Xe-131m belong to the fourth radiotoxicity group (weak radiotoxicity). In the IRA methodology, the noble gas which has the maximum total DPUR value and belongs to the fourth group is Kr-79 (the two noble gases which have a higher DPUR value are Rn-222 and Ar-41 but they belong to the third radiotoxicity group – moderate radiotoxicity). The Kr-79 DPUR values are therefore chosen to calculate annual doses from Xe-135 and Xe-131m discharges.

The resulting values are italicised in the table (Annex 1 - Table E) above. It can be noticed that the contribution of these radionuclides to the total annual dose is relatively small (around 4%). So any uncertainties introduced by this simple scaling approach will not affect the estimated total annual dose rates presented in the table.

Table F: Releases to coastal or estuary water – Stage 1

Radionuclides	Discharge (Bq y^{-1})	Total DPUR (µSv y^{-1} per Bq y^{-1})	Dose (µSv y^{-1})	Contribution (%)
Ag-110m	5.70E+08	4.00E-09	2.28E+00	3.8%
Co-58	2.07E+09	6.90E-11	1.43E-01	0.2%
Co-60	3.00E+09	2.80E-09	8.40E+00	14.0%
Cs-134	5.60E+08	1.20E-10	6.72E-02	0.1%
Cs-137	9.45E+08	1.50E-10	1.42E-01	0.2%
Mn-54	2.70E+08	2.30E-10	6.21E-02	0.1%
Sb-124	4.90E+08	*6.80E-09*	*3.33E+00*	5.6%
Te-123m	2.60E+08	*6.80E-09*	*1.77E+00*	3.0%
Ni-63	9.60E+08	3.60E-12	3.46E-03	*
Sb-125	8.15E+08	2.90E-11	2.36E-02	*
Cr-51	6.00E+07	6.00E-13	3.60E-05	*
I-131	5.00E+07	2.50E-12	1.25E-04	*
H-3	7.50E+13	8.90E-16	6.68E-02	0.1%
C-14	9.50E+10	4.60E-10	4.37E+01	72.8%
		Total Dose (µSv y^{-1})	**60.0**	**~100%**

* negligible contribution (< 0.04%)

In the IRA methodology, the DPUR values are not available for Sb-124 and Te-123m. Sb-124 and Te-123m are radionuclides which belong to the third radiotoxicity group (moderate radiotoxicity). In the IRA methodology, the radionuclide which has the maximum DPUR value and belongs to the third group is P-32 (the only radionuclide which has a higher DPUR value is Pb-210 but it belongs to the first radiotoxicity group – very high radiotoxicity). The P-32 DPUR values are therefore chosen to calculate annual doses from Sb-124 and Te-123m discharges.

The resulting values are italicised in the above table (Annex 1 - Table F). It can be noticed that the contribution of these radionuclides to the total annual dose is small (around 9%). So any uncertainties introduced by this simple scaling approach will not affect the estimated total annual dose rates presented in the table.

ANNEX 2 – ANNUAL DOSES – STAGE 2

Table A: Releases to air – Stage 2

Releases to air Exposure group - Local resident family			**Food dose scaling factor**		0.31
			Inhalation and external dose scaling factor		0.04
Radionuclides	**Discharge (Bq y^{-1})**	**Food DPUR (µSv y^{-1} per Bq y^{-1})**	**External DPUR (µSv y^{-1} per Bq y^{-1})**	**Inhalation DPUR (µSv y^{-1} per Bq y^{-1})**	**Dose (µSv y^{-1})**
H-3	3.00E+12	2.70E-13	0.00E+00	6.90E-13	3.34E-01
C-14	9.00E+11	3.30E-11	6.40E-17	3.50E-11	1.05E+01
Kr-85	3.13E+12	0.00E+00	1.30E-14	0.00E+00	1.63E-03
Xe-133	1.42E+13	0.00E+00	7.00E-14	0.00E+00	3.98E-02
Xe-135	4.46E+12	*0.00E+00*	*5.90E-13*	*0.00E+00*	*1.05E-01*
Ar-41	6.53E+11	0.00E+00	3.20E-12	0.00E+00	8.35E-02
Xe-131m	6.75E+10	*0.00E+00*	*5.90E-13*	*0.00E+00*	*1.59E-03*
I-131	1.82E+08	4.10E-09	3.80E-11	3.90E-10	2.35E-01
I-133	2.18E+08	7.20E-11	7.60E-12	9.70E-11	5.77E-03
Co-58	8.67E+07	4.40E-12	2.70E-10	3.60E-11	1.18E-03
Co-60	1.02E+08	5.30E-11	1.10E-08	2.20E-10	4.76E-02
Cs-134	7.96E+07	4.70E-10	3.60E-09	1.50E-10	2.35E-02
Cs-137	7.14E+07	3.80E-10	6.50E-09	1.00E-10	2.73E-02
				Total dose (µSv y^{-1})	**11.4**

Table B: Releases to air - Stage 2 - Doses for each exposure pathway

Radionuclides	**Dose owing to food ingestion (µSv y^{-1})**	**Dose owing to external exposure (µSv y^{-1})**	**Dose owing to Inhalation exposure (µSv y^{-1})**
H-3	2.51E-01	0.00E+00	8.28E-02
C-14	9.21E+00	2.30E-06	1.26E+00
Kr-85	0.00E+00	1.63E-03	0.00E+00
Xe-133	0.00E+00	3.98E-02	0.00E+00
Xe-135	*0.00E+00*	*1.05E-01*	*0.00E+00*
Ar-41	0.00E+00	8.35E-02	0.00E+00
Xe-131m	*0.00E+00*	*1.59E-03*	*0.00E+00*
I-131	2.32E-01	2.77E-04	2.85E-03
I-133	4.86E-03	6.62E-05	8.44E-04
Co-58	1.18E-04	9.36E-04	1.25E-04
Co-60	1.68E-03	4.50E-02	9.01E-04
Cs-134	1.16E-02	1.15E-02	4.77E-04
Cs-137	8.41E-03	1.86E-02	2.86E-04
Total Dose (µSv y^{-1})	**9.7**	**0.3**	**1.4**

Table C: Releases to coastal or estuary water – Stage 2

Radionuclides	Discharge ($Bq\ y^{-1}$)	External exposure DPUR ($\mu Sv\ y^{-1}$ per $Bq\ y^{-1}$)	Seafood consumption DPUR ($\mu Sv\ y^{-1}$ per $Bq\ y^{-1}$)	Total Dose ($\mu Sv\ y^{-1}$)
Ag-110m	5.70E+08	1.20E-10	3.90E-09	1.76E+00
Co-58	2.07E+09	5.40E-11	1.50E-11	1.10E-01
Co-60	3.00E+09	2.70E-09	7.50E-11	6.40E+00
Cs-134	5.60E+08	8.40E-11	4.00E-11	5.34E-02
Cs-137	9.45E+08	1.20E-10	2.80E-11	1.08E-01
Mn-54	2.70E+08	2.20E-10	5.00E-12	4.67E-02
Sb-124	4.90E+08	*1.30E-17*	*6.80E-09*	*2.56E+00*
Te-123m	2.60E+08	*1.30E-17*	*6.80E-09*	*1.36E+00*
Ni-63	9.60E+08	0.00E+00	3.60E-12	2.66E-03
Sb-125	8.15E+08	1.50E-11	1.50E-11	1.88E-02
Cr-51	6.00E+07	3.70E-13	2.30E-13	2.77E-05
I-131	5.00E+07	2.50E-15	2.50E-12	9.63E-05
H-3	7.50E+13	0.00E+00	8.90E-16	5.13E-02
C-14	9.50E+10	1.60E-16	4.60E-10	3.36E+01
			Total dose ($\mu Sv\ y^{-1}$)	**46.1**

Table D: Releases to coastal or estuary water – Stage 2 – Doses for each exposure pathway

Radionuclides	Dose owing to external exposure ($\mu Sv\ y^{-1}$)	Dose owing to the ingestion of seafood ($\mu Sv\ y^{-1}$)
Ag-110m	5.26E-02	1.71E+00
Co-58	8.60E-02	2.39E-02
Co-60	6.23E+00	1.73E-01
Cs-134	3.62E-02	1.72E-02
Cs-137	8.72E-02	2.04E-02
Mn-54	4.57E-02	1.04E-03
Sb-124	*4.90E-09*	*2.56E+00*
Te-123m	*2.60E-09*	*1.36E+00*
Ni-63	0.00E+00	2.66E-03
Sb-125	9.40E-03	9.40E-03
Cr-51	1.71E-05	1.06E-05
I-131	9.62E-08	9.62E-05
H-3	0.00E+00	5.13E-02
C-14	1.17E-05	3.36E+01
Total Dose ($\mu Sv\ y^{-1}$)	**6.6**	**39.5**

ANNEX 3 – ANNUAL DOSES – STAGE 3

Table A: Summary of dose coefficients used for all exposure pathways

Radionuclides	f1	Ingestion Adult ($Sv\ Bq^{-1}$)	Ingestion Child ($Sv\ Bq^{-1}$)	Ingestion Infant ($Sv\ Bq^{-1}$)	Absor. Type	Inhalation Adult ($Sv\ Bq^{-1}$)	Inhalation Child ($Sv\ Bq^{-1}$)	Inhalation infant ($Sv\ Bq^{-1}$)	Ext. deposited gamma ($Sv\ Bq^{-1}\ m^{-2}\ s^{-1}$) [b]	Ext. deposited Beta ($Sv\ Bq^{-1}\ m^{-2}\ s^{-1}$)	Ext. Cloud Gamma ($Sv\ Bq^{-1}\ m^{-2}\ s^{-1}$) [c]	Ext. Cloud Beta ($Sv\ Bq^{-1}\ m^{-2}\ s^{-1}$)
H-3	1	1.8×10^{-11}	2.3×10^{-11}	4.8×10^{-11}	'V'	1.8×10^{-11}	2.3×10^{-11}	4.8×10^{-11}	-	-	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$
C-14 (atmos.) [e]	1	5.8×10^{-10}	8×10^{-10}	1.6×10^{-9}	'V'	5.8×10^{-10}	7.9×10^{-10}	1.6×10^{-9}	-	-	$0.0 \times 10^{+0}$	2.16×10^{-8}
C-14 (marine) [a]					'M'	2.0×10^{-9}	2.8×10^{-9}	6.6×10^{-9}			-	-
Cr-51	0.1	3.8×10^{-11}	7.8×10^{-11}	2.3×10^{-10}	'S'	3.7×10^{-11}	6.6×10^{-11}	2.1×10^{-10}	-	-	-	-
Mn-54	0.1	7.1×10^{-10}	1.3×10^{-9}	3.1×10^{-9}	'M'	1.5×10^{-9}	2.4×10^{-9}	6.2×10^{-9}	-	-	-	-
Co-58	0.1	7.4×10^{-10}	1.7×10^{-9}	4.4×10^{-9}	'M'	1.6×10^{-9}	2.4×10^{-9}	6.5×10^{-9}	0.17	9.86×10^{-10}	8.78×10^{-13}	5.37×10^{-10}
Co-60	0.1	3.4×10^{-9}	1.1×10^{-8}	2.7×10^{-8}	'M'	1.0×10^{-8}	1.5×10^{-8}	3.4×10^{-8}	7.309	$0.0 \times 10^{+0}$	2.16×10^{-12}	1.36×10^{-7}
Ni-63	0.05	1.5×10^{-10}	2.8×10^{-10}	8.4×10^{-10}	M'	4.8×10^{-10}	7.0×10^{-10}	1.9×10^{-9}	-	-	-	-
Ag-110m	0.05	2.8×10^{-9}	5.2×10^{-9}	1.4×10^{-8}	'M'	7.6×10^{-9}	1.2×10^{-8}	2.8×10^{-8}	-	-	-	-
Sb-124	0.1	2.5×10^{-9}	5.2×10^{-9}	1.6×10^{-8}	'M'	6.4×10^{-9}	9.6×10^{-9}	2.4×10^{-8}	-	-	-	-
Sb-125	0.1	1.1×10^{-9}	2.1×10^{-9}	6.1×10^{-9}	'M'	4.8×10^{-9}	6.8×10^{-9}	1.6×10^{-8}	-	-	-	-
Te-123m	0.3	1.4×10^{-9}	2.8×10^{-9}	8.8×10^{-9}	'M'	4.0×10^{-9}	5.7×10^{-9}	1.3×10^{-8}	-	-	-	-
I-131 (atmos.) [d]	1	2.2×10^{-8}	5.2×10^{-8}	1.8×10^{-7}	'V'	2.0×10^{-8}	4.8×10^{-8}	1.6×10^{-7}	7.819×10^{-3}	1.42×10^{-8}	3.53×10^{-13}	3.44×10^{-7}
I-131 (marine)					'F'	7.4×10^{-9}	1.9×10^{-8}	7.2×10^{-8}			-	-
I-133 [d]	1	4.3×10^{-9}	1.0×10^{-8}	4.4×10^{-8}	'V'	4.0×10^{-9}	9.7×10^{-9}	4.1×10^{-8}	1.414×10^{-3}	9.62×10^{-8}	5.48×10^{-13}	7.19×10^{-7}
Cs-134	1	1.9×10^{-8}	1.4×10^{-8}	1.6×10^{-8}	'F'	6.6×10^{-9}	5.3×10^{-9}	7.3×10^{-9}	2.286	1.70×10^{-8}	1.41×10^{-12}	2.87×10^{-7}
Cs-137	1	1.3×10^{-8}	1.0×10^{-8}	1.2×10^{-8}	'F'	4.6×10^{-9}	3.7×10^{-9}	5.4×10^{-9}	4.267	2.95×10^{-8}	5.11×10^{-13}	4.16×10^{-7}
Ar-41	-	-	-	-	'G'	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	-	-	1.09×10^{-12}	7.62×10^{-7}
Kr-85	-	-	-	-	'G'	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	-	-	2.04×10^{-15}	3.89×10^{-7}
Xe-131m	-	-	-	-	'G'	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	-	-	8.70×10^{-15}	1.98×10^{-7}
Xe-133	-	-	-	-	'G'	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	-	-	3.91×10^{-14}	1.62×10^{-7}
Xe-135	-	-	-	-	'G'	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	-	-	2.36×10^{-13}	5.99×10^{-7}

a For the inhalation exposure pathway, the seaspray is considered to be an aerosol. The form 'M' is recommended by ICRP 72.
b Deposited gamma dose coefficients taken from GRANIS output.
c Cloud Gamma dose coefficients taken from PLUME output for a 20 m stack at 500 m summed for 70% category D (NRPB-W91 figure 11).
d The form considered for iodine isotopes is elementary iodine (conservative assumption).
e For the inhalation exposure pathway, carbon-14 is in the form of carbon vapour (conservative assumption).

The dose coefficients are issued from the Federal Guidance Report n°12 (External exposure to radionuclides in air, water and soil. Oak Ridge National Laboratory, 1993).

Table B: Annual dose to the most exposed members of the public from gaseous discharges – Adult

Radio-nuclides	Annual Dose ($\mu Sv\ y^{-1}$) by exposure pathway															
	Inhal.	Cld gamma	Dep gamma	Resus.	Cloud beta	Dep. beta	Green veg.	Root veg.	Cow meat	Cow liver	Sheep meat	Sheep liver	Milk	Milk prods	Fruit	Total
H-3	4.1×10^{-2}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	4.2×10^{-3}	2.7×10^{-2}	1.4×10^{-3}	2.5×10^{-4}	7.4×10^{-4}	2.5×10^{-4}	5.7×10^{-2}	1.0×10^{-3}	2.1×10^{-3}	1.4×10^{-1}
C-14	2.0×10^{-1}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	7.6×10^{-6}	0.0×10^{0}	9.5×10^{-2}	1.4×10^{0}	1.2×10^{-1}	2.2×10^{-2}	6.5×10^{-2}	2.2×10^{-2}	1.3×10^{0}	3.3×10^{-1}	1.1×10^{-1}	3.7×10^{0}
Ar-41	0.0×10^{0}	1.4×10^{-2}	0.0×10^{0}	0.0×10^{0}	1.9×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.4×10^{-2}
Co-58	5.3×10^{-5}	1.4×10^{-6}	4.3×10^{-4}	3.0×10^{-8}	1.8×10^{-11}	7.1×10^{-7}	5.4×10^{-6}	1.1×10^{-7}	1.7×10^{-7}	3.2×10^{-6}	1.6×10^{-7}	5.4×10^{-6}	4.2×10^{-5}	1.9×10^{-5}	5.4×10^{-7}	5.6×10^{-4}
Co-60	3.9×10^{-4}	4.2×10^{-6}	2.2×10^{-2}	4.0×10^{-7}	5.4×10^{-9}	0.0×10^{0}	3.7×10^{-5}	1.2×10^{-5}	4.0×10^{-6}	7.4×10^{-5}	3.2×10^{-6}	1.1×10^{-4}	3.1×10^{-4}	1.4×10^{-4}	8.1×10^{-6}	2.3×10^{-2}
Kr-85	0.0×10^{0}	1.2×10^{-4}	0.0×10^{0}	0.0×10^{0}	4.8×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	6.0×10^{-4}
I-131	1.4×10^{-3}	1.2×10^{-6}	3.1×10^{-4}	2.9×10^{-6}	2.4×10^{-8}	1.6×10^{-4}	1.2×10^{-3}	1.8×10^{-3}	2.5×10^{-4}	5.4×10^{-5}	2.0×10^{-4}	7.0×10^{-5}	2.2×10^{-2}	8.6×10^{-3}	5.0×10^{-4}	3.7×10^{-2}
I-133	3.3×10^{-4}	2.3×10^{-6}	6.8×10^{-5}	1.1×10^{-7}	6.0×10^{-8}	1.3×10^{-3}	4.1×10^{-5}	2.3×10^{-6}	6.3×10^{-7}	5.7×10^{-7}	1.0×10^{-6}	3.5×10^{-7}	3.4×10^{-4}	3.2×10^{-5}	2.0×10^{-5}	2.2×10^{-3}
Xe-131m	0.0×10^{0}	1.1×10^{-5}	0.0×10^{0}	0.0×10^{0}	5.2×10^{-6}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.6×10^{-5}
Xe-133	0.0×10^{0}	1.1×10^{-2}	0.0×10^{0}	0.0×10^{0}	9.0×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.1×10^{-2}
Xe-135	0.0×10^{0}	2.0×10^{-2}	0.0×10^{0}	0.0×10^{0}	1.0×10^{-3}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	2.1×10^{-2}
Cs-134	2.0×10^{-4}	2.1×10^{-6}	5.3×10^{-3}	1.8×10^{-7}	8.9×10^{-9}	1.1×10^{-5}	1.8×10^{-4}	1.2×10^{-3}	4.7×10^{-4}	8.8×10^{-5}	4.9×10^{-4}	1.7×10^{-4}	3.1×10^{-3}	1.4×10^{-3}	5.8×10^{-5}	1.3×10^{-2}
Cs-137	1.3×10^{-4}	6.9×10^{-7}	8.9×10^{-3}	1.6×10^{-7}	1.2×10^{-8}	1.8×10^{-5}	1.3×10^{-4}	8.6×10^{-4}	3.4×10^{-4}	6.2×10^{-5}	3.8×10^{-4}	1.3×10^{-4}	2.1×10^{-3}	9.7×10^{-4}	3.7×10^{-5}	1.4×10^{-2}
Total	2.4×10^{-1}	4.4×10^{-2}	3.7×10^{-2}	3.8×10^{-6}	2.6×10^{-3}	1.5×10^{-3}	1.0×10^{-1}	1.4×10^{0}	1.2×10^{-1}	2.3×10^{-2}	6.7×10^{-2}	2.3×10^{-2}	1.4×10^{0}	3.4×10^{-1}	1.1×10^{-1}	4.0×10^{0}

