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UK HPR1000 GDA Project

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Preliminary Safety Report

Chapter 26

Environment

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SENSITIVE INFORMATION RECORD

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26.1 List of Abbreviations and Acronyms

ALARA	As Low As Reasonably Achievable
BAT	Best Available Technique
BSSD	Basic Safety Standards Directive
CGN	China General Nuclear Power Corporation
CI	Conventional Island
COMAH	Control of Major Accident Hazards
CRF	Circulating Water System [CWS]
CVI	Condensate Vacuum System [CVS]
DPUR	Dose Per Unit Release
EA	Environment Agency
EMCL	Environmental Medic Concentration Limit
EPR16	Environmental Permitting Regulations 2016
EPR-RSR	Environmental Permitting Regulations – Radioactive Substances Regulations
EQSs	Environmental Quality Standards
ETS	Emissions Trading Scheme
EU	European Union
F-Gas	Fluorinated Greenhouse Gases
GDA	Generic Design Assessment
GHG	Greenhouse Gas
GWP	Global Warming Potential
HPR1000 (FCG3)	Hua-long Pressurized Reactor under construction at Fangchenggang nuclear power plant unit 3
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IED	Industrial Emissions Directive
IRA	Initial Radiological Assessment
IRAT	Initial Radiological Assessment Tool

LT	Lower Tier
MAPP	Major Accident Prevention Policy
MATTE	Major Accident to the Environment
MCERTS	Monitoring Certification Scheme
MRR	Monitoring and Reporting Regulation
MRV	Monitoring, Reporting and Verification
MWth	Megawatt (thermal input)
NHS	Non-human Species
NI	Nuclear Island
ODS	Ozone-depleting Substances
P&ID	Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs
REPs	Radioactive Substances Regulation – Environmental Principles
PHE	Public Health England
RPE	Nuclear Island Vent and Drains System [VDS]
RQ	Risk Quotient
RRI	Component Cooling Water System [CCWS]
SED	NI Demineralized Water Distribution System [DWDS(NI)]
SER	CI Demineralized Water Distribution System [DWDS(CI)]
SBO	Station Black Out
SEC	Essential Service Water System [ESWS]
TEG	Gaseous Waste Treatment System [GWTS]
UT	Upper Tier
UK	United Kingdom of Great Britain and Northern Ireland
UK HPR1000	The UK version of the Hua-long Pressurized Reactor

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Circulating Water System (CRF [CWS]).

26.2 Introduction

This chapter presents preliminary information pertaining to the likely impact on the environment at the Generic Site of radiological and non-radiological discharges from The UK version of the Hua-long Pressurized Reactor (UK HPR1000). It therefore satisfies the requirements of items 5, 6, 7 and 8 of Table 1 of the Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs (P&ID) (Reference [1]) at a level of detail consistent with the Step 2 Generic Design Assessment (GDA) process. Throughout the chapter specific P&ID requirements are highlighted along with their underlying regulatory context.

This chapter supports the following high level objective: The design, and intended construction and operation, of the UK HPR1000 will be developed to reduce, so far as is reasonably practicable, the impact on the workers, the public, and the environment.

This objective will be demonstrated as the following:

- The plant design and operations limit (in terms of quantity and activity) the creation of radioactive waste;
- The non-radiological impact on the environment will be limited;
- Best Available Techniques (BAT) will be adopted for the managing, sampling/monitoring, handling and storage/disposal of waste (including spent fuel) to limit the impact on the environment (see notably Chapter 23).

Information on radiological discharges, monitoring and impacts is given first. Initially, a definition of ‘normal’ operation is provided, where this definition includes routine station operation, start-up and shutdown, maintenance and testing activities, and expected events. The assumptions which have been used in support of radiological discharge estimates and corresponding limits are then listed. Key radionuclides – i.e. those that are significant in terms of radiological impact, the quantity of radioactivity discharged, half-life, or as indicators of facility performance – are identified and provisional discharge estimates are provided. Discharge limits are proposed.

The proposed approach to radiological sampling and monitoring is described. However, it is highlighted that the description is high level because at this stage of the GDA process specific details have not yet been developed. The compliance of the monitoring proposals with Best Available Techniques (BAT) is made through commitment to a number of high level design principles. Finally, an evaluation of the impact of radiological discharges is made through the use of a number of tools, including the Initial Radiological Assessment (IRA) Tool in Reference [2] and [3]. Potential exposure of members of the public, wider populations and non-human species (NHS) are estimated for a number of different pathways at the Generic Site. Conclusions are reached with regard to the acceptability of the estimated exposure levels.