Table C: Annual dose to the most exposed members of the public from gaseous discharges – Child

Radio-nuclides	Annual Dose ($\mu Sv\ y^{-1}$) by exposure pathway														
	Inhal.	Cld gamma	Dep gamma	Resus.	Cloud beta	Dep. beta	Green veg.	Root veg.	Cow meat	Cow liver	Sheep meat	Sheep liver	Milk	Milk prods	Fruit	Total
H-3	3.0×10^{-2}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	2.3×10^{-3}	2.6×10^{-2}	1.8×10^{-3}	1.8×10^{-4}	4.7×10^{-4}	1.8×10^{-4}	7.3×10^{-2}	1.0×10^{-3}	2.0×10^{-3}	1.4×10^{-1}
C-14	1.6×10^{-1}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	7.6×10^{-6}	0.0×10^{0}	5.6×10^{-2}	1.4×10^{0}	1.7×10^{-1}	1.7×10^{-2}	4.5×10^{-2}	1.7×10^{-2}	1.8×10^{0}	3.4×10^{-1}	1.1×10^{-1}	4.1×10^{0}
Ar-41	0.0×10^{0}	8.1×10^{-3}	0.0×10^{0}	0.0×10^{0}	1.9×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	8.3×10^{-3}
Co-58	4.5×10^{-5}	8.7×10^{-7}	2.2×10^{-4}	2.6×10^{-8}	1.8×10^{-11}	2.9×10^{-7}	5.4×10^{-6}	1.9×10^{-7}	4.0×10^{-7}	4.1×10^{-6}	1.8×10^{-7}	6.8×10^{-6}	9.6×10^{-5}	3.2×10^{-5}	9.3×10^{-7}	4.1×10^{-4}
Co60	3.3×10^{-4}	2.5×10^{-6}	1.1×10^{-2}	3.5×10^{-7}	5.4×10^{-9}	0.0×10^{0}	5.1×10^{-5}	2.9×10^{-5}	1.3×10^{-5}	1.3×10^{-4}	5.2×10^{-6}	1.9×10^{-4}	1.0×10^{-3}	3.5×10^{-4}	2.0×10^{-5}	1.3×10^{-2}
Kr-85	0.0×10^{0}	7.3×10^{-5}	0.0×10^{0}	0.0×10^{0}	4.8×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	5.5×10^{-4}
I-131	1.9×10^{-3}	7.3×10^{-7}	1.6×10^{-4}	4.0×10^{-6}	2.4×10^{-8}	6.5×10^{-5}	1.2×10^{-3}	3.1×10^{-3}	5.9×10^{-4}	7.0×10^{-5}	2.4×10^{-4}	9.0×10^{-5}	5.3×10^{-2}	1.5×10^{-2}	8.8×10^{-4}	7.6×10^{-2}
I-133	4.6×10^{-4}	1.4×10^{-6}	3.4×10^{-5}	1.5×10^{-7}	6.0×10^{-8}	5.3×10^{-4}	4.0×10^{-5}	3.9×10^{-6}	1.5×10^{-6}	7.3×10^{-7}	1.2×10^{-6}	4.4×10^{-7}	7.9×10^{-4}	5.5×10^{-5}	3.5×10^{-5}	2.0×10^{-3}
Xe-131m	0.0×10^{0}	6.7×10^{-6}	0.0×10^{0}	0.0×10^{0}	5.2×10^{-6}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.2×10^{-5}
Xe-133	0.0×10^{0}	6.3×10^{-3}	0.0×10^{0}	0.0×10^{0}	9.0×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	7.2×10^{-3}
Xe-135	0.0×10^{0}	1.2×10^{-2}	0.0×10^{0}	0.0×10^{0}	1.0×10^{-3}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.3×10^{-2}
Cs-134	9.2×10^{-5}	1.3×10^{-6}	2.7×10^{-3}	8.4×10^{-8}	8.9×10^{-9}	4.5×10^{-6}	5.8×10^{-5}	6.7×10^{-4}	3.5×10^{-4}	3.5×10^{-5}	1.8×10^{-4}	6.8×10^{-5}	2.3×10^{-3}	7.8×10^{-4}	3.2×10^{-5}	7.2×10^{-3}
Cs-137	5.8×10^{-5}	4.2×10^{-7}	4.5×10^{-3}	7.3×10^{-8}	1.2×10^{-8}	7.0×10^{-6}	4.1×10^{-5}	4.9×10^{-4}	2.6×10^{-4}	2.6×10^{-5}	1.4×10^{-4}	5.4×10^{-5}	1.6×10^{-3}	5.6×10^{-4}	2.1×10^{-5}	7.8×10^{-3}
Total	1.9×10^{-1}	2.7×10^{-2}	1.9×10^{-2}	4.7×10^{-6}	2.6×10^{-3}	6.0×10^{-4}	6.0×10^{-2}	1.5×10^{0}	1.7×10^{-1}	1.7×10^{-2}	4.6×10^{-2}	1.7×10^{-2}	1.9×10^{0}	3.6×10^{-1}	1.2×10^{-1}	4.4×10^{0}

Table D: Annual dose to the most exposed members of the public from gaseous discharges – Infant

Radio-nuclides	Annual Dose (µSv y^{-1}) by exposure pathway														
	Inhal.	Cld gamma	Dep gamma	Resus.	Cloud beta	Dep. beta	Green veg.	Root veg.	Cow meat	Cow liver	Sheep meat	Sheep liver	Milk	Milk prods	Fruit	Total
H-3	2.2×10^{-2}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.6×10^{-3}	2.5×10^{-2}	7.4×10^{-4}	1.2×10^{-4}	2.0×10^{-4}	1.2×10^{-4}	2.0×10^{-1}	2.1×10^{-3}	2.5×10^{-3}	2.6×10^{-1}
C-14	1.1×10^{-1}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	7.6×10^{-6}	0.0×10^{0}	3.8×10^{-2}	1.3×10^{0}	6.7×10^{-2}	1.1×10^{-2}	1.8×10^{-2}	1.1×10^{-2}	4.8×10^{0}	6.8×10^{-1}	1.3×10^{-1}	7.2×10^{0}
Ar-41	0.0×10^{0}	6.3×10^{-3}	0.0×10^{0}	0.0×10^{0}	1.9×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	6.5×10^{-3}
Co-58	4.2×10^{-5}	6.8×10^{-7}	1.5×10^{-4}	2.4×10^{-8}	1.8×10^{-11}	1.4×10^{-7}	4.6×10^{-6}	2.3×10^{-7}	2.1×10^{-7}	3.5×10^{-6}	9.4×10^{-8}	5.9×10^{-6}	3.3×10^{-4}	8.4×10^{-5}	1.4×10^{-6}	6.2×10^{-4}
Co-60	2.6×10^{-4}	2.0×10^{-6}	7.5×10^{-3}	2.7×10^{-7}	5.4×10^{-9}	0.0×10^{0}	4.2×10^{-5}	3.4×10^{-5}	6.4×10^{-6}	1.1×10^{-4}	2.5×10^{-6}	1.6×10^{-4}	3.3×10^{-3}	8.5×10^{-4}	2.9×10^{-5}	1.2×10^{-2}
Kr-85	0.0×10^{0}	5.7×10^{-5}	0.0×10^{0}	0.0×10^{0}	4.8×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	5.3×10^{-4}
I-131	2.2×10^{-3}	5.7×10^{-7}	1.1×10^{-4}	4.6×10^{-6}	2.4×10^{-8}	3.3×10^{-5}	1.4×10^{-3}	5.1×10^{-3}	4.1×10^{-4}	8.1×10^{-5}	1.7×10^{-4}	1.0×10^{-4}	2.4×10^{-1}	5.3×10^{-2}	1.8×10^{-3}	3.1×10^{-1}
I-133	6.7×10^{-4}	1.1×10^{-6}	2.3×10^{-5}	2.2×10^{-7}	6.0×10^{-8}	2.6×10^{-4}	5.9×10^{-5}	8.1×10^{-6}	1.3×10^{-6}	1.1×10^{-6}	1.0×10^{-6}	6.5×10^{-7}	4.7×10^{-3}	2.4×10^{-4}	9.2×10^{-5}	6.0×10^{-3}
Xe-131m	0.0×10^{0}	5.2×10^{-6}	0.0×10^{0}	0.0×10^{0}	5.2×10^{-6}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.0×10^{-5}
Xe-133	0.0×10^{0}	4.9×10^{-3}	0.0×10^{0}	0.0×10^{0}	9.0×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	5.8×10^{-3}
Xe-135	0.0×10^{0}	9.3×10^{-3}	0.0×10^{0}	0.0×10^{0}	1.0×10^{-3}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.0×10^{-2}
Cs-134	4.4×10^{-5}	1.0×10^{-6}	1.8×10^{-3}	4.0×10^{-8}	8.9×10^{-9}	2.3×10^{-6}	2.2×10^{-5}	3.6×10^{-4}	8.0×10^{-5}	1.3×10^{-5}	4.2×10^{-5}	2.6×10^{-5}	3.4×10^{-3}	8.9×10^{-4}	2.2×10^{-5}	6.8×10^{-3}
Cs-137	2.9×10^{-5}	3.2×10^{-7}	3.1×10^{-3}	3.7×10^{-8}	1.2×10^{-8}	3.5×10^{-6}	1.7×10^{-5}	2.8×10^{-4}	6.2×10^{-5}	1.0×10^{-5}	3.5×10^{-5}	2.2×10^{-5}	2.6×10^{-3}	6.7×10^{-4}	1.5×10^{-5}	6.8×10^{-3}
Total	1.3×10^{-1}	2.1×10^{-2}	1.3×10^{-2}	5.1×10^{-6}	2.6×10^{-3}	3.0×10^{-4}	4.1×10^{-2}	1.4×10^{0}	6.9×10^{-2}	1.2×10^{-2}	1.8×10^{-2}	1.2×10^{-2}	5.3×10^{0}	7.3×10^{-1}	1.4×10^{-1}	7.8×10^{0}

Table E: Annual dose to the most exposed members of the public from liquid discharges – Adult

Radio-nuclides	Annual Dose (μSv y^{-1}) by exposure pathway								
	Fish	Crustacea	Mollusca	Gamma(s)	Beta(s)	Gamma(f)	Beta(f)	Seaspray	Total
Ag-110m	7.2×10^{-3}	1.4×10^{-2}	2.9×10^{-2}	3.3×10^{-3}	6.2×10^{-7}	3.3×10^{-5}	8.6×10^{-7}	4.5×10^{-12}	5.3×10^{-2}
C-14	10.0×10^{0}	2.0×10^{0}	2.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.3×10^{-3}	2.0×10^{-10}	1.4×10^{1}
Co-58	2.8×10^{-3}	2.8×10^{-3}	2.8×10^{-3}	5.6×10^{-2}	1.0×10^{-5}	5.6×10^{-4}	1.6×10^{-5}	1.4×10^{-12}	6.5×10^{-2}
Co-60	2.1×10^{-2}	2.1×10^{-2}	2.1×10^{-2}	3.0×10^{0}	0.0×10^{0}	3.0×10^{-2}	9.5×10^{-4}	1.4×10^{-11}	3.1×10^{0}
Cr-51	1.9×10^{-6}	9.3×10^{-7}	1.5×10^{-6}	1.1×10^{-5}	0.0×10^{0}	1.1×10^{-7}	0.0×10^{0}	1.3×10^{-15}	1.6×10^{-5}
Cs-134	9.4×10^{-3}	5.6×10^{-4}	5.6×10^{-4}	1.3×10^{-2}	2.6×10^{-5}	1.3×10^{-4}	1.1×10^{-5}	3.8×10^{-12}	2.4×10^{-2}
Cs-137	1.1×10^{-2}	6.6×10^{-4}	6.6×10^{-4}	2.4×10^{-2}	8.3×10^{-5}	2.4×10^{-4}	8.5×10^{-5}	4.6×10^{-12}	3.7×10^{-2}
H-3	1.3×10^{-2}	2.6×10^{-3}	2.6×10^{-3}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.5×10^{-9}	1.8×10^{-2}
I-131	5.4×10^{-5}	1.1×10^{-5}	1.1×10^{-5}	1.8×10^{-8}	1.2×10^{-10}	1.8×10^{-10}	7.4×10^{-11}	2.1×10^{-13}	7.6×10^{-5}
Mn-54	1.5×10^{-4}	3.7×10^{-5}	3.7×10^{-4}	2.5×10^{-2}	0.0×10^{0}	2.5×10^{-4}	$0.0\ 10^{0}$	1.8×10^{-13}	2.6×10^{-2}
Ni-63	4.9×10^{-4}	9.8×10^{-5}	2.0×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	2.7×10^{-13}	7.9×10^{-4}
Sb-124	4.0×10^{-3}	8.0×10^{-4}	4.0×10^{-4}	4.6×10^{-4}	3.8×10^{-6}	4.6×10^{-6}	2.6×10^{-7}	3.0×10^{-12}	5.7×10^{-3}
Sb-125	3.3×10^{-3}	6.6×10^{-4}	3.3×10^{-4}	2.2×10^{-3}	3.8×10^{-6}	2.2×10^{-5}	4.2×10^{-6}	4.2×10^{-12}	6.6×10^{-3}
Te-123m	3.2×10^{-3}	6.3×10^{-4}	6.3×10^{-4}	4.1×10^{-5}	0.0×10^{0}	4.1×10^{-7}	2.2×10^{-7}	1.1×10^{-12}	4.5×10^{-3}
Total	10.0×10^{0}	2.1×10^{0}	2.1×10^{0}	3.2×10^{0}	1.3×10^{-4}	3.2×10^{-2}	2.4×10^{-3}	1.7×10^{-9}	1.7×10^{1}

Table F: Annual dose to the most exposed members of the public from liquid discharges – Child

Radio-nuclides	Annual Dose (μSv y^{-1}) by exposure pathway						
	Fish	Crustacea	Mollusca	Gamma(s)	Beta(s)	Seaspray	Total
Ag-110m	2.7×10^{-3}	6.6×10^{-3}	1.3×10^{-2}	5.0×10^{-4}	9.4×10^{-8}	7.1×10^{-13}	2.3×10^{-2}
C-14	2.8×10^{0}	6.9×10^{-1}	6.9×10^{-1}	0.0×10^{0}	0.0×10^{0}	2.8×10^{-11}	4.2×10^{0}
Co-58	1.3×10^{-3}	1.6×10^{-3}	1.6×10^{-3}	8.3×10^{-3}	1.5×10^{-6}	2.1×10^{-13}	1.3×10^{-2}
Co-60	1.3×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	4.6×10^{-1}	0.0×10^{0}	2.1×10^{-12}	5.0×10^{-1}
Cr-51	7.6×10^{-7}	4.8×10^{-7}	7.6×10^{-7}	1.7×10^{-6}	0.0×10^{0}	2.3×10^{-16}	3.7×10^{-6}
Cs-134	1.4×10^{-3}	1.0×10^{-4}	1.0×10^{-4}	2.0×10^{-3}	3.9×10^{-6}	3.1×10^{-13}	3.6×10^{-3}
Cs-137	1.7×10^{-3}	1.3×10^{-4}	1.3×10^{-4}	3.6×10^{-3}	1.2×10^{-5}	3.7×10^{-13}	5.6×10^{-3}
H-3	3.3×10^{-3}	8.2×10^{-4}	8.2×10^{-4}	0.0×10^{0}	0.0×10^{0}	1.9×10^{-10}	4.9×10^{-3}
I-131	2.6×10^{-5}	6.4×10^{-6}	6.4×10^{-6}	2.8×10^{-9}	1.9×10^{-11}	5.4×10^{-14}	3.8×10^{-5}
Mn-54	5.4×10^{-5}	1.7×10^{-5}	1.7×10^{-4}	3.8×10^{-3}	0.0×10^{0}	2.9×10^{-14}	4.0×10^{-3}
Ni-63	1.8×10^{-4}	4.6×10^{-5}	9.2×10^{-5}	0.0×10^{0}	0.0×10^{0}	4.0×10^{-14}	3.2×10^{-4}
Sb-124	1.7×10^{-3}	4.2×10^{-4}	2.1×10^{-4}	6.9×10^{-5}	5.7×10^{-7}	4.5×10^{-13}	2.4×10^{-3}
Sb-125	1.3×10^{-3}	3.2×10^{-4}	1.6×10^{-4}	3.4×10^{-4}	5.8×10^{-7}	5.9×10^{-13}	2.1×10^{-3}
Te-123m	1.3×10^{-3}	3.2×10^{-4}	3.2×10^{-4}	6.1×10^{-6}	0.0×10^{0}	1.5×10^{-13}	1.9×10^{-3}
Total	2.8×10^{0}	7.2×10^{-1}	7.3×10^{-1}	4.8×10^{-1}	1.9×10^{-5}	2.2×10^{-10}	4.7×10^{0}

Table G: Annual dose to the most exposed members of the public from liquid discharges – Infant

Radio-nuclides	Annual Dose (µSv y^{-1}) by exposure pathway						
	Fish	Crustacea	Mollusca	Gamma(s)	Beta(s)	Seaspray	Total
Ag-110m	1.8×10^{-3}	0.0×10^{0}	0.0×10^{0}	5.0×10^{-5}	9.4×10^{-9}	5.2×10^{-14}	1.8×10^{-3}
C-14	1.4×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	2.1×10^{-12}	1.4×10^{0}
Co-58	8.5×10^{-4}	0.0×10^{0}	0.0×10^{0}	8.3×10^{-4}	1.5×10^{-7}	1.8×10^{-14}	1.7×10^{-3}
Co-60	8.1×10^{-3}	0.0×10^{0}	0.0×10^{0}	4.6×10^{-2}	0.0×10^{0}	1.5×10^{-13}	5.4×10^{-2}
Cr-51	5.6×10^{-7}	0.0×10^{0}	0.0×10^{0}	1.7×10^{-7}	0.0×10^{0}	2.3×10^{-17}	7.4×10^{-7}
Cs-134	4.0×10^{-4}	0.0×10^{0}	0.0×10^{0}	2.0×10^{-4}	3.9×10^{-7}	1.3×10^{-14}	6.0×10^{-4}
Cs-137	5.1×10^{-4}	0.0×10^{0}	0.0×10^{0}	3.6×10^{-4}	1.2×10^{-6}	1.7×10^{-14}	8.7×10^{-4}
H-3	1.7×10^{-3}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	1.2×10^{-11}	1.7×10^{-3}
I-131	2.2×10^{-5}	0.0×10^{0}	0.0×10^{0}	2.8×10^{-10}	1.9×10^{-12}	6.4×10^{-15}	2.2×10^{-5}
Mn-54	3.2×10^{-5}	0.0×10^{0}	0.0×10^{0}	3.8×10^{-4}	0.0×10^{0}	2.3×10^{-15}	4.1×10^{-4}
Ni-63	1.4×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	3.4×10^{-15}	1.4×10^{-4}
Sb-124	1.3×10^{-3}	0.0×10^{0}	0.0×10^{0}	6.9×10^{-6}	5.7×10^{-8}	3.5×10^{-14}	1.3×10^{-3}
Sb-125	9.2×10^{-4}	0.0×10^{0}	0.0×10^{0}	3.4×10^{-5}	5.8×10^{-8}	4.3×10^{-14}	9.5×10^{-4}
Te-123m	9.9×10^{-4}	0.0×10^{0}	0.0×10^{0}	6.1×10^{-7}	0.0×10^{0}	1.1×10^{-14}	9.9×10^{-4}
Total	1.4×10^{0}	0.0×10^{0}	0.0×10^{0}	4.8×10^{-2}	1.9×10^{-6}	1.5×10^{-11}	1.5×10^{0}

Table H: Annual dose to the most exposed members of the public from aerial discharges including ingestion of locally caught seafoods – Adult

Radio-nuclides	Annual Dose (µSv y^{-1}) by exposure pathway					
	Total Terrestrial	Seafood Consumption at Average Rates				Total
		Fish	Crustacea	Molluscs	Total	
Ag-110m		1.1×10^{-3}	1.3×10^{-3}	2.6×10^{-3}	4.9×10^{-3}	4.9×10^{-3}
Ar-41	1.4×10^{-2}					1.4×10^{-2}
C-14	3.7×10^{0}	1.5×10^{0}	1.8×10^{-1}	1.8×10^{-1}	1.9×10^{0}	5.6×10^{0}
Co-58	5.6×10^{-4}	4.3×10^{-4}	2.6×10^{-4}	2.6×10^{-4}	9.4×10^{-4}	1.5×10^{-3}
Co-60	2.3×10^{-2}	3.1×10^{-3}	1.8×10^{-3}	1.8×10^{-3}	6.8×10^{-3}	3.0×10^{-2}
Cr-51		2.8×10^{-7}	8.4×10^{-8}	1.3×10^{-7}	5.0×10^{-7}	5.0×10^{-7}
Cs-134	1.3×10^{-2}	1.4×10^{-3}	5.1×10^{-5}	5.1×10^{-5}	1.5×10^{-3}	1.5×10^{-2}
Cs-137	1.4×10^{-2}	1.7×10^{-3}	5.9×10^{-5}	5.9×10^{-5}	1.8×10^{-3}	1.6×10^{-2}
H-3	1.4×10^{-1}	1.9×10^{-3}	2.3×10^{-4}	2.3×10^{-4}	2.4×10^{-3}	1.4×10^{-1}
I-131	3.7×10^{-2}	8.1×10^{-6}	9.7×10^{-7}	9.7×10^{-7}	1.0×10^{-5}	3.7×10^{-2}
I-133	2.2×10^{-3}					2.2×10^{-3}
Kr-85	6.0×10^{-4}					6.0×10^{-4}
Mn-54		2.2×10^{-5}	3.3×10^{-6}	3.3×10^{-5}	5.9×10^{-5}	5.9×10^{-5}
Ni-63		7.4×10^{-5}	8.8×10^{-6}	1.8×10^{-5}	1.0×10^{-4}	1.0×10^{-4}
Sb-124		6.0×10^{-4}	7.2×10^{-5}	3.6×10^{-5}	7.1×10^{-4}	7.1×10^{-4}
Sb-125		5.0×10^{-4}	5.9×10^{-5}	3.0×10^{-5}	5.8×10^{-4}	5.8×10^{-4}
Te-123m		4.7×10^{-4}	5.7×10^{-5}	5.7×10^{-5}	5.9×10^{-4}	5.9×10^{-4}
Xe-131m	1.6×10^{-5}					1.6×10^{-5}
Xe-133	1.1×10^{-2}					1.1×10^{-2}
Xe-135	2.1×10^{-2}					2.1×10^{-2}
Total	4.0×10^{0}	1.5×10^{0}	1.9×10^{-1}	1.9×10^{-1}	1.9×10^{0}	5.9×10^{0}

Table I: Annual dose to the most exposed members of the public from aerial discharges including ingestion of locally caught seafoods – Child

Radio-nuclides	Annual Dose ($\mu Sv\ y^{-1}$) by exposure pathway					
	Total Terrestrial	Seafood Consumption at Average Rates				Total
		Fish	Crustacea	Molluscs	Total	
Ag-110m		8.0×10^{-4}	1.7×10^{-3}	3.5×10^{-3}	6.0×10^{-3}	6.0×10^{-3}
Ar-41	8.3×10^{-3}					8.3×10^{-3}
C-14	4.1×10^{0}	8.3×10^{-1}	1.8×10^{-1}	1.8×10^{-1}	1.2×10^{0}	5.3×10^{0}
Co-58	4.1×10^{-4}	3.9×10^{-4}	4.3×10^{-4}	4.3×10^{-4}	1.2×10^{-3}	1.6×10^{-3}
Co-60	1.3×10^{-2}	4.0×10^{-3}	4.3×10^{-3}	4.3×10^{-3}	1.3×10^{-2}	2.6×10^{-2}
Cr-51		2.3×10^{-7}	1.2×10^{-7}	2.0×10^{-7}	5.5×10^{-7}	5.5×10^{-7}
Cs-134	7.2×10^{-3}	4.2×10^{-4}	2.7×10^{-5}	2.7×10^{-5}	4.7×10^{-4}	7.7×10^{-3}
Cs-137	7.8×10^{-3}	5.1×10^{-4}	3.3×10^{-5}	3.3×10^{-5}	5.7×10^{-4}	8.4×10^{-3}
H-3	1.4×10^{-1}	9.8×10^{-4}	2.1×10^{-4}	2.1×10^{-4}	1.4×10^{-3}	1.4×10^{-1}
I-131	7.6×10^{-2}	7.7×10^{-6}	1.7×10^{-6}	1.7×10^{-6}	1.1×10^{-5}	7.6×10^{-2}
I-133	2.0×10^{-3}					2.0×10^{-3}
Kr-85	5.5×10^{-4}					5.5×10^{-4}
Mn-54		1.6×10^{-5}	4.4×10^{-6}	4.4×10^{-5}	6.5×10^{-5}	6.5×10^{-5}
Ni-63		5.5×10^{-5}	1.2×10^{-5}	2.4×10^{-5}	9.1×10^{-5}	9.1×10^{-5}
Sb-124		5.0×10^{-4}	1.1×10^{-4}	5.4×10^{-5}	6.6×10^{-4}	6.6×10^{-4}
Sb-125		3.8×10^{-4}	8.2×10^{-5}	4.1×10^{-5}	5.0×10^{-4}	5.0×10^{-4}
Te-123m		3.8×10^{-4}	8.2×10^{-5}	8.2×10^{-5}	5.4×10^{-4}	5.4×10^{-4}
Xe-131m	1.2×10^{-5}					1.2×10^{-5}
Xe-133	7.2×10^{-3}					7.2×10^{-3}
Xe-135	1.3×10^{-2}					1.3×10^{-2}
Total	4.4×10^{0}	8.4×10^{-1}	1.9×10^{-1}	1.9×10^{-1}	1.2×10^{0}	5.6×10^{0}

Table J: Annual dose to the most exposed members of the public from aerial discharges including ingestion of locally caught seafoods – Infant

Radio-nuclides	Annual Dose ($\mu Sv\ y^{-1}$) by exposure pathway					
	Total Terrestrial	Seafood Consumption at Average Rates				Total
		Fish	Crustacea	Molluscs	Total	
Ag-110m		1.3×10^{-3}	0.0×10^{0}	0.0×10^{0}	1.3×10^{-3}	1.3×10^{-3}
Ar-41	6.5×10^{-3}					6.5×10^{-3}
C-14	7.2×10^{0}	9.7×10^{-1}	0.0×10^{0}	0.0×10^{0}	9.7×10^{-1}	8.2×10^{0}
Co-58	6.2×10^{-4}	5.9×10^{-4}	0.0×10^{0}	0.0×10^{0}	5.9×10^{-4}	1.2×10^{-3}
Co-60	1.2×10^{-2}	5.7×10^{-3}	0.0×10^{0}	0.0×10^{0}	5.7×10^{-3}	1.8×10^{-2}
Cr-51		3.9×10^{-7}	0.0×10^{0}	0.0×10^{0}	3.9×10^{-7}	3.9×10^{-7}
Cs-134	6.8×10^{-3}	2.8×10^{-4}	0.0×10^{0}	0.0×10^{0}	2.8×10^{-4}	7.1×10^{-3}
Cs-137	6.8×10^{-3}	3.6×10^{-4}	0.0×10^{0}	0.0×10^{0}	3.6×10^{-4}	7.2×10^{-3}
H-3	2.6×10^{-1}	1.2×10^{-3}	0.0×10^{0}	0.0×10^{0}	1.2×10^{-3}	2.6×10^{-1}
I-131	3.1×10^{-1}	1.5×10^{-5}	0.0×10^{0}	0.0×10^{0}	1.5×10^{-5}	3.1×10^{-1}
I-133	6.0×10^{-3}					6.0×10^{-3}
Kr-85	5.3×10^{-4}					5.3×10^{-4}
Mn-54		2.3×10^{-5}	0.0×10^{0}	0.0×10^{0}	2.3×10^{-5}	2.3×10^{-5}
Ni-63		9.6×10^{-5}	0.0×10^{0}	0.0×10^{0}	9.6×10^{-5}	9.6×10^{-5}
Sb-124		9.0×10^{-4}	0.0×10^{0}	0.0×10^{0}	9.0×10^{-4}	9.0×10^{-4}
Sb-125		6.4×10^{-4}	0.0×10^{0}	0.0×10^{0}	6.4×10^{-4}	6.4×10^{-4}
Te-123m		6.9×10^{-4}	0.0×10^{0}	0.0×10^{0}	6.9×10^{-4}	6.9×10^{-4}
Xe-131m	1.0×10^{-5}					1.0×10^{-5}
Xe-133	5.8×10^{-3}					5.8×10^{-3}
Xe-135	1.0×10^{-2}					1.0×10^{-2}
Total	7.8×10^{0}	9.8×10^{-1}	0.0×10^{0}	0.0×10^{0}	9.8×10^{-1}	8.8×10^{0}

Table K: Annual dose to the most exposed members of the public from liquid discharges also consuming locally grown terrestrial foods – Adult

Radio-nuclides	Annual Dose ($\mu Sv\ y^{-1}$) by exposure pathway											
	Total Marine	Terrestrial Foods Consumption at Average Rates 50% Locally produced										Total
		Green veg	Root veg	Cow meat	Cow liver	Sheep meat	Sheep liver	Milk	Milk prod	Fruit	Total	
Ag-110m	5.3×10^{-2}											5.3×10^{-2}
Ar-41		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
C-14	1.4×10^{1}	9.5×10^{-2}	3.3×10^{-1}	1.2×10^{-1}	2.2×10^{-2}	6.5×10^{-2}	2.2×10^{-2}	2.6×10^{-1}	3.3×10^{-1}	1.1×10^{-1}	1.3×10^{0}	1.5×10^{1}
Co-58	6.5×10^{-2}	5.4×10^{-6}	2.6×10^{-8}	1.7×10^{-7}	3.2×10^{-6}	1.6×10^{-7}	5.4×10^{-6}	8.3×10^{-6}	1.9×10^{-5}	5.4×10^{-7}	4.2×10^{-5}	6.5×10^{-2}
Co-60	3.1×10^{0}	3.7×10^{-5}	2.8×10^{-6}	4.0×10^{-6}	7.4×10^{-5}	3.2×10^{-6}	1.1×10^{-4}	6.2×10^{-5}	1.4×10^{-4}	8.1×10^{-6}	4.4×10^{-4}	3.1×10^{0}
Cr-51	1.6×10^{-5}											1.6×10^{-5}
Cs-134	2.4×10^{-2}	1.8×10^{-4}	2.9×10^{-4}	4.7×10^{-4}	8.8×10^{-5}	4.9×10^{-4}	1.7×10^{-4}	6.1×10^{-4}	1.4×10^{-3}	5.8×10^{-5}	3.8×10^{-3}	2.8×10^{-2}
Cs-137	3.7×10^{-2}	1.3×10^{-4}	2.0×10^{-4}	3.4×10^{-4}	6.2×10^{-5}	3.8×10^{-4}	1.3×10^{-4}	4.2×10^{-4}	9.7×10^{-4}	3.7×10^{-5}	2.7×10^{-3}	4.0×10^{-2}
H-3	1.8×10^{-2}	4.2×10^{-3}	6.3×10^{-3}	1.4×10^{-3}	2.5×10^{-4}	7.4×10^{-4}	2.5×10^{-4}	1.1×10^{-2}	1.0×10^{-3}	2.1×10^{-3}	2.8×10^{-2}	4.6×10^{-2}
I-131	7.6×10^{-5}	1.2×10^{-3}	4.2×10^{-4}	2.5×10^{-4}	5.4×10^{-5}	2.0×10^{-4}	7.0×10^{-5}	4.4×10^{-3}	8.6×10^{-3}	5.0×10^{-4}	1.6×10^{-2}	1.6×10^{-2}
I-133		4.1×10^{-5}	5.3×10^{-7}	6.3×10^{-7}	5.7×10^{-7}	1.0×10^{-6}	3.5×10^{-7}	6.7×10^{-5}	3.2×10^{-5}	2.0×10^{-5}	1.6×10^{-4}	1.6×10^{-4}
Kr-85		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Mn-54	2.6×10^{-2}											2.6×10^{-2}
Ni-63	7.9×10^{-4}											7.9×10^{-4}
Sb-124	5.7×10^{-3}											5.7×10^{-3}
Sb-125	6.6×10^{-3}											6.6×10^{-3}
Te-123m	4.5×10^{-3}											4.5×10^{-3}
Xe-131m		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Xe-133		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Xe-135		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Total	1.7×10^{1}	1.0×10^{-1}	3.3×10^{-1}	1.2×10^{-1}	2.3×10^{-2}	6.7×10^{-2}	2.3×10^{-2}	2.8×10^{-1}	3.4×10^{-1}	1.1×10^{-1}	1.4×10^{0}	1.8×10^{1}

Table L: Annual dose to the most exposed members of the public from liquid discharges also consuming locally grown terrestrial foods – Child