Information on the impacts of non-radiological discharges – i.e. ‘conventional’ impacts –

is presented in the order in which the topic areas are listed in item 8 of Table 1 of the P&ID, Reference [1]. The following aspects are addressed:

- Water use and abstraction;
- Discharges to surface waters;
- Discharges to groundwater;
- Operation of installations (combustion plant and incinerators);
- Substances subject to the Control of Major Accident Hazards (COMAH) Regulations; and,
- Fluorinated greenhouse gases (F-Gas) and ozone-depleting substances (ODS).

Generally speaking, information on these areas is limited at the present time. The approach has therefore been to provide background information relevant to future assessment, with a view to undertaking the necessary assessments at a later stage of the GDA process.

26.3 Radiological Discharges, Monitoring and Impacts

26.3.1 Prospective Discharges and Limits

The discharge source term for the UK HPR1000 is still being developed and an outline of this process can be found in Chapter 22. In its absence estimated discharge data have been taken from HPR1000 (FCG3) source term design, which is the starting basis for the design of the UK HPR1000. Using the estimated discharge data, proposed limits for the UK HPR1000 are provided in the chapter below. It is expected that these will be refined as the source term is developed and the design of the new facility is optimised notably through the application of BAT.

26.3.1.1 P&ID Requirements

The P&ID sets the following requirements with respect to discharges and limits for radioactive waste disposal:

For gaseous and aqueous radioactive wastes, estimate the monthly discharges:

- *on an individual radionuclide basis for significant radionuclides;*
- *on a group basis (for example 'total alpha' or 'total beta') for other radionuclides;*
- *via each discharge point and discharge route.*

'Significant ' radionuclides are those which:

- *are significant in terms of radiological impact for people or non-human species;*
- *are significant in terms of the quantity of radioactivity discharged (that is, numerically high);*
- *have long half-lives, may persist and/or accumulate in the environment, and may contribute*

significantly to collective dose;

- *are significant indicators of facility performance and process control.*

The radionuclide selection should be consistent with reference EU, 2004.

For combustible and other radioactive wastes, estimate the annual arisings and disposals during operation and give an indication of the likely arisings during decommissioning. Identify wastes in terms of their category (HLW, ILW, LLW, VLLW), physico-chemical characteristics and proposed disposal route (if any). Quantification should be in terms of activity of key individual radionuclides and overall groupings of radionuclides (for example, total beta), together with mass and / or volume.

Estimates of discharges and disposals should clearly show the contribution of each constituent aspect of normal operations, including:

- *routine operation (that is, typically, the design basis or "flowsheet design" and the minimum level of disposals);*
- *start-up and shutdown;*
- *maintenance and testing;*
- *infrequent but necessary aspects of operation, for example, plant wash-out; and the foreseeable, undesired deviations from planned operation (based on a fault analysis) consistent with the use of BAT, for example, occasional fuel pin failures.*

Support your estimates with performance data from similar facilities and explain, where relevant, how changes in design or operation from those facilities affect the expected discharges and disposals. Demonstrate that discharges and waste arisings will not exceed those of comparable power stations across the world (as required by UK Government policy (GB Parliament, 2008)).

Provide your proposed limits for:

- *gaseous discharges;*
- *aqueous discharges;*
- *disposal of combustible waste by on-site incineration.*

Provide proposals for annual site limits (on a rolling twelve months basis) for gaseous and aqueous discharges, and monthly limits for disposals by on-site incineration, and describe how these were derived. If desired, additionally propose limits to reflect an operating cycle, that is, 'campaign' limits.

26.3.1.2 Regulatory Context

Discharge limits and notification levels are set by the Environment Agency (EA) within permit conditions for the following reasons in Reference [4]:

- Ensure that the radiation exposure of members of the public is less than the statutory dose limits and constraints and is as low as reasonably achievable (ALARA);
- Ensure the environment is protected; and,
- Provide a reference for the indication of operational discharge performance and

the application of the best available techniques to minimise discharges.

26.3.1.3 Assumptions on Discharges

For the purpose of undertaking an initial assessment of the radioactive discharges to the environment the source term based on HPR1000 (FCG3) design has been used. It is expected that this would represent an initial estimate of the resulting impacts as the UK HPR1000 design will go through optimisation following the BAT process. But for optimisation to progress a starting point is needed, which is what this step will produce. The source term used for the assessment includes all the inputs from normal operations (including failed fuel). The discharge data based on the source terms design of HPR1000 (FCG3) is shown in T-26.3-1 and T-26.3-2.