Radio-nuclides	Annual Dose ($\mu Sv\ y^{-1}$) by exposure pathway											
	Total Marine	Terrestrial Foods Consumption at Average Rates 50% Locally produced										Total
		Green veg	Root veg	Cow meat	Cow liver	Sheep meat	Sheep liver	Milk	Milk prod	Fruit	Total	
Ag-110m	2.3×10^{-2}											2.3×10^{-2}
Ar-41		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
C-14	4.2×10^{0}	5.6×10^{-2}	3.7×10^{-1}	1.7×10^{-1}	1.7×10^{-2}	4.5×10^{-2}	1.7×10^{-2}	4.1×10^{-1}	3.4×10^{-1}	1.1×10^{-1}	1.5×10^{0}	5.7×10^{0}
Co-58	1.3×10^{-2}	5.4×10^{-6}	5.0×10^{-8}	4.0×10^{-7}	4.1×10^{-6}	1.8×10^{-7}	6.8×10^{-6}	2.2×10^{-5}	3.2×10^{-5}	9.3×10^{-7}	7.2×10^{-5}	1.3×10^{-2}
Co-60	5.0×10^{-1}	5.1×10^{-5}	7.6×10^{-6}	1.3×10^{-5}	1.3×10^{-4}	5.2×10^{-6}	1.9×10^{-4}	2.3×10^{-4}	3.5×10^{-4}	2.0×10^{-5}	1.0×10^{-3}	5.0×10^{-1}
Cr-51	3.7×10^{-6}											3.7×10^{-6}
Cs-134	3.6×10^{-3}	5.8×10^{-5}	1.8×10^{-4}	3.5×10^{-4}	3.5×10^{-5}	1.8×10^{-4}	6.8×10^{-5}	5.2×10^{-4}	7.8×10^{-4}	3.2×10^{-5}	2.2×10^{-3}	5.8×10^{-3}
Cs-137	5.6×10^{-3}	4.1×10^{-5}	1.3×10^{-4}	2.6×10^{-4}	2.6×10^{-5}	1.4×10^{-4}	5.4×10^{-5}	3.7×10^{-4}	5.6×10^{-4}	2.1×10^{-5}	1.6×10^{-3}	7.2×10^{-3}
H-3	4.9×10^{-3}	2.3×10^{-3}	6.7×10^{-3}	1.8×10^{-3}	1.8×10^{-4}	4.7×10^{-4}	1.8×10^{-4}	1.7×10^{-2}	1.0×10^{-3}	2.0×10^{-3}	3.1×10^{-2}	3.6×10^{-2}
I-131	3.8×10^{-5}	1.2×10^{-3}	8.2×10^{-4}	5.9×10^{-4}	7.0×10^{-5}	2.4×10^{-4}	9.0×10^{-5}	1.2×10^{-2}	1.5×10^{-2}	8.8×10^{-4}	3.1×10^{-2}	3.1×10^{-2}
I-133		4.0×10^{-5}	1.0×10^{-6}	1.5×10^{-6}	7.3×10^{-7}	1.2×10^{-6}	4.4×10^{-7}	1.8×10^{-4}	5.5×10^{-5}	3.5×10^{-5}	3.2×10^{-4}	3.2×10^{-4}
Kr-85		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Mn-54	4.0×10^{-3}											4.0×10^{-3}
Ni-63	3.2×10^{-4}											3.2×10^{-4}
Sb-124	2.4×10^{-3}											2.4×10^{-3}
Sb-125	2.1×10^{-3}											2.1×10^{-3}
Te-123m	1.9×10^{-3}											1.9×10^{-3}
Xe-131m		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Xe-133		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Xe-135		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Total	4.7×10^{0}	6.0×10^{-2}	3.8×10^{-1}	1.7×10^{-1}	1.7×10^{-2}	4.6×10^{-2}	1.7×10^{-2}	4.4×10^{-1}	3.6×10^{-1}	1.2×10^{-1}	1.6×10^{0}	6.3×10^{0}

Table M: Annual dose to the most exposed members of the public from liquid discharges also consuming locally grown terrestrial foods – Infant

Radio-nuclides	Annual Dose ($\mu Sv\ y^{-1}$) by exposure pathway											
	Total Marine	Terrestrial Foods Consumption at Average Rates 50% Locally produced										Total
		Green veg	Root veg	Cow meat	Cow liver	Sheep meat	Sheep liver	Milk	Milk prod	Fruit	Total	
Ag-110m	1.8×10^{-3}											1.8×10^{-3}
Ar-41		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
C-14	1.4×10^{0}	3.8×10^{-2}	2.2×10^{-1}	6.7×10^{-2}	1.1×10^{-2}	1.8×10^{-2}	1.1×10^{-2}	9.8×10^{-1}	6.8×10^{-1}	1.3×10^{-1}	2.2×10^{0}	3.6×10^{0}
Co-58	1.7×10^{-3}	4.6×10^{-6}	3.9×10^{-8}	2.1×10^{-7}	3.5×10^{-6}	9.4×10^{-8}	5.9×10^{-6}	6.7×10^{-5}	8.4×10^{-5}	1.4×10^{-6}	1.7×10^{-4}	1.9×10^{-3}
Co-60	5.4×10^{-2}	4.2×10^{-5}	5.6×10^{-6}	6.4×10^{-6}	1.1×10^{-4}	2.5×10^{-6}	1.6×10^{-4}	6.7×10^{-4}	8.5×10^{-4}	2.9×10^{-5}	1.9×10^{-3}	5.6×10^{-2}
Cr-51	7.4×10^{-7}											7.4×10^{-7}
Cs-134	6.0×10^{-4}	2.2×10^{-5}	6.0×10^{-5}	8.0×10^{-5}	1.3×10^{-5}	4.2×10^{-5}	2.6×10^{-5}	7.0×10^{-4}	8.9×10^{-4}	2.2×10^{-5}	1.8×10^{-3}	2.4×10^{-3}
Cs-137	8.7×10^{-4}	1.7×10^{-5}	4.6×10^{-5}	6.2×10^{-5}	1.0×10^{-5}	3.5×10^{-5}	2.2×10^{-5}	5.3×10^{-4}	6.7×10^{-4}	1.5×10^{-5}	1.4×10^{-3}	2.3×10^{-3}
H-3	1.7×10^{-3}	1.6×10^{-3}	4.2×10^{-3}	7.4×10^{-4}	1.2×10^{-4}	2.0×10^{-4}	1.2×10^{-4}	4.1×10^{-2}	2.1×10^{-3}	2.5×10^{-3}	5.3×10^{-2}	5.5×10^{-2}
I-131	2.2×10^{-5}	1.4×10^{-3}	8.5×10^{-4}	4.1×10^{-4}	8.1×10^{-5}	1.7×10^{-4}	1.0×10^{-4}	5.0×10^{-2}	5.3×10^{-2}	1.8×10^{-3}	1.1×10^{-1}	1.1×10^{-1}
I-133		5.9×10^{-5}	1.3×10^{-6}	1.3×10^{-6}	1.1×10^{-6}	1.0×10^{-6}	6.5×10^{-7}	9.4×10^{-4}	2.4×10^{-4}	9.2×10^{-5}	1.3×10^{-3}	1.3×10^{-3}
Kr-85		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Mn-54	4.1×10^{-4}											4.1×10^{-4}
Ni-63	1.4×10^{-4}											1.4×10^{-4}
Sb-124	1.3×10^{-3}											1.3×10^{-3}
Sb-125	9.5×10^{-4}											9.5×10^{-4}
Te-123m	9.9×10^{-4}											9.9×10^{-4}
Xe-131m		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Xe-133		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Xe-135		0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Total	1.5×10^{0}	4.1×10^{-2}	2.3×10^{-1}	6.9×10^{-2}	1.2×10^{-2}	1.8×10^{-2}	1.2×10^{-2}	1.1×10^{0}	7.3×10^{-1}	1.4×10^{-1}	2.3×10^{0}	$3.8\ \ 10^{0}$

Figure A: Ingestion dose by terrestrial food group for all foodstuffs at critical rates – Adults

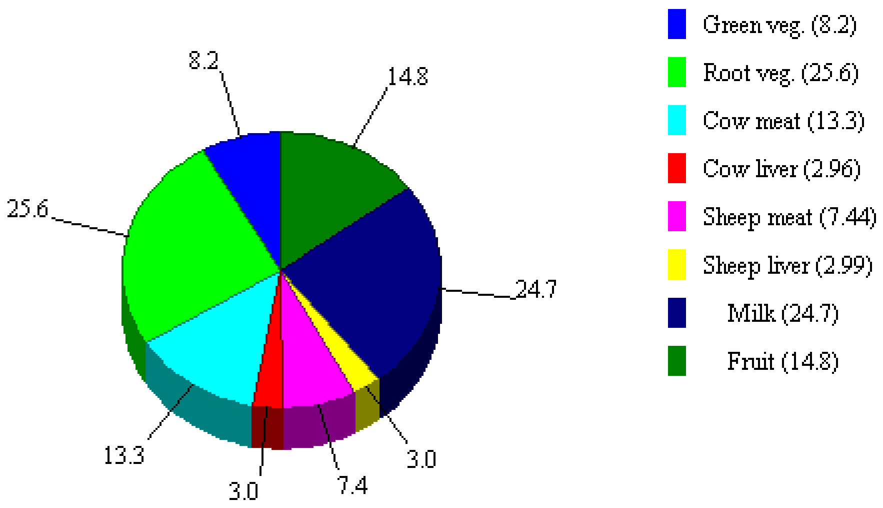


Figure B: Ingestion dose by terrestrial food group for all foodstuffs at critical rates – 10 year old Children

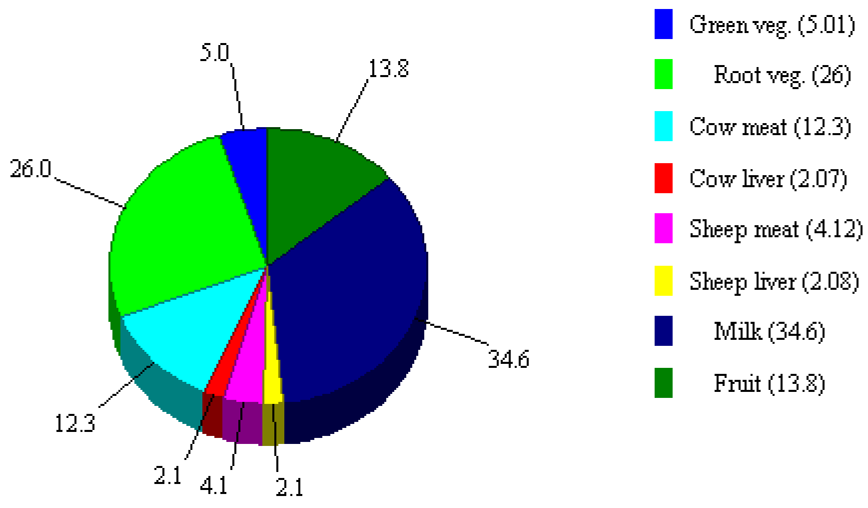
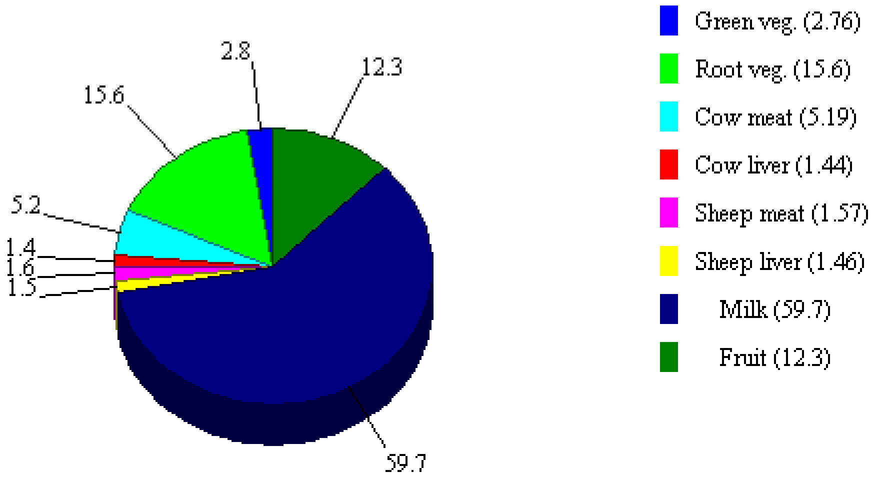


Figure C: Ingestion dose by terrestrial food group for all foodstuffs at critical rates – 1 year old Infants



ANNEX 4 – SHORT-TERM DOSES

Determination of the wind angle (σ_θ)

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:

$$\sigma_y^{\ 2} = \sigma_{y_t}^{\ 2} + \sigma_{y_w}^{\ 2}$$

Where: σ_{yt} = the turbulent diffusion component; and

Σ_{yw} = the component due to fluctuations in wind direction.

$$\sigma_{yw} = 0.065x\sqrt{\frac{7}{u}T}$$

Where: x = the downwind distance (m);

u = the windspeed at 10 m above ground level (m s^{-1}); and

T = the release duration (h).

At a downwind distance of 500 m, the turbulent diffusion standard deviation in the crosswind direction is 36 m ([Ref-1] - figure 10).

The wind angle (as used in ADMS 4) is therefore calculated from the standard deviation and distance:

$$\sigma_\theta = 2Tan^{-1}(\frac{0.5\sigma_y}{x})$$

This gives a wind angle of 21.7 degrees for a 24 hour release.

Table A: Time integrated concentration results (with assumptions for preparation losses)

Foodstuffs	TIC	Preparation losses (PF)
Milk	Peak concentration taken, and decayed through 365 days. Cs-137 inhalation:3.556 x 10^{-1} Bq kg^{-1}d per Bq m^{-3} ingestion: 3.406 x 10^{-1} Bq kg^{-1}d per Bq m^{-2} Cs-134 inhalation:3.052 x 10^{-1} Bq kg^{-1}d per Bq m^{-3} ingestion: 2.911 x 10^{-1} Bq kg^{-1}d per Bq m^{-2} I-131 inhalation:1.661 x 10^{-2} Bq kg^{-1}d per Bq m^{-3} ingestion: 1.800 x 10^{-2} Bq kg^{-1}d per Bq m^{-2} I-133 inhalation:8.765 x 10^{-4} Bq kg^{-1}d per Bq m^{-3} ingestion: 2.274 x 10^{-4} Bq kg^{-1}d per Bq m^{-2} Co-58 inhalation:1.057 x 10^{-1} Bq kg^{-1}d per Bq m^{-3} ingestion: 6.065 x 10^{-2} Bq kg^{-1}d per Bq m^{-2} Co-60 inhalation:3.676 x 10^{-1} Bq kg^{-1}d per Bq m^{-3} ingestion: 2.255 x 10^{-1} Bq kg^{-1}d per Bq m^{-2}	-
Cow meat	Peak concentration taken, and decayed through 365 days. Cs-137 inhalation:1.937 x 10^{+0} Bq kg^{-1}d per Bq m^{-3} ingestion: 5.702 x 10^{+0} Bq kg^{-1}d per Bq m^{-2} Cs-134 inhalation:1.660 x 10^{+0} Bq kg^{-1}d per Bq m^{-3} ingestion: 4.910 x 10^{+0} Bq kg^{-1}d per Bq m^{-2} I-131 inhalation:5.302 x 10^{-2} Bq kg^{-1}d per Bq m^{-3} ingestion: 3.385 x 10^{-2} Bq kg^{-1}d per Bq m^{-2} I-133 inhalation:2.799 x 10^{-3} Bq kg^{-1}d per Bq m^{-3} ingestion: 2.033 x 10^{-5} Bq kg^{-1}d per Bq m^{-2} Co-58 inhalation:2.474 x 10^{-3} Bq kg^{-1}d per Bq m^{-3} ingestion: 6.531 x 10^{-3} Bq kg^{-1}d per Bq m^{-2} Co-60 inhalation:8.902 x 10^{-3} Bq kg^{-1}d per Bq m^{-3} ingestion: 2.907 x 10^{-2} Bq kg^{-1}d per Bq m^{-2}	-
Sheep meat	Averaged between peak and end of year. Cs-137 inhalation:8.581 x 10^{-2} Bq kg^{-1}d per Bq m^{-3} ingestion: 2.719 x 10^{-1} Bq kg^{-1}d per Bq m^{-2} Cs-134 inhalation:8.365 x 10^{-2} Bq kg^{-1}d per Bq m^{-3} ingestion: 2.578 x 10^{-1} Bq kg^{-1}d per Bq m^{-2} I-131 inhalation:1.847 x 10^{-2} Bq kg^{-1}d per Bq m^{-3} ingestion: 5.625 x 10^{-3} Bq kg^{-1}d per Bq m^{-2} I-133 inhalation:2.682 x 10^{-3} Bq kg^{-1}d per Bq m^{-3} ingestion: 1.183 x 10^{-4} Bq kg^{-1}d per Bq m^{-2} Co-58 inhalation:1.001 x 10^{-3} Bq kg^{-1}d per Bq m^{-3} ingestion: 1.441 x 10^{-2} Bq kg^{-1}d per Bq m^{-2} Co-60 inhalation:2.597 x 10^{-3} Bq kg^{-1}d per Bq m^{-3} ingestion: 4.415 x 10^{-3} Bq kg^{-1}d per Bq m^{-2}	-
Green vegetables	Time integrated concentration from day 0 to 365. Cs-137 5.708 x 10^{+0} Bq kg^{-1}d per Bq m^{-2} Cs-134 5.618 x 10^{+0} Bq kg^{-1}d per Bq m^{-2} I-131 2.284 x 10^{+0} Bq kg^{-1}d per Bq m^{-2} I-133 5.224 x 10^{-1} Bq kg^{-1}d per Bq m^{-2} Co-58 5.641 x 10^{+0} Bq kg^{-1}d per Bq m^{-2} Co-60 4.814 x 10^{+0} Bq kg^{-1}d per Bq m^{-2}	0.2

Table A: Time integrated concentration results (with assumptions for preparation losses) (continued)

Foodstuffs	TIC	Preparation losses (PF)
Root vegetables	Activity in first 32 days, with no decay, followed by activity at day 32 decayed to day 133. Activity at 1st Feb. noted and model re-run to determine activity concentration in potatoes for days 349-365. Cs-137 $4.452 \times 10^{+0}$ Bq kg $^{-1}$d per Bq m^{-2} Cs-134 $3.764 \times 10^{+0}$ Bq kg $^{-1}$d per Bq m^{-2} I-131 3.526×10^{-2} Bq kg $^{-1}$d per Bq m^{-2} I-133 1.455×10^{-4} Bq kg $^{-1}$d per Bq m^{-2} Co-58 1.575×10^{-3} Bq kg $^{-1}$d per Bq m^{-2} Co-60 7.066×10^{-3} Bq kg $^{-1}$d per Bq m^{-2}	-
Fruit	Activity concentration at day 77 taken and decayed for remainder of year. No ingestion assumed for days 1-76. Cs-137 2.769×10^{-2} Bq kg $^{-1}$d per Bq m^{-2} Cs-134 2.296×10^{-2} Bq kg $^{-1}$d per Bq m^{-2} I-131 1.640×10^{-6} Bq kg $^{-1}$d per Bq m^{-2} I-133 $0.000 \times 10^{+0}$ Bq kg $^{-1}$d per Bq m^{-2} Co-58 4.664×10^{-4} Bq kg $^{-1}$d per Bq m^{-2} Co-60 2.590×10^{-2} Bq kg $^{-1}$d per Bq m^{-2}	-

Table B : Dose coefficients for external exposure

Radionuclides	Effective Cloud dose coefficient (Sv s^{-1} per Bq m^{-3})	Cloud skin dose coefficient (Sv s^{-1} per Bq m^{-3})	Effective deposit dose coefficient (Sv s^{-1} per Bq m^{-2})
H-3	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$	$0.0 \times 10^{+0}$
C-14	2.6×10^{-18}	2.43×10^{-16}	-
Co-58	4.44×10^{-14}	5.58×10^{-14}	9.25×10^{-16}
Co-60	1.19×10^{-13}	1.45×10^{-13}	2.3×10^{-15}
I-131*	1.69×10^{-14}	2.99×10^{-14}	3.64×10^{-16}
I-133*	2.89×10^{-14}	6.34×10^{-14}	6.56×10^{-16}
Cs-134	7.06×10^{-14}	9.45×10^{-14}	1.48×10^{-15}
Cs-137*	2.55×10^{-14}	4.39×10^{-14}	5.51×10^{-16}
Ar-41	6.14×10^{-14}	1.01×10^{-13}	1.22×10^{-15}
Kr-85	2.4×10^{-16}	1.32×10^{-14}	1.05×10^{-17}
Xe-131m	3.49×10^{-16}	4.82×10^{-15}	1.6×10^{-17}
Xe-133	1.33×10^{-15}	4.97×10^{-15}	3.95×10^{-17}
Xe-135**	1.1×10^{-14}	3.12×10^{-14}	2.5×10^{-16}

* For these radionuclides, the dose coefficients take into account the daughters.

** For Xe-135, the daughter is not taken into account, the half life of the daughter Cs-135 is so long in comparison with the half-life of Xe-135 that equilibrium cannot be achieved.

The dose coefficients are issued from the Federal Guidance Report n°12 (External exposure to radionuclides in air, water and soil. Oak Ridge National Laboratory, 1993). For the external effective dose coefficients (cloud and deposit), the tissue weighting factors which are taken into account come from ICRP 60.

Table C: Dose (Sv) to the Critical Group for Short-Term Aerial Discharges – Adult exposures, 24 hour release scenario

Radio-nuclides	Dose per short-term discharge (Sv)					
	inhalation	ingestion	cloud eff.	ground eff.	cloud skin	total eff *
Ar-41	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	1.21×10^{-8}	$0.00\ 10^{+0}$	1.98×10^{-8}	1.21×10^{-8}
C-14	4.06×10^{-8}	6.18×10^{-7}	3.52×10^{-13}	$0.00 \times 10^{+0}$	3.29×10^{-11}	6.59×10^{-7}
Co-58	4.31×10^{-11}	7.84×10^{-11}	2.59×10^{-12}	4.89×10^{-9}	3.26×10^{-12}	5.01×10^{-9}
Co-60	3.18×10^{-10}	8.91×10^{-10}	8.21×10^{-12}	4.94×10^{-8}	1.00×10^{-11}	5.07×10^{-8}
Cs-134	1.63×10^{-10}	3.30×10^{-8}	3.79×10^{-12}	2.24×10^{-8}	5.07×10^{-12}	5.55×10^{-8}
Cs-137	1.02×10^{-10}	2.38×10^{-8}	1.23×10^{-12}	8.71×10^{-9}	2.11×10^{-12}	3.26×10^{-8}
H-3	3.78×10^{-9}	1.64×10^{-8}	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	2.02×10^{-8}
I-131	2.16×10^{-9}	4.87×10^{-9}	3.97×10^{-12}	9.45×10^{-10}	7.01×10^{-12}	7.99×10^{-9}
I-133	5.16×10^{-10}	1.26×10^{-10}	8.11×10^{-12}	2.19×10^{-10}	1.78×10^{-11}	8.69×10^{-10}
Kr-85	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	2.26×10^{-10}	$0.00 \times 10^{+0}$	1.24×10^{-8}	2.26×10^{-10}
Xe-131m	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	7.09×10^{-12}	$0.00 \times 10^{+0}$	9.80×10^{-11}	7.09×10^{-12}
Xe-133	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	5.69×10^{-9}	$0.00 \times 10^{+0}$	2.12×10^{-8}	5.69×10^{-9}
Xe-135	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	1.48×10^{-8}	$0.00 \times 10^{+0}$	4.19×10^{-8}	1.48×10^{-8}
Total	4.76×10^{-8}	6.97×10^{-7}	3.28×10^{-8}	8.66×10^{-8}	9.56×10^{-8}	8.64×10^{-7}

* The total effective results do not take into account the cloud skin doses

Table D: Dose (Sv) to the Critical Group for Short-Term Aerial Discharges – Child exposures, 24 hour release scenario

Radio-nuclides	Dose per short-term discharge (Sv)					
	inhalation	ingestion	cloud eff.	ground eff.	cloud skin	total eff *
Ar-41	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	7.24×10^{-9}	$0.00 \times 10^{+0}$	1.19×10^{-8}	7.24×10^{-9}
C-14	3.16×10^{-8}	7.26×10^{-7}	2.11×10^{-13}	$0.00 \times 10^{+0}$	1.98×10^{-11}	7.58×10^{-7}
Co-58	2.64×10^{-11}	1.21×10^{-10}	1.56×10^{-12}	2.49×10^{-9}	1.96×10^{-12}	2.64×10^{-9}
Co-60	1.94×10^{-10}	2.49×10^{-9}	4.92×10^{-12}	2.52×10^{-8}	6.00×10^{-12}	2.79×10^{-8}
Cs-134	5.34×10^{-11}	1.86×10^{-8}	2.27×10^{-12}	1.14×10^{-8}	3.04×10^{-12}	3.01×10^{-8}
Cs-137	3.35×10^{-11}	1.41×10^{-8}	7.37×10^{-13}	4.44×10^{-9}	1.27×10^{-12}	1.85×10^{-8}
H-3	2.76×10^{-9}	1.89×10^{-8}	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	2.17×10^{-8}
I-131	2.12×10^{-9}	7.62×10^{-9}	2.38×10^{-12}	4.81×10^{-10}	4.21×10^{-12}	1.02×10^{-8}
I-133	5.11×10^{-10}	1.31×10^{-10}	4.86×10^{-12}	1.12×10^{-10}	1.07×10^{-11}	7.58×10^{-10}
Kr-85	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	1.36×10^{-10}	$0.00 \times 10^{+0}$	7.46×10^{-9}	1.36×10^{-10}
Xe-131m	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	4.26×10^{-12}	$0.00 \times 10^{+0}$	5.88×10^{-11}	4.26×10^{-12}
Xe-133	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	3.41×10^{-9}	$0.00 \times 10^{+0}$	1.27×10^{-8}	3.41×10^{-9}
Xe-135	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	8.86×10^{-9}	$0.00 \times 10^{+0}$	2.52×10^{-8}	8.86×10^{-9}
Total	3.73×10^{-8}	7.88×10^{-7}	1.97×10^{-8}	4.41×10^{-8}	5.74×10^{-8}	8.89×10^{-7}

* The total effective results do not take into account the cloud skin doses

Table E : Dose (Sv) to the Critical Group for Short-Term Aerial Discharges – Infant exposures, 24 hour release scenario

Radio-nuclides	Dose per short-term discharge (Sv)					
	inhalation	ingestion	cloud eff.	ground eff.	cloud skin	total eff *
Ar-41	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	5.63×10^{-9}	$0.00 \times 10^{+0}$	9.26×10^{-9}	5.63×10^{-9}
C-14	2.21×10^{-8}	1.30×10^{-6}	1.64×10^{-13}	$0.00 \times 10^{+0}$	1.54×10^{-11}	1.32×10^{-6}
Co-58	2.21×10^{-11}	3.01×10^{-10}	1.21×10^{-12}	1.69×10^{-9}	1.52×10^{-12}	2.01×10^{-9}
Co-60	1.36×10^{-10}	7.34×10^{-9}	3.83×10^{-12}	1.71×10^{-8}	4.67×10^{-12}	2.46×10^{-8}
Cs-134	2.27×10^{-11}	1.23×10^{-8}	1.77×10^{-12}	7.74×10^{-9}	2.36×10^{-12}	2.01×10^{-8}
Cs-137	1.51×10^{-11}	9.72×10^{-9}	5.74×10^{-13}	3.01×10^{-9}	9.86×10^{-13}	1.27×10^{-8}
H-3	1.99×10^{-9}	4.25×10^{-8}	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	4.44×10^{-8}
I-131	2.18×10^{-9}	1.98×10^{-8}	1.85×10^{-12}	3.26×10^{-10}	3.27×10^{-12}	2.23×10^{-8}
I-133	6.68×10^{-10}	2.31×10^{-10}	3.78×10^{-12}	7.57×10^{-11}	8.30×10^{-12}	9.78×10^{-10}
Kr-85	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	1.05×10^{-10}	$0.00 \times 10^{+0}$	5.80×10^{-9}	1.05×10^{-10}
Xe-131m	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	3.31×10^{-12}	$0.00 \times 10^{+0}$	4.57×10^{-11}	3.31×10^{-12}
Xe-133	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	2.65×10^{-9}	$0.00 \times 10^{+0}$	9.91×10^{-9}	2.65×10^{-9}
Xe-135	$0.00 \times 10^{+0}$	$0.00 \times 10^{+0}$	6.89×10^{-9}	$0.00 \times 10^{+0}$	1.96×10^{-8}	6.89×10^{-9}
total	2.71×10^{-8}	1.39×10^{-6}	1.53×10^{-8}	2.99×10^{-8}	4.46×10^{-8}	1.46×10^{-6}

* The total effective results do not take into account the cloud skin doses

ANNEX 5 – BUILD-UP

Table A: Soil concentrations for a unit deposition rate at year 60

Radionuclides	Soil concentration at year 60 (Bq kg^{-1})
Co-60	4.36E-03
Co-58	1.68E-04
Cs-134	1.45E-03
Cs-137	1.11E-02
I-131	3.32E-04
I-133	4.17E-05

Table B: Determination of the effective deposition rates

Radio-nuclides	Activity concentration in air (NRPB-R91 tab p 57) (Bq s m^{-3} per unit release 1 Bq)	EPR activity released (Bq s^{-1})	Activity concentration in air for EPR release (Bq m^{-3})	Deposition velocity (m s^{-1})	Deposition rate at 200 m (Bq m^{-2} s^{-1})
Co-60	2.50E-06	3.23E+00	8.09E-06	0.001	8.09E-09
Co-58	2.50E-06	2.75E+00	6.87E-06	0.001	6.87E-09
Cs-134	2.50E-06	2.52E+00	6.31E-06	0.001	6.31E-09
Cs-137	2.50E-06	2.26E+00	5.66E-06	0.001	5.66E-09
I-131	2.50E-06	5.77E+00	1.44E-05	0.01	1.44E-07
I-133	2.50E-06	6.91E+00	1.73E-05	0.01	1.73E-07

Table C: Determination of the actual soil concentrations at year 60

Radio-nuclides	Soil concentration at year 60 (Bq kg^{-1}) for 1 Bq m^{-2} s^{-1}	Deposition rate at 200 m (Bq m^{-2} s^{-1})	Soil concentration for EPR deposition rate at 200 m (Bq kg^{-1})
Co-60	5.396E+05	8.09E-09	4.36E-03
Co-58	2.440E+04	6.87E-09	1.68E-04
Cs-134	2.303E+05	6.31E-09	1.45E-03
Cs-137	1.957E+06	5.66E-09	1.11E-02
I-131	2.304E+03	1.44E-07	3.32E-04
I-133	2.415E+02	1.73E-07	4.17E-05

Table D: Activity concentrations in air for the radionuclides which are not likely to be deposited on the soil at year 60

Radio-nuclides	Air concentration ($Bq\ m^{-3}$)
H-3	2.38E-01
C-14	7.13E-02
Kr-85	2.48E-01
Xe-133	1.13E+00
Xe-135	3.54E-01
Ar-41	5.18E-02
Xe-131m	5.35E-03

Table E: Dose associated to the build-up in soil ($Sv\ y^{-1}$) at year 60

Radio-nuclides	Activity concentration in soil at year 60 ($Bq\ g^{-1}$)	Factor from NRPB-W36 (Dose $Sv\ y^{-1}$ per $Bq\ g^{-1}$)	Dose associated to the build-up in soil ($Sv\ y^{-1}$)
Co-60	4.36E-06	1.11E-03	4.84E-09
Cs-134	1.45E-06	6.34E-04	9.21E-10
Cs-137	1.11E-05	2.41E-04	2.67E-09
Total dose associated to the build-up in soil			**8.43E-09**

Table F: Dose associated to the build-up (Sv y^{-1}) at year 60 – Swimmers

Radionuclides	Activity concentrations in seabed sediments (Bq kg^{-1})	Dose per unit contamination (Table 17, NRPB W36) (Sv y^{-1} per Bq g^{-1})	Dose (Swimmers) (Sv y^{-1})
Ag-110m*	5.70E-03	*7.52E-06*	*4.29E-11*
C-14*	1.60E+01	*7.52E-06*	*1.20E-07*
Co-60	5.70E+00	7.52E-06	4.29E-08
Cs-134	4.00E-02	4.50E-06	1.80E-10
Cs-137	2.00E-01	1.72E-06	3.44E-10
H-3	4.90E+00	7.20E-14	3.53E-16
Mn-54*	1.40E-01	*7.52E-06*	*1.05E-09*
Ni-63	2.80E+00	4.20E-14	1.18E-16
Sb-125*	2.40E-02	*7.52E-06*	*1.80E-10*
Te-123*	6.60E-16	*7.52E-06*	*4.96E-24*
Te-123m*	1.30E-03	*7.52E-06*	*9.78E-12*
Te-125m*	2.20E-02	*7.52E-06*	*1.65E-10*
Total (Sv y^{-1})			**1.65E-07**

* *The doses per unit contamination retained for these radionuclides correspond to the maximum value among all the radionuclides presented in the NRPB-W36 report, Table 17.*

Table G: Dose associated to the build-up (Sv y^{-1}) at year 60 – Fisherman and his family

Radionuclides	Activity concentrations in seabed sediments[17] (Bq kg^{-1})	Dose per unit contamination (Table 15, NRPB W36) (Sv y^{-1} per Bq g^{-1})	Dose (Fisherman and his family) (Sv y^{-1})
Ag-110m*	5.70E-03	*4.14E-04*	*2.36E-09*
C-14*	1.60E+01	*4.14E-04*	*6.62E-06*
Co-60	5.70E+00	*4.14E-04*	*2.36E-06*
Cs-134	4.00E-02	*2.38E-04*	*9.52E-09*
Cs-137	2.00E-01	*9.06E-05*	*1.81E-08*
H-3	4.90E+00	*6.48E-12*	*3.18E-14*
Mn-54*	1.40E-01	*4.14E-04*	*5.80E-08*
Ni-63	2.80E+00	*4.13E-10*	*1.21E-12*
Sb-125*	2.40E-02	*4.14E-04*	*9.94E-09*
Te-123*	6.60E-16	*4.14E-04*	*2.73E-22*
Te-123m*	1.30E-03	*4.14E-04*	*5.38E-10*
Te-125m*	2.20E-02	*4.14E-04*	*9.11E-09*
Total (Sv y^{-1})			**9.09E-06**

* *The doses per unit contamination retained for these radionuclides correspond to the maximum value among all the radionuclides presented in the NRPB-W36 report, Table 15.*

[17] Activity concentrations in seabed sediment are taken into account because they are higher than activity concentrations in land.