T-26.3-1 Gaseous discharge data based on source terms design of HPR1000 (FCG3)

Nuclide	Discharge (Bq a^{-1})	Nuclide	Discharge (Bq a^{-1})
Noble Gases		Mo-99	5.37E+04
Kr-85m	2.02E+12	Tc-99m	2.23E+03
Kr-85	1.87E+13	Ru-103	5.75E+02
Kr-87	2.10E+12	Ru-106	1.38E+02
Kr-88	4.31E+12	Te-131m	1.87E+03
Xe-133m	3.16E+13	Te-131	7.01E+04
Xe-133	1.06E+12	Te-132	1.76E+04
Xe-135	1.66E+13	Te-134	1.03E+05
Xe-138	2.35E+12	Cs-134	5.51E+06
Radioiodines		Cs-136	2.63E+05
I-131	2.10E+08	Cs-137	1.08E+07
I-132	1.06E+08	Cs-138	1.38E+07
I-133	2.20E+08	Ba-140	2.59E+04
I-134	1.67E+07	La-140	1.00E+03
I-135	8.75E+07	Ce-141	5.83E+02
Others		Ce-143	3.19E+03
H-3	4.98E+12	Ce-144	3.94E+02
C-14	4.18E+11	Pr-143	3.45E+03
Particulates		Pr-144	1.83E+02
Sr-89	1.44E+04	Cr-51	3.70E+05
Sr-90	5.91E+03	Mn-54	2.77E-05
Sr-91	2.14E+04	Fe-59	5.66E-05
Sr-92	3.91E+04	Co-58	1.52E-04
Y-90	3.21E+01	Co-60	1.24E-04
Y-91	5.12E+02	Ag-110m	1.99E-05
Zr-95	8.17E+02	Sb-122	1.31E-05
Nb-95	5.01E+02	Sb-124	1.23E-05

T-26.3-2 Aqueous discharge data based on source terms design of HPR1000 (FCG3)

Nuclide	Discharge (Bq a^{-1})	Nuclide	Discharge (Bq a^{-1})
H-3	4.48E+13	I-133	9.72E+08
C-14	1.74E+10	I-134	1.83E+07
Sr-89	3.19E+06	I-135	2.36E+08
Sr-90	6.40E+04	Cs-134	4.98E+08
Sr-91	4.07E+05	Cs-136	2.28E+08
Sr-92	4.34E+05	Cs-137	7.29E+08
Y-90	2.79E+03	Cs-138	5.32E+07
Y-91	2.41E+06	Ba-140	5.76E+06
Zr-95	1.54E+05	La-140	7.04E+05
Nb-95	1.31E+05	Ce-141	1.67E+05
Mo-99	6.19E+06	Ce-143	2.22E+05
Tc-99m	5.14E+05	Ce-144	9.67E+04
Ru-103	1.64E+05	Pr-143	9.71E+05
Rh-106	8.87E+00	Pr-144	4.32E+02
Ru-106	4.56E+04	Cr-51	1.39E+08
Te-131m	1.25E+05	Mn-54	1.16E+07
Te-131	2.37E+05	Fe-59	2.27E+07
Te-132	2.33E+06	Co-58	5.21E+07
Te-134	5.00E+05	Co-60	5.01E+07
I-131	2.29E+09	Sb-122	1.52E+06
I-132	2.02E+08	Sb-124	3.52E+06

The gaseous discharge is not constant during an operational cycle. The worst monthly discharge will correspond to the discharge requirement from Regulations for Environmental Radiation Protection of Nuclear Power Plant (GB 6249-2011), Reference [5]. The monthly discharge must not exceed one-fifth of annual discharge limit. It is a conservative estimate on the occasion that the actual situation is far less than the limit.

The aqueous discharges are made in a batched manner. However, they are discharged on such a regular basis that they are assumed to be continuous.

26.3.1.4 Definition of ‘Normal Operation’

Normal operation for the HPR1000 (FCG3) include operation, maintenance and inspection (see Chapter 22).

26.3.1.5 Key Radionuclides

The EU2004 (Reference [6]) recommends a range of radionuclides whose discharged activity should be assessed. The nuclides identified for new nuclear power stations for both gaseous and aqueous discharges are shown in T-26.3-3 and T-26.3-4 respectively.