ANNEX 6 – COLLECTIVE DOSES

Table A: Collective Dose to UK, European and World populations from Atmospheric discharges

Collective Dose (man Sv) truncated at year 500			
Radionuclides	**Population of interest**		
	UK	**Europe**	**World**
H-3	2.3×10^{-3}	7.8×10^{-3}	
C-14	2.0×10^{-1}	1.2×10^{0}	
Ar-41	6.0×10^{-5}	7.0×10^{-5}	
Co-58	1.1×10^{-5}	2.4×10^{-5}	
Co-60	5.2×10^{-4}	1.1×10^{-3}	
Kr-85	1.4×10^{-5}	4.7×10^{-5}	
I-131	9.6×10^{-5}	9.9×10^{-5}	
I-133	1.2×10^{-5}	1.8×10^{-5}	
Xe-131m	4.6×10^{-7}	1.4×10^{-6}	
Xe-133	3.9×10^{-4}	1.1×10^{-3}	
Xe-135	3.6×10^{-4}	5.4×10^{-4}	
Cs-134	2.8×10^{-4}	9.0×10^{-4}	
Cs-137	3.5×10^{-4}	9.4×10^{-4}	
Total first pass	2.0×10^{-1}	1.2×10^{0}	
H-3 Global	5.4×10^{-6}	6.9×10^{-5}	9.8×10^{-4}
C-14 Global	8.7×10^{-2}	$1.1 \times 10^{+0}$	$1.6 \times 10^{+1}$
Kr-85 Global	4.4×10^{-6}	5.5×10^{-5}	7.9×10^{-4}
Total (first pass and global circulation)	$\mathbf{2.9 \times 10^{-1}}$	$\mathbf{2.3 \times 10^{0}}$	$\mathbf{1.6 \times 10^{+1}}$

Table B: Collective Dose to UK, European and World populations from liquid discharges

Collective Dose (man Sv) truncated at year 500			
Radionuclides	**Population of interest**		
	UK	**Europe**	**World**
I-131	1.8×10^{-8}	2.3×10^{-8}	2.3×10^{-8}
H-3	1.4×10^{-5}	6.1×10^{-5}	6.2×10^{-5}
H-3 Global	1.8×10^{-5}	2.3×10^{-4}	3.2×10^{-3}
Total H-3	3.2×10^{-5}	2.9×10^{-4}	3.3×10^{-3}
C-14	1.4×10^{-2}	7.5×10^{-2}	8.1×10^{-2}
C-14 Global	5.7×10^{-3}	7.0×10^{-2}	1.0×10^{0}
Total C-14	2.0×10^{-2}	1.5×10^{-1}	1.1×10^{0}
Cr-51	1.2×10^{-9}	2.3×10^{-9}	2.3×10^{-9}
Mn-54	6.0×10^{-7}	1.8×10^{-6}	1.8×10^{-6}
Co-58	3.4×10^{-6}	9.8×10^{-6}	9.8×10^{-6}
Co-60	5.7×10^{-5}	2.2×10^{-4}	2.2×10^{-4}
Ni-63	7.7×10^{-7}	3.7×10^{-6}	3.8×10^{-6}
Ag-110m	5.4×10^{-5}	9.6×10^{-5}	9.6×10^{-5}
Sb-124	1.2×10^{-6}	3.7×10^{-6}	3.7×10^{-6}
Sb-125	2.5×10^{-6}	1.1×10^{-5}	1.2×10^{-5}
Te-123m	1.7×10^{-6}	5.2×10^{-6}	5.2×10^{-6}
Cs-134	5.5×10^{-6}	2.9×10^{-5}	2.9×10^{-5}
Cs-137	9.2×10^{-6}	5.2×10^{-5}	5.4×10^{-5}
Total first pass	1.4×10^{-2}	7.6×10^{-2}	8.1×10^{-2}
Total Global	5.7×10^{-3}	7.1×10^{-2}	1.0×10^{0}
Total (first pass and global circulation)	$\mathbf{2.0 \times 10^{-2}}$	$\mathbf{1.5 \times 10^{-1}}$	$\mathbf{1.1 \times 10^{0}}$

SUB-CHAPTER 11.1 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

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[Ref-2] B Lambers, R W Allott and J G Titley. Initial Radiological Assessment Methodology – Part 1 User Report. Science Report: SC030162/SR1. Environment Agency. May 2006. (E)

[Ref-3] B Lambers and M C Thorne. Initial Radiological Assessment Methodology – Part 2 Methods and Input Data. Science Report: SC030162/SR2. Environment Agency. May 2006. (E)

[Ref-4] J R Simmonds, G Lawson and A Mayall. Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment. EUR 15760 EN. Radiation Protection 72. European Commission. 1995. (E)

1.1. STAGE 1 OF THE INITIAL RADIOLOGICAL ASSESSMENT METHODOLOGY

1.1.1. Assessment methodology

[Ref-1] ICRP Publication 88. Doses to the Embryo and Fetus from Intakes of Radionuclides by the Mother. (E)

a) Exposure groups

[Ref-1] B Lambers and M C Thorne. Initial Radiological Assessment Methodology – Part 2 Methods and Input Data. Science Report: SC030162/SR2. Environment Agency. May 2006. (E)

b) Food intake

[Ref-1] K R Smith and A L Jones. Generalised Habit Data for Radiological Assessments. NRPB-W41. National Radiological Protection Board. ISBN 0 85951 513 3. May 2003. (E)

c) Other parameters

[Ref-1] B Lambers and M C Thorne. Initial Radiological Assessment Methodology – Part 2 Methods and Input Data. Science Report: SC030162/SR2. Environment Agency. May 2006. (E)

1.3. STAGE 3 OF THE INITIAL RADIOLOGICAL ASSESSMENT METHODOLOGY

[Ref-1] A Mayall, T Cabianca, C Attwood, C A Fayers, J G Smith, J Penfold, D Steadman, G Martin, T P Morris and J R Simmonds. PC CREAM Installing and using the PC system for assessing the radioalogical impact of routine releases. EUR 17791 EN, NRPB-SR296. National Radiological Protection Board. 1997. (E)

1.3.1. Site characteristics

[Ref-1] R H Clarke Chairman of the Working Group. A Model for Short and Medium Range Dispersion of Radionuclides Released to the Atmosphere. NRPB-R91. National Radiological Protection Board. 1979. (E)

[Ref-2] J R Simmonds, G Lawson and A Mayall. Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment. EUR 15760 EN. Radiation Protection 72. European Commission. 1995. (E)

1.3.2. Annual dose to the most exposed members of the public from gaseous discharges

1.3.2.1. Assessment methodology

a) Exposure group and habit data

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c) Food intake

[Ref-1] K R Smith and A L Jones. Generalised Habit Data for Radiological Assessments. NRPB-W41. National Radiological Protection Board. ISBN 0 85951 513 3. May 2003. (E)

1.3.3. Annual dose to the most exposed members of the public from liquid discharges

1.3.3.1. Assessment methodology

a) Exposure group and habit data

[Ref-1] K R Smith and A L Jones. Generalised Habit Data for Radiological Assessments. NRPB-W41. National Radiological Protection Board. ISBN 0 85951 513 3. May 2003. (E)

[Ref-2] ICRP Publication 66: Human Respiratory Tract Model for Radiological Protection, 66. Annals of the ICRP Volume 24/1-3. International Commission on Radiological Protection. ISBN 978-0-08-041154-5. Elsevier. 1995. (E)

c) Food intake

[Ref-1] K R Smith and A L Jones. Generalised Habit Data for Radiological Assessments. NRPB-W41. National Radiological Protection Board. ISBN 0 85951 513 3. May 2003. (E)

1.3.4. Annual dose to the most exposed members of the public from all discharges

1.3.4.1. Terrestrial members of public also consuming sea food

a) Assessment methodology

[Ref-1] K R Smith and A L Jones. Generalised Habit Data for Radiological Assessments. NRPB-W41. National Radiological Protection Board. ISBN 0 85951 513 3. May 2003. (E)

1.3.4.2. Marine members of public also consuming terrestrial foodstuffs.

a) Assessment methodology

[Ref-1] K R Smith and A L Jones. Generalised Habit Data for Radiological Assessments. NRPB-W41. National Radiological Protection Board. ISBN 0 85951 513 3. May 2003. (E)

1.3.5. Annual dose from direct radiation to the most exposed members of the public

1.3.5.1. Methodology and inputs

[Ref-1] B Lambers and M C Thorne. Initial Radiological Assessment Methodology – Part 2 Methods and Input Data. Science Report: SC030162/SR2. Environment Agency. May 2006. (E)

1.3.5.3. Discussion

[Ref-1] S J Watson, A L Jones, W B Oatway and J S Hughes. Ionising Radiation Exposure of the UK Population: 2005 Review. HPA-RPD-001. Health Protection Agency, Centre for Radiation Chemical and Environmental Hazards, Radiation Protection Division. 2005. (E)

1.3.7. Conclusion

[Ref-1] S J Watson, A L Jones, W B Oatway and J S Hughes. Ionising Radiation Exposure of the UK Population: 2005 Review. HPA-RPD-001. Health Protection Agency, Centre for Radiation Chemical and Environmental Hazards, Radiation Protection Division. 2005 (E)

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2.1. ASSESSMENT METHODOLOGY

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[Ref-4] J R Simmonds, G Lawson and A Mayall, Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment. EUR 15760 EN. Radiation Protection 72. European Commission. 1995. (E)

[Ref-5] P Teale and J Brown. Modelling Approach for the Transfer of Actinides to Fruit Species of Importance in the UK. NRPB-W46. National Radiological Protection Board. 2003. (E)

2.3. DEFINITION OF REPRESENTATIVE SITE PARAMETERS FOR SHORT-TERM DISCHARGE

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[Ref-2] ICRP Publication 66: Human Respiratory Tract Model As a Tool for Predicting Lung Burdens for Risk Assessment of Ambient Aerosols. (E)

2.5. INGESTION DOSE MODELLING

2.5.1. Methodology

[Ref-1] J Brown and J R Simmonds. FARMLAND A Dynamic Model for the Transfer of Radionuclides through Terrestrial Foodchains. NRPB-R273. National Radiological Protection Board. 1995. (E)

[Ref-2] B Lambers and M C Thorne. Initial Radiological Assessment Methodology – Part 2 Methods and Input Data. Science Report: SC030162/SR2. Environment Agency. May 2006. (E)

3. POTENTIAL BUILD-UP OF RADIONUCLIDES IN THE ENVIRONMENT

3.1. ASSESSMENT METHODOLOGY

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[Ref-2] W B Oatway and S F Mobbs. Methodology for Estimating the Doses to members of the Public from the Future Use of Land Previously Contaminated with Radioactivity. NRPB-W36. National Radiological Protection Board. May 2003. (E)

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4.1. ASSESSMENT METHODOLOGY

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4.2. RESULTS

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ANNEX 4

[Ref-1] R H Clarke Chairman of the Working Group. A Model for Short and Medium Range Dispersion of Radionuclides Released to the Atmosphere. NRPB-R91. National Radiological Protection Board. 1979. (E)

SUB-CHAPTER 11.2 – IMPACT OF RADIOACTIVE DISCHARGES ON NON HUMAN SPECIES

ANNEX 1 - LIST OF TABLES

ANNEX 2 - LIST OF TABLES

1. METHODOLOGY AND INPUTS

The ERICA (Beresford, 2007 [Ref-1]) integrated approach to the assessment and management of environmental risks from ionising radiation is used to meet the requirements of Environment Agency (E) Process and Information (P&I) Document [Ref-2] requirement 2.10. Use of ERICA as the assessment tool in this situation is warranted as this method is the current European standard.

The Tier 1 ERICA assessment is designed to be simple and conservative, requiring a minimum of input data and enabling the user to exit the process and exempt the situation from further evaluation, provided the assessment meets a predefined screening criterion. The default screening criterion in the ERICA Integrated Approach is an *incremental dose rate of 10 µGy* h^{-1}, to be used for all ecosystems and organisms. This value was derived from a species sensitivity distribution analysis performed on chronic exposure data in the FREDERICA database and is supported by other methods for determining predicted no-effect values.

For Tier 1, the predefined screening dose rate is back-calculated to yield Environmental Media Concentration Limits (EMCLs) for all reference organism or radionuclide combinations. The Tool compares the input media concentrations with the most restrictive EMCL for each radionuclide and determines a Risk Quotient (RQ). If the RQ is less than one, then the tool suggests that the user should exit the assessment process. If the RQ is greater than one, the user is advised to continue with the assessment.

At this generic stage, it is assumed that all reference organisms specified in ERICA are present. There are a number of species that do not directly map over from EA R&D report 128 (Copplestone, 2001 [Ref-3]) to ERICA, these include: moss, germinating seed, fungus, caterpillar, ant, herbivorous mammal and carnivorous mammal for terrestrial organisms and: small and large benthic crustacean, fish egg, seal and whale for marine organisms. However, for many of these organisms, there is a similar organism in ERICA that is sufficient for this assessment.

Not all radionuclides are available at Tier 1, it is therefore necessary to carry out a Tier 2 assessment using the default values for all parameters. Doses to non human species from noble gases cannot be assessed using the ERICA model at any tier, so they have not been included in the terrestrial assessment of the generic site. For the specific site R&D report 128 will be used to assess the impact of noble gases on the terrestrial ecosystem. The tellurium radionuclides of interest are not available at Tier 1, however, there is a tellurium radionuclide by default, and therefore concentration ratios and distribution coefficients for this element are available at Tier 2. There is no inbuilt data available for concentration ratios and distribution coefficients for chromium in the marine environment in ERICA. Therefore data for this element was taken from IAEA TRS422 (IAEA, 2004 [Ref-4]) where available. Where no data was available, the most restrictive value for other radionuclides was used. Chromium is not a limiting radionuclide so this method is reasonable. The concentration ratios and occupancy factors for each marine organism are presented in Annex 1 - Tables 3 and 4 respectively for all discharged elements. The marine distribution coefficients are presented in Annex 1 - Table 5.

The concentration ratios and occupancy factors for each terrestrial organism are presented in Annex 1 - Tables 6 and 7 respectively for each of the discharged elements.

In order to carry out an assessment, it is necessary to determine the activity concentration of discharged nuclides in seawater and seabed sediments (Annex 1 - Table 2) and in air and soil (Annex 1 - Table 1). These values are calculated in Sub-chapter 11.1 for the assessment of the potential build-up of radionuclides in the environment, and are used as the input activity concentrations in ERICA.

2. RESULTS

The risk quotient for releases to the marine environment on marine organisms is presented in Annex 2 - Table 1 for each of the default ERICA organisms based on a screening value of 10 µGy h^{-1}. The maximum risk quotient was 1.1×10^{-3} for polychaete worms. The associated dose for these organisms is 1.1×10^{-2} µGy h^{-1}. The total dose for all ERICA marine organisms is presented in Annex 2 - Table 2.

The risk quotient for atmospheric releases to the terrestrial environment on terrestrial organisms is presented in Annex 2 - Table 4 for each of the default ERICA organisms based on a screening value of 10 µGy h^{-1}. The maximum risk quotient was 3.14×10^{-4} for mammals. The associated dose for these organisms is 3.14×10^{-3} µGy h^{-1}. The total dose for all ERICA terrestrial organisms is presented in Annex 2 - Table 5.

3. DISCUSSION

The greatest dose impact to all non human species from atmospheric discharges is from carbon-14 (Annex 2 - Table 6). Cobalt-60 is the dominant radionuclide for dose to many of the ERICA marine organisms, including Polychaete worms which receive the highest dose of all marine organisms. Carbon-14 gives the highest dose for some organisms (Annex 2 - Table 3).

All doses to non human species are below the ERICA screening value of 10 µGy h^{-1} and are far below the EA biota dose limits:

- terrestrial animal populations at chronic dose rates below 40 µGy h^{-1};
- terrestrial plant populations at chronic dose rates below 400 µGy h^{-1}; and
- populations of freshwater and coastal organisms at chronic dose rates below 400 µGy h^{-1};

The impact of the radioactive discharges on non human species can be regarded as negligible.

ANNEX 1 – INPUT DATA

Annex 1 - Table 1: Activity concentration in air and soil at year 60

Radionuclides	Air conc. ($Bq\ m^{-3}$)	Soil conc. ($Bq\ kg^{-1}$)
H-3	2.38×10^{-1}	
C-14	7.13×10^{-2}	
Co-58	6.87×10^{-6}	1.68×10^{-4}
Co-60	8.09×10^{-6}	4.36×10^{-3}
Cs-134	6.31×10^{-6}	1.45×10^{-3}
Cs-137	5.66×10^{-6}	1.11×10^{-2}
I-131	1.44×10^{-5}	3.32×10^{-4}
I-133	1.73×10^{-5}	4.17×10^{-5}
Ar-41	5.18×10^{-2}	
Kr-85	2.48×10^{-1}	
Xe-131m	5.35×10^{-3}	
Xe-133	1.13×10^{0}	
Xe-135	3.54×10^{-1}	

Annex 1 - Table 2: Activity concentration in unfiltered seawater and seabed sediments at year 60

Radionuclides	Seawater conc. ($Bq\ l^{-1}$)	Sediment conc. ($Bq\ kg^{-1}$)
Ag-110m	5.1×10^{-5}	5.7×10^{-3}
C-14	8.8×10^{-3}	1.6×10^{1}
Co-58	7.7×10^{-5}	2.7×10^{-1}
Co-60	1.2×10^{-4}	5.7×10^{0}
Cr-51	3.1×10^{-6}	1.7×10^{-3}
Cs-134	5.0×10^{-5}	4.0×10^{-2}
Cs-137	8.6×10^{-5}	2.0×10^{-1}
H-3	7.1×10^{0}	4.9×10^{0}
I-131	2.5×10^{-6}	2.2×10^{-7}
Mn-54	1.0×10^{-5}	1.4×10^{-1}
Ni-63	4.9×10^{-5}	2.8×10^{0}
Sb-124	4.0×10^{-5}	1.2×10^{-3}
Sb-125	7.5×10^{-5}	2.4×10^{-2}
Te-123[(1)]	5.5×10^{-20}	6.6×10^{-16}
Te-123m	2.3×10^{-5}	1.3×10^{-3}
Te-125m[(1)]	2.6×10^{-6}	2.2×10^{-2}

(1) These are daughter products of Sb-125 and Te-123m whose results are presented in ASSESSOR outputs.

Annex 1 - Table 3: Concentration ratios for marine non human species

Elements	Concentration ratio (Bq kg^{-1} or Bq l^{-1})													
	Wading bird	Benthic fish	Benthic mollusc	Crust-acean	Macro-algae	Mammal	Pelagic fish	Phyto-plankton	Poly-chaete worm	Reptile	Sea anemone or true corals - colony	Sea anemone or true corals - polyp	Vascular plant	Zoo-plankton
Ag	22,000	2900	32,000	16,000	1300	22,000	2900	56,000	27,000	22,000	3300	3300	1300	17,000
C	17,000	12,000	10,000	10,000	8000	17,000	12,000	5600	10,000	17,000	11,000	11,000	8000	10,000
Co	500	5600	5100	1800	2100	500	5600	3100	8300	500	330	330	2100	4800
Cs	460	86	66	41	120	210	86	130	180	460	380	380	22	110
H	1	1	1	1	1	1	1	1	1	1	1	1	1	1
I	0.68	3.6	14	3.6	4100	0.68	3.6	960	14	0.68	53	53	4100	3000
Mn	4600	740	11,000	5900	7900	4600	740	3500	3200	4600	12,000	12,000	30,000	2500
Ni	170	170	6400	550	790	170	170	1400	4200	170	3800	3800	790	1000
Sb	230	230	530	1400	160	230	230	1000	1400	230	90	90	160	1300
Te	1000	1000	1000	1000	10,000	1000	1000	13,000	1000	1000	1000	1000	10,000	1000
Cr	22,000	200	2000	100	6000	6000	200	5000	5000	22,000	12,000	12,000	30,000	1000

Values entered in blue above for Cr have been taken from IAEA TRS422.
Values entered in red above for Cr have been taken from the most limiting element for the particular organism.

Annex 1 - Table 4: Occupancy factors for marine non human species

	Wading bird	Benthic fish	Benthic mollusc	Crust-acean	Macro-algae	Mammal	Pelagic fish	Phyto-plankton	Poly-chaete worm	Reptile	Sea anemone or true corals - colony	Sea anemone or true corals - polyp	Vascular plant	Zoo-plankton
Water-surface	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	1	0	0	0	0	1	1	1	0	1	0	0	0	1
Sediment-surface	0	1	1	1	1	0	0	0	0	0	1	1	1	0
Sediment	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Annex 1 - Table 5: Distribution coefficients for marine environment

Elements	**Kd (l kg^{-1})**
Ag	10000
C	1000
Co	300,000
Cs	4000
H	1
I	70
Mn	2,000,000
Ni	20,000
Sb	2000
Te	1000
Cr	50,000

Annex 1 - Table 6: Concentration ratios for terrestrial non human species

Elements	Concentration ratio (Bq kg^{-1} or Bq l^{-1})													
	Amphibian	Bird	Bird egg	Detritivorous invertebrate	Flying insects	Gastropod	Grasses & Herbs	Lichen & bryophytes	Mammal (Deer)	Mammal (Rat)	Reptile	Shrub	Soil Invertebrate (worm)	Tree
C	1340	1340	890	430	430	430	890	890	1340	1340	1340	890	430	1300
Co	0.2955	0.2955	0.2955	0.0035	0.0061	0.0061	0.0135	0.216	0.2955	0.2955	0.2955	0.7503	0.0061	0.0183
Cs	0.5369	0.7503	0.03	0.1341	0.0551	0.0427	0.6934	5.6047	2.874	2.874	3.59	3.9723	0.0894	0.1632
H	150	150	150	150	150	150	150	150	150	150	150	150	150	150
I	0.4	0.4	160	0.3011	0.3011	0.1798	0.14	0.36	0.4	0.4	0.4	0.14	0.1562	0.14

Annex 1 - Table 7: Occupancy factors for terrestrial non human species

	Amphibian	Bird	Bird egg	Detritivorous invertebrate	Flying insects	Gastropod	Grasses & Herbs	Lichen & bryophytes	Mammal (Deer)	Mammal (Rat)	Reptile	Shrub	Soil Invertebrate (worm)	Tree
In-air	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In-soil	0	0	0	1	0	0	0	0	0	1	0	0	1	0
On-soil	1	1	1	0	1	1	1	1	1	0	1	1	0	1

ANNEX 2 – RESULTS

Annex 2 - Table 1: Risk to non human species from marine discharges

Organisms	Risk Quotients
(Wading) bird	4.8×10^{-4}
Benthic fish	7.2×10^{-4}
Benthic mollusc	7.0×10^{-4}
Crustacean	6.8×10^{-4}
Macroalgae	6.3×10^{-4}
Mammal	5.6×10^{-4}
Pelagic fish	3.4×10^{-4}
Phytoplankton	4.3×10^{-6}
Polychaete worm	1.1×10^{-3}
Reptile	5.6×10^{-4}
Sea anemones or true corals - colony	6.7×10^{-4}
Sea anemones or true corals - polyp	7.0×10^{-4}
Vascular plant	6.3×10^{-4}
Zooplankton	2.7×10^{-4}

Annex 2 - Table 2: Dose to non human species from marine discharges

Organisms	Total dose rate per organism ($\mu Gy\ h^{-1}$)
(Wading) bird	4.8×10^{-3}
Benthic fish	7.2×10^{-3}
Benthic mollusc	7.0×10^{-3}
Crustacean	6.8×10^{-3}
Macroalgae	6.3×10^{-3}
Mammal	5.6×10^{-3}
Pelagic fish	3.4×10^{-3}
Phytoplankton	4.3×10^{-5}
Polychaete worm	1.1×10^{-2}
Reptile	5.6×10^{-3}
Sea anemones or true corals - colony	6.7×10^{-3}
Sea anemones or true corals - polyp	7.0×10^{-3}
Vascular plant	6.3×10^{-3}
Zooplankton	2.7×10^{-3}

Annex 2 - Table 3: Total dose rate from marine discharges

μGy h-1	Bird	Benthic fish	Benthic mollusc	Crustacean	Macroalgae	Mammal	Pelagic fish
C-14	*4,43E-03*	3,12E-03	2,51E-03	2,60E-03	2,01E-03	*4,43E-03*	*3,12E-03*
Co-60	1,46E-05	*3,82E-03*	*4,05E-03*	*3,75E-03*	*4,01E-03*	4,69E-05	1,28E-04
Co-58	4,00E-06	1,00E-04	9,02E-05	8,01E-05	8,05E-05	1,30E-05	3,57E-05
Ag-110m	2,92E-04	3,09E-05	1,71E-04	1,92E-04	8,79E-06	9,99E-04	3,11E-05
H-3	5,86E-05	5,86E-05	5,86E-05	5,86E-05	5,86E-05	5,86E-05	5,86E-05
I-131	7,13E-10	1,44E-09	4,49E-09	1,52E-09	1,03E-06	6,31E-10	1,67E-09
Mn-54	3,37E-06	3,12E-05	3,55E-05	3,39E-05	3,46E-05	1,22E-05	4,19E-07
Ni-63	1,02E-07	1,04E-07	3,86E-06	3,33E-07	4,85E-07	1,02E-07	1,02E-07
Sb-124	3,26E-06	3,28E-06	5,50E-06	1,91E-05	1,83E-06	6,92E-06	2,89E-06
Sb-125	1,81E-06	4,19E-06	5,77E-06	1,28E-05	3,77E-06	3,53E-06	1,61E-06
Cs-134	5,10E-06	1,72E-05	1,78E-05	1,62E-05	1,86E-05	6,22E-06	8,58E-07
Cs-137	7,54E-06	3,13E-05	3,29E-05	2,96E-05	3,54E-05	5,97E-06	1,36E-06
Te-123	8,19E-22	2,78E-21	3,53E-21	2,46E-21	8,41E-21	1,02E-21	7,55E-22
Te-123m	1,81E-06	1,73E-06	1,58E-06	1,80E-06	1,46E-05	2,75E-06	1,71E-06
Te-125m	2,24E-07	3,49E-07	3,89E-07	3,32E-07	2,19E-06	2,43E-07	2,19E-07
Cr-51	6,84E-07	1,96E-08	6,39E-08	1,64E-08	1,53E-07	3,41E-07	5,79E-09

μGy h-1	Phytoplankto n	Polychaete worm	Reptile	Sea anemones or true corals - colony	Sea anemones or true corals - polyp	Vascular plant	zooplankton
C-14	3,46E-07	2,51E-03	*4,43E-03*	2,77E-03	2,77E-03	2,01E-03	*2,51E-03*
Co-60	1,81E-07	*8,06E-03*	4,63E-05	*3,71E-03*	*3,99E-03*	*4,02E-03*	3,24E-05
Co-58	4,49E-08	1,73E-04	1,26E-05	6,87E-05	7,51E-05	8,02E-05	9,36E-06
Ag-110m	8,74E-08	1,27E-04	9,87E-04	4,44E-05	1,66E-05	1,18E-05	4,16E-05
H-3	*2,44E-05*	5,86E-05	5,86E-05	5,86E-05	5,86E-05	5,86E-05	5,86E-05
I-131	8,35E-10	3,90E-09	6,38E-10	2,01E-08	1,49E-08	1,23E-06	7,36E-07
Mn-54	4,82E-09	6,64E-05	1,22E-05	3,76E-05	3,48E-05	3,99E-05	2,42E-07
Ni-63	5,40E-10	2,54E-06	1,02E-07	2,35E-06	2,30E-06	4,81E-07	6,02E-07
Sb-124	5,21E-08	1,36E-05	6,83E-06	1,74E-06	1,40E-06	2,16E-06	6,80E-06
Sb-125	2,35E-08	1,32E-05	3,53E-06	3,12E-06	3,34E-06	3,77E-06	5,92E-06
Cs-134	4,95E-08	3,62E-05	1,34E-05	1,96E-05	1,97E-05	1,76E-05	5,08E-07
Cs-137	4,05E-08	6,82E-05	1,27E-05	3,39E-05	3,76E-05	3,23E-05	1,17E-06
Te-123	5,76E-21	6,95E-21	1,01E-21	1,85E-21	3,87E-21	8,77E-21	4,66E-22
Te-123m	1,57E-05	1,60E-06	2,71E-06	2,07E-06	1,53E-06	1,54E-05	1,42E-06
Te-125m	2,19E-06	5,96E-07	2,42E-07	3,02E-07	4,07E-07	2,23E-06	1,94E-07
Cr-51	1,07E-07	1,49E-07	1,23E-06	4,17E-07	2,95E-07	7,55E-07	2,24E-08

Grey highlighted cells: Radionuclide contributing most to the dose received by every reference organism.

Please note that the comma used in the tables above is the French equivalent of the ‘decimal point’.

Annex 2 - Table 4: Risk to non human species from aerial discharges

Organisms	Risk Quotients
Amphibian	3.03×10^{-4}
Bird	3.13×10^{-4}
Bird egg	2.12×10^{-4}
Detritivorous invertebrate	1.18×10^{-4}
Flying insects	1.16×10^{-4}
Gastropod	1.17×10^{-4}
Grasses & herbs	2.11×10^{-4}
Lichen & bryophytes	2.11×10^{-4}
Mammal (Deer)	3.14×10^{-4}
Mammal (Rat)	3.14×10^{-4}
Reptile	3.13×10^{-4}
Shrub	2.12×10^{-4}
Soil invertebrate (worm)	1.18×10^{-4}
Tree	3.04×10^{-4}

Annex 2 - Table 5: Dose to non human species from aerial discharges

Organisms	Total dose rate per organism (µGy h^{-1})
Amphibian	3.03×10^{-3}
Bird	3.13×10^{-3}
Bird egg	2.12×10^{-3}
Detritivorous invertebrate	1.18×10^{-3}
Flying insects	1.16×10^{-3}
Gastropod	1.17×10^{-3}
Grasses & herbs	2.11×10^{-3}
Lichen & bryophytes	2.11×10^{-3}
Mammal (Deer)	3.14×10^{-3}
Mammal (Rat)	3.14×10^{-3}
Reptile	3.13×10^{-3}
Shrub	2.12×10^{-3}
Soil invertebrate (worm)	1.18×10^{-3}
Tree	3.04×10^{-3}

Annex 2 - Table 6: Total dose rate from aerial discharges

μGy h-1	Amphibian	Bird	Gastropod	Bird egg	Detritivorus invertebrate	Flying insects	Grasses & herbs
H-3	2,95E-04	2,95E-04	2,95E-04	2,95E-04	2,95E-04	2,76E-04	2,95E-04
C-14	*2,73E-03*	*2,83E-03*	*8,76E-04*	*1,81E-03*	*8,76E-04*	*8,76E-04*	*1,81E-03*
Co-58	3,60E-08	3,87E-08	3,36E-08	3,62E-08	8,74E-08	3,36E-08	3,20E-08
Co-60	2,28E-06	2,45E-06	2,18E-06	2,29E-06	5,67E-06	2,18E-06	2,10E-06
Cs-134	5,65E-07	6,89E-07	4,70E-07	4,56E-07	1,24E-06	4,72E-07	5,50E-07
Cs-137	2,11E-06	2,80E-06	1,40E-06	1,27E-06	3,62E-06	1,42E-06	2,30E-06
I-131	4,15E-08	4,42E-08	3,25E-08	6,40E-06	7,31E-08	3,59E-08	3,07E-08
I-133	9,01E-09	9,67E-09	6,58E-09	1,67E-06	1,56E-08	7,51E-09	6,29E-09

μGy h-1	Lichen bryophytes	Mammal (Deer)	Mammal (Rat)	Reptile	Shrub	Soil Invertebrate (worm)	Tree
H-3	2,95E-04	2,95E-04	2,95E-04	2,95E-04	2,95E-04	2,95E-04	2,95E-04
C-14	*1,81E-03*	*2,83E-03*	*2,83E-03*	*2,83E-03*	*1,81E-03*	*8,76E-04*	*2,74E-03*
Co-58	8,87E-10	3,47E-08	8,60E-08	3,52E-08	3,44E-08	8,74E-08	2,79E-08
Co-60	5,19E-08	2,23E-06	5,45E-06	2,24E-06	2,20E-06	5,67E-06	1,76E-06
Cs-134	6,66E-07	2,86E-06	1,84E-06	1,27E-06	9,96E-07	1,22E-06	5,00E-07
Cs-137	6,84E-06	1,15E-05	8,53E-06	8,00E-06	7,39E-06	3,47E-06	1,58E-06
I-131	1,14E-08	4,55E-08	7,70E-08	4,15E-08	2,90E-08	6,88E-08	3,19E-08
I-133	2,40E-09	1,00E-08	1,68E-08	9,34E-09	6,29E-09	1,48E-08	6,60E-09

Grey highlighted cells: Radionuclide contributing most to the dose received by every reference organism.

Please note that the comma used in the tables above is the French equivalent of the ‘decimal point’.

SUB-CHAPTER 11.2 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

1. METHODOLOGY AND INPUTS

[Ref-1] D-ERICA: An Integrated Approach to the assessment and management of environmental risks from ionising radiation – Description of purpose, methodology and application. 2007. (E)

[Ref-2] Process and Information Document for Generic Assessment of Candidate Nuclear Power Designs. The Environment Agency. January 2007. (E)

[Ref-3] D Copplestone, et al. Impact Assessment of Ionising Radiation on Wildlife. R&D Report: N° 128. Environment Agency. 2001. (E)

[Ref-4] Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment. Technical Reports Series N° 422. IAEA. Vienna. 2004. (E)

SUB-CHAPTER 11.3 – UNCERTAINTIES OF THE METHODS

1. RADIOLOGICAL HEALTH IMPACT – UNCERTAINTIES OF THE METHODS

This section deals with requirements 2.7, 2.8 and 2.9 of the Environment Agency (EA) Process and Information (P&I) Document [Ref-1].

1.1. UNCERTAINTIES OF THE MODELS

To assess the consequence of radioactive discharges, the PC CREAM [Ref-1] software is used. It includes a suite of models which are all intended for use in assessing the consequences of continuous releases. PC CREAM consists of six programs, the assessment program (ASSESSOR) and five supporting programs (DORIS, PLUME, FARMLAND, GRANIS, RESUS). Much use is made of annual averages for parameters such as weather conditions, water flow and consumption of foods. This is considered adequate when assessing the radiological consequences of routine releases integrated over long periods of time.

The ASSESSOR component of PC CREAM is limited by the number of integration times for assessment of individual dose. Doses can be assessed at year 1, 5 or 50. The life expectancy of the EPR unit is about 60 years. In order to determine the effect on effective dose of a 10 year discrepancy in the build-up of radioactivity, various programs (e.g. DORIS, FARMLAND) within PC CREAM were run for a number of discharge periods. With the exception of Cs-137, activity concentrations in soil plateau before year 50, and therefore there is no consequence of using 50 years in the calculation rather than 60. With the exception of Ni-63, activity concentrations in seabed sediments for all radionuclides of interest plateau by 50 years. In the case of Ni-63, the plateau occurs around year 70. The difference in activity concentration between year 50 and 70 is trivial, and coupled with the low dose impact compared with other radionuclides, the uncertainty in calculating activities at 50 years as opposed to 60 is insignificant for the annual dose assessment.

As it is possible to calculate soil concentrations at user defined times in FARMLAND, soil concentrations are calculated at 60 years for all radionuclides when assessing the impact of the build-up of radionuclides. In the same way, concentrations in the marine environment at year 60 are calculated in assessing the impact of build-up of radionuclides in the vicinity of the plant using the DORIS model.

To assess collective doses to the populations of UK, Europe and the World, PC CREAM is used. Since PC CREAM was created in 1998, Europe has changed greatly. Therefore, the Europe dose calculated is the dose to the European population as in 1998 and will not include the newer member states.

1.2. UNCERTAINTIES OF THE PARAMETERS

Values for all parameters used for annual dose assessments are chosen to be realistically conservative for a UK site. There will be uncertainties in parameters as a result of, for example, changes and differences in individual habits. The uncertainty in some parameters is possibly high. For example, regarding radioactive gaseous discharges, the stack height, the location of the public receptor point and the meteorological conditions are essential parameters to evaluate the dispersion of the discharges. The assumed values for the effective stack height and for the public receptor point location which are 20 m (equivalent to a real stack height of 60 m) and 500 m respectively are representative of potential sites in UK. Moreover, to characterise the meteorological conditions, a uniform windrose at 70% Pasquill stability category D is retained. These conditions are likely to be different to the conditions that would exist at the receptor point location, and this difference may lead to uncertainties. Nevertheless, actual meteorological data will approximate to 70% category D for continuous releases, which minimises the uncertainty. Regarding radioactive liquid discharges, the volumetric exchange rate chosen is the rate in some UK waters; however in other locations in the UK exchange rates can be higher which leads to greater dispersion, and therefore lower activities in seawater and sediments and thus lower doses.

For some parameters like deposition velocities and washout coefficients, the uncertainties are very limited as the retained values are standard values that have been ascertained through modelling and are widely used. Regarding the roughness, a roughness length of 0.3 is considered as this value is typical of UK urban and agricultural areas. However, other values may be appropriate if, for example, there is a wood or forest between the source and receptor, or only grassy fields are present rather than crops and hedgerows. Nevertheless, the associated uncertainty to the roughness can reasonably be considered as low.

A discussion of the effects of varying numerous parameters in the short-term assessment is included in the appendices of NRPB-W54 [Ref-1]. The uncertainties in carrying out any prospective short-term dose assessments are obviously great as almost all parameters are currently unknown: the discharge period, time of day and season will all have a great effect on the pathways that need to be considered and the persons likely to be exposed. Weather conditions will strongly affect deposition, and wind direction can have an enormous effect on the pathways and persons exposed. For example, at the time of discharge, the wind could be blowing out to sea and would therefore not result in any dose to the public from any of the standard pathways. Nevertheless, the short-term release is considered a 24 hour release. The uncertainty in the weather conditions for this short-term release is potentially high as, for a single day, the weather conditions could be far from stable, and wind direction and strength could vary significantly over a 24 hour period.