T-26.3-3 List of nuclides from EU2004 (Reference [6]) for gaseous discharges

Gaseous discharge nuclides from EU2004				
H-3	Kr-85m	Sb-124	Xe-135	Pu-239+240
C-14	Kr-87	Sb-125	Xe-135m	Am-241
Ar-41	Kr-88	I-131	Cs-137	Cm-242
Cr-51	Kr-89	Xe-131m	Xe137	Cm-243
Mn-54	Sr-89	I-132	Xe-138	Cm-244
Co-58	Sr-90	I-133	Ba-140	Total alpha
Fe-59	Zr-95	Xe-133	La-140	
Co-60	Nb-95	Xe-133m	Ce-141	
Zn-65	Ag-110m	Cs-134	Ce-144	
Kr-85	Sb-122	I-135	Pu-238	

T-26.3-4 List of nuclides from EU2004 (Reference [6]) for aqueous discharges

Aqueous discharge nuclides from EU2004				
H-3	Ni-63	Ag-110m	La-140	Cm-244
S-35	Zn-65	Sb-122	Ce-141	Total alpha
Cr-51	Sr-89	Sb-124	Ce-144	
Mn-54	Sr-90	Sb-125	Pu-238	
Fe-55	Zr-95	I-131	Pu-238+239	
Co-58	Nb-95	Sc-134	Am-241	
Fe-59	Ru-103	Cs-137	Cm-242	
Co-60	Ru-106	Ba-140	Cm-243	

The number of nuclides (or groups of nuclides) listed within EU2004 in Reference [6] is substantial. However, the guidance for limit-setting states that the number of limits set should be kept to a minimum whilst ensuring adequate control of discharges and adequate monitoring of process performance in Reference [4]. Therefore these lists have been narrowed down to identify the significant nuclides i.e. those meeting the following criteria, which are consistent with both the P&ID in Reference [1] and the appropriate guidance in Reference [4]:

- Nuclide that has a discharge greater than 1 TBq a^{-1};

- Nuclides whose dose contributes more than 1 μSv a^{-1} to the most exposed group;
- Nuclides whose dose to NHS is greater than 40 μGy hr^{-1} to any reference organism;
- Nuclides whose collective dose to UK, EU and the world, when truncated over 500 years, is greater than 1 man Sv; and,
- Nuclides that are key indicators of plant performance and process control.

The results from using the above criteria are summarised in the T-26.3-5.

T-26.3-5 Significant nuclides identified at this initial phase for the HPR1000 (FCG3)

Definition Criteria	Gaseous	Aqueous
Discharged activity (greater than 1 TBq a^{-1})	H-3 Kr-85m Kr-85 Kr-87 Kr-88 Xe-133m Xe-133 Xe-135 Xe-138	H-3
Dose to most exposed person (greater than 1 μSv a^{-1})	C-14	C-14
Dose to NHS (greater than 40 μGy hr-1)	-	-
Collective Dose (greater than 1 manSv)	C-14	-
Plant performance indicators	I-131 Total beta/gamma	I-131 Total gamma

26.3.1.6 Proposed Limits

The limits for the significant nuclides identified were proposed. The current discharges have been conservatively considered, and the proposed limits for liquid and gaseous discharges are provided in T-26.3-6. It should be noted that these are provisional and will be updated when the source term for UK HPR1000 is developed and optimised.

T-26.3-6 Provisional proposed discharge limits for significant nuclides

Provisional Proposed Limits for Gaseous Discharges	
Nuclide/Group	**Annual Limit (Bq a^{-1})**
Total Noble Gases	7.9×10^{13}
H-3	5.0×10^{12}
C-14	4.2×10^{11}
I-131	2.1×10^{8}
Cs-137 associated with particulate matter	1.0×10^{7}
Provisional Proposed Limits for Aqueous Discharges	
Nuclide/Group	**Annual Limit (Bq a^{-1})**
H-3	4.5×10^{13}
C-14	1.7×10^{10}
Other activity	3.8×10^{9}

26.3.2 Approach to Sampling and Monitoring

Specific sampling and monitoring plans for the UK HPR1000, including sampling and monitoring of effluents, the environment and processes will be developed through the GDA process based on the design of HPR1000 (FCG3).

26.3.2.1 P&ID Requirements

The P&ID sets the following requirements with respect to sampling arrangements, techniques and systems for measurement and assessment of discharges and disposals of radioactive waste:

Include:

- *details of in-process monitoring arrangements;*
- *details of arrangements for monitoring final discharges of gaseous and aqueous wastes;*
- *details of arrangements for monitoring disposals of non-aqueous liquid and solid wastes;*
- *a demonstration that the proposals represent the best available techniques for monitoring;*
- *confirmation that the sensitivity is sufficient to:*
  - *readily demonstrate compliance with the proposed limits;*
  - *meet the levels of detection specified in reference EU, 2004.*
- *a description of the facilities provided for independent periodic sampling (by the regulator) of final discharges