Regarding the potential build-up assessment, the doses associated to this build-up are assessed using the methodology described in NRPB-W36 [Ref-2]. Nevertheless, the number of possible scenarios which are considered in this report is limited and can thus entail some uncertainties. Additionally, the number of radionuclides which are considered is also limited. A pessimistic approach is taken to enable the associated doses for the radionuclides which are not included in the report to be assumed to be covered.

Collective doses truncated at 500 years are assessed [Ref-3]. The time at which collective doses are truncated is clearly important in relation to optimisation studies. The rate of increment of collective doses is highest in the first few hundred years. Concerns are raised about whether, in some circumstances, it is appropriate to integrate the collective dose to infinity but there are difficulties with the use of an un-truncated time period. In addition, the collective dose assessment assumes that the population size remains the same for all time periods considered. Increasing the population size will increase the collective dose provided that the amount of food produced also increases (as the collective dose from the ingestion of food is based on food production data rather than size of the population). For discharges to the marine environment, the collective dose due to ingestion of seafood is based on data for seafood catches for 1998 and their use at later times must be regarded as increasingly uncertainty with amounts, types and sources of seafood catches all likely to change. For terrestrial food production, the data used are for past agricultural practices and again the amounts, types and sources of foods are likely to change.

2. IMPACT OF RADIOACTIVE DISCHARGES ON NON HUMAN SPECIES – UNCERTAINTIES OF THE METHODS

This section deals with requirements 2.9 and 2.10 of the EA P&I Document [Ref-1].

The outcome of a generic assessment is to carry out a very conservative estimate.

The 95th percentile of the RQ is estimated by multiplying the expected value of the RQ by an uncertainty factor (UF = 3 in the ERICA Tool). It tests for a 5% probability of exceeding the dose screening value, assuming exponential distribution of RQ values.

Annex A of the D-ERICA report describes the uncertainties in ERICA and practical options for dealing with uncertainties and data gaps.

SUB-CHAPTER 11.3 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

1. RADIOLOGICAL HEALTH IMPACT – UNCERTAINTIES OF THE METHODS

[Ref-1] Process and Information Document for Generic Assessment of Candidate Nuclear Power Designs. The Environment Agency. January 2007. (E)

1.1. UNCERTAINTIES OF THE MODELS

[Ref-1] A Mayall, T Cabianca, C Attwood, C A Fayers, J G Smith, J Penfold, D Steadman, G Martin, T P Morris and J R Simmonds. PC CREAM Installing and using the PC system for assessing the radioalogical impact of routine releases. EUR 17791 EN. NRPB-SR296. National Radiological Protection Board. 1997. (E)

1.2. UNCERTAINTIES OF THE PARAMETERS

[Ref-1] J G Smith, P Bedwell, C Walsh and S M Haywood. A Methodology for Assessing Doses from Short-Term Planned Discharges to Atmosphere. NRPB-W54. National Radiological Protection Board. March 2004. (E)

[Ref-2] W B Oatway and S F Mobbs. Methodology for Estimating the Doses to members of the Public from the Future Use of Land Previously Contaminated with Radioactivity. NRPB-W36. National Radiological Protection Board. May 2003. (E)

[Ref-3] Guidance on the calculation, presentation, and use of collective doses for routine discharges. Radiation Protection 144. European Commission. 2007. (E)

2. IMPACT OF RADIOACTIVE DISCHARGES ON NON HUMAN SPECIES – UNCERTAINTIES OF THE METHODS

[Ref-1] Process and Information Document for Generic Assessment of Candidate Nuclear Power Designs. The Environment Agency. January 2007. (E)

SUB-CHAPTER 11.4 – ENVIRONMENTAL MONITORING

1. INTRODUCTION

Nuclear sites are the main focus for radiological monitoring and sampling programmes because they are responsible for the individual discharges of radioactive waste. Monitoring and sampling regimes vary from site to site and year to year, and are selected to be representative of existing exposure pathways. Knowledge of these pathways is developed from regular surveys of local peoples' diets and way of life. This routine monitoring is supplemented by additional monitoring where necessary, for example in response to incidents or reports of unusual discharges of radioactive material.

The main aim of the programme is to monitor the environment and diet of local people living near or working at a nuclear site. These groups of people are at most risk from disposals of radioactive waste and can be termed the 'critical group'. It is assumed that if the most exposed group has a dose below the legal limit, then all others should be at even lower risk [Ref-1].

For gaseous discharges, the most relevant exposure pathways are ingestion of terrestrial foods, inhalation of airborne activity and external exposure from material in the air and deposited on land. Inhalation of airborne material and external exposure are difficult to assess directly and may be monitored using environmental models.

For liquid discharges from coastal nuclear power plants, the pathways of greatest relevance are the ingestion of marine fish and seafood, and external exposure from contaminated silts and sediments. The monitoring programme is therefore directed at a wide range of foodstuffs and external dose rate measurements on shores of seas and estuaries.

The assessment of exposures to the public may be addressed in one of several ways:

- A theoretical approach based on models which are specifically designed for measuring the transport of different radioisotopes in the environment; these models are described in more detail in Sub-chapter 11.1;
- Environmental samples are collected and analysed for their radionuclide content in the laboratory; and
- Radiation dose rate measurements can be performed directly in the environment.

2. TERRESTRIAL ENVIRONMENT

2.1. SAMPLE ANALYSIS

Laboratory analysis of samples varies according to the identity of the radionuclide. Gamma ray spectrometry is a very cost-effective method for detecting a wide range of nuclides that may be found in environmental samples.

Alternatively, radiochemical methods can be used which generally involve chemical separation techniques to quantify specific alpha and beta emitting radionuclides. These are sensitive but are much more labour intensive and are only used if the required information cannot be gathered using gamma ray spectrometry. Typically a laboratory will work to standard published procedures that have been well established for the assay of environmental media for their radioactive content [Ref-1]. The laboratory may also participate in an Accreditation scheme such as UKAS and participate in inter-comparison exercises to test and demonstrate the quality of its measurement and analytical capability.

A common strategy for collecting terrestrial samples is to divide areas into an inner zone, which is 1 to 6 km from the station and an outer zone, which is 6 to 19 km from the station. This division helps to distinguish effects that might be due to power station operations from those attributable to external effects [Ref-2].

The sampling strategy may be enhanced by using the Data Quality Objectives Process. This process will make certain that environmental data is of the right type, quality and quantity to support defensible, confident decisions when planning a sampling programme.

2.1.1. Milk

Radiological analysis of milk is very important in the assessment of doses to the public. The environmental pathway for milk is ‘soil-pasture-cows-milk’, which makes milk a convenient foodstuff indicator because it is produced by cows that effectively sample a large area of local grass. Samples are typically screened for gamma emitting nuclides (e.g. iodine-131) on a monthly basis, while carbon-14 analysis occurs quarterly [Ref-1]. Farms from both the inner and outer zones would be sampled to ensure that the data is representative of the entire area.

2.1.2. Herbage

Herbage (mainly grass) would be collected from farms where milk is collected and also at sampling sites local to the power station. Areas from both the inner and outer zones would also be included in the survey.

Grass is comparable to fresh vegetables in the ability to concentrate nuclides from the air [Ref-1]. Consequently, the samples would be analysed by gamma ray spectrometry or radiochemical separation and carbon-14 would be analysed quarterly.

2.1.3. Other foodstuffs

Herbage is generally considered to be the most useful indicator for the assessment of radioactivity in plants [Ref-1], but additional sampling may be undertaken by other agencies to ensure that there is no long-term accumulation of radioactivity in other foodstuffs.

Several local councils in the UK also have gamma ray spectrometry programmes to analyse leafy vegetables (sprouts, cabbage, broccoli and cauliflowers), fruit (mainly berries), root vegetables (onions, potatoes, carrots, turnips and parsnips), meat (beef, pork, lamb, venison and chicken) and eggs [Ref-2].

2.1.4. Soil cores

Soil cores can be taken at inner zone locations on a rotational basis so that each site is sampled at least once every five years. The value of soil core analysis is questionable [Ref-1] because it is an insensitive technique and does not have a public exposure pathway not already covered by herbage and milk.

2.1.5. Tacky shades

Tacky shades, otherwise known as dry cloth collectors, are suspended from poles above ground level. They collect dust particles blown in the wind, some of which might be radioactive. These would generally be positioned 1 to 2 km from site covering all prevailing wind directions.

2.2. DOSE RATE MEASUREMENTS

The environmental radiation dose rate would be measured quarterly at locations around the power station up to 10 km from site. The locations would be divided into two zones; 0 - 2 km and 2 - 10 km from site.

Measurements of gamma dose rate in air are normally made at 1 m above ground using an instrument similar to a Mini Instruments environmental radiation meter type 680 with a compensated Geiger-Muller tube type MC-71. These portable instruments are calibrated against recognised reference standards and the inherent instrument background is subtracted [Ref-1].

There are two quantities that can be presented as measures of external gamma dose rate; total gamma dose rate or terrestrial gamma dose rate. Total gamma dose rate includes all external radiation sources, while terrestrial gamma dose rate includes all sources except cosmic radiation. Both sets of gamma dose rates are usually reported.

3. MARINE ENVIRONMENT

3.1. SAMPLE ANALYSIS

Marine samples are analysed in a similar fashion to terrestrial samples; using gamma ray spectrometry and radiochemical separation methods where required. The marine programme would include sampling of fish and shellfish and analysis of silt and sediment from the shoreline and seabed.

3.1.1. Fish and shellfish

Fish and shellfish are ‘indicator’ species because they are both foodstuffs and can indicate accumulations of radioactivity in the environment. They essentially ‘sample’ the local water and consume other organisms and therefore sampling of locally caught fish is an important part of the marine programme.

Samples are analysed by gamma spectrometry and for beta radioactivity. Detection by gamma spectrometry in marine environmental samples may indicate discharges from plant.

Several local councils have gamma spectrometry programmes which also analyse local fish, crustaceans and molluscs on an annual or biannual basis [Ref-1].

3.1.2. Silt and sediment

Radionuclides can often fix or absorb themselves onto silt particles. This is particularly useful for scientists examining discharge patterns from nuclear licensed sites over a period of several decades.

Silt samples can often be difficult to collect as the proportion of sand and silt can vary considerably. The natural radioactivity levels in silt are generally higher than those measured in sand. Samples will be analysed by gamma spectrometry and for gross beta radioactivity [Ref-1].

3.2. DOSE RATE MEASUREMENTS

Environmental dose rate measurements would be taken at locations along the shoreline and over areas of sediment. This would be included as part of the terrestrial environment monitoring programme and measurements would be performed quarterly.

Beta-gamma contamination surveys may occasionally be carried out along the beach strand-line. This high tide line is where deposited materials from the marine environment might be found. Strand-line monitoring is usually only performed as part of a post-incident response. Similarly, the measurement of external beta doses on fishing equipment using Mini 900/EP 15 contamination monitors, for example, would not be performed routinely [Ref-1].

4. DETECTION LIMITS

Gamma ray spectrometry can produce a large number of results at the limit of detection or at the minimum reporting level. In order to minimise the presentation of redundant information, results at these levels would only be reported when:

- the radionuclide is one which is in the relevant authorisation;
- it has been analysed by radiochemical methods;
- it has been reported as being a positive value in the previous years; or
- a positive result is detected in any other sample.

Naturally occurring radionuclides measured by gamma spectrometry would not usually be reported unless they are intended to establish whether there is any enhancement above expected background levels.

SUB-CHAPTER 11.4 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

1. INTRODUCTION

[Ref-1] Radioactivity in food and the Environment, 2006. RIFE-12. Centre for Environment, Fisheries and Aquaculture Science (CEFAS). 2006. (E)

2. TERRESTRIAL ENVIRONMENT

2.1. SAMPLE ANALYSIS

[Ref-1] Sampling and measurement of radionuclides in the environment. RADRE. ISBN 0117522619. HMSO 1989. (E)

[Ref-2] Sizewell ‘B’ Power Station Environmental Support Group Report. SZB/THR/042. British Energy Generation Ltd. 2005. (E)

2.1.1. Milk

[Ref-1] Sizewell ‘B’ Power Station Environmental Support Group Report. SZB/THR/042. British Energy Generation Ltd. 2005. (E)

2.1.2. Herbage

[Ref-1] Sampling and measurement of radionuclides in the environment. RADRE. ISBN 0117522619. HMSO 1989. (E)

2.1.3. Other foodstuffs

[Ref-1] Sizewell ‘B’ Power Station Environmental Support Group Report. SZB/THR/042. British Energy Generation Ltd. 2005. (E)

[Ref-2] LARnet. Annual Report. 2005. NNC. (E)

2.1.4. Soil cores

[Ref-1] Sizewell ‘B’ Power Station Environmental Support Group Report. SZB/THR/042. British Energy Generation Ltd. 2005. (E)

2.2. DOSE RATE MEASUREMENTS

[Ref-1] Routine measurement of gamma ray air kerma rate in the environment. Technical guidance note M5. HMIP ISBN 011751324. HMSO. 1995. (E)

3. MARINE ENVIRONMENT

3.1. SAMPLE ANALYSIS

3.1.1. Fish and shellfish

[Ref-1] LARnet. Annual Report. 2005. NNC. (E)

3.1.2. Silt and sediment

[Ref-1] Sizewell 'B' Power Station Environmental Support Group Report. SZB/THR/042. British Energy Generation Ltd. 2005. (E)

3.2. DOSE RATE MEASUREMENTS

[Ref-1] Sizewell 'B' Power Station Environmental Support Group Report. SZB/THR/042. British Energy Generation Ltd. 2005. (E)

SUB-CHAPTER 11.5 – CONCLUSIONS

1. RADIOLOGICAL HEALTH IMPACT

The methodology used to carry out the Initial Radiological Assessment (IRA) is provided by the Environment Agency. Taking into account simple cautious assumptions (with conservatism), considering Stage 1 and 2 of this IRA methodology, the annual doses for the critical group are 138.3 µSv y^{-1} and 63.0 µSv y^{-1} respectively.

The Stage 3 assessment is carried out using a set of site parameters appropriate for potential EPR UK sites. The highest total dose is calculated to be 25.8 µSv y^{-1} to an adult of the critical group. Most of the parameters used for this assessment are conservative for potential EPR UK sites and lead to a dose slightly higher than the threshold of 20 µSv y^{-1}.

These values ensure compliance with the dose limit for members of the public, i.e. 1000 µSv y^{-1} and the Government's dose constraint[1] for a single source, i.e. 300 µSv y^{-1}.

Nevertheless, it should be remembered that the population of the UK is exposed to an average radiation dose of 2700 µSv y^{-1} [Ref-1]. Most of this radiation comes from natural sources, such as cosmic radiation and radon gas. Less than 1 % comes from general industrial use including nuclear industry.

The total doses for a single short-term discharge received by each age group are 0.86, 0.89 and 1.46 µSv in the year following the release for adults, children and infants respectively assuming all radionuclides are discharged together in the same release. Despite this conservative assumption, the total short-term doses are less than the total continuous release doses.

The doses associated to the potential build-up of radionuclides are equal to 8.4×10^{-3} µSv y^{-1} for land, 1.7×10^{-1} µSv y^{-1} ('Swimmer') and 9.1 µSv y^{-1} ('Fisherman and his family') for seabed sediments which are far lower than 20 µSv y^{-1} which broadly corresponds to the risk value of 10^{-6} y^{-1}. Consequently, there would be no radiological protection reasons to restrict future use of the land and of the local coast.

For the collective dose, the average per caput doses to UK, European and World populations are respectively 5.6, 3.5 and 1.7 nSv. The per caput doses of less than a few nanosieverts per year of discharge can be regarded as trivial [Ref-2]. Therefore design could be considered as optimised.

2. IMPACT OF RADIOACTIVE DISCHARGES ON NON HUMAN SPECIES

The methodology used to assess the impact of radioactive discharges on non human species is the ERICA Integrated approach.

1 In its advice on UK application of ICRP's new recommendations on radiological protection, the UK Health Protection Agency (HPA) proposes that for new nuclear power stations this constraint should be reduced to some value less than 150 µSv y^{-1}. As it is a recommendation and not a regulatory value, the value of 150 µSv y^{-1} is only given for information.

The risk quotient for releases to the marine environment on marine organisms was calculated for each of the default ERICA organisms based on a screening value of 10 µGy h^{-1}. The maximum risk quotient was 1.1 x 10^{-3} for polychaete worms. The associated dose for these organisms is 1.1 x 10^{-2} µGy h^{-1}. The total dose for all ERICA marine organisms is presented in Sub-chapter 11.2.

The risk quotient for atmospheric releases to the terrestrial environment on terrestrial organisms was calculated for each of the default ERICA organisms based on a screening value of 10 µGy h^{-1}. The maximum risk quotient was 3.14 x 10^{-4} for mammals. The associated dose for these organisms is 3.14 x 10^{-3} µGy h^{-1}. The total dose for all ERICA marine organisms is presented in Sub-chapter 11.2.

In conclusion, no environmental risk connected to the EPR radioactive effluents discharge will be noticed.

SUB-CHAPTER 11.5 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

1. RADIOLOGICAL HEALTH IMPACT

[Ref-1] S J Watson, A L Jones, W B Oatway and J S Hughes. Ionising Radiation Exposure of the UK Population: 2005 Review, HPA-RPD-001. Health Protection Agency, Centre for Radiation Chemical and Environmental Hazards, Radiation Protection Division. 2005. (E)

[Ref-2] Radioactive Substances Regulation, Authorisation of Discharges of Radioactive Waste to the Environment - Principles for the Assessment of Prospective Public Doses. Interim Guidance 1. Environment Agency. December 2002. (E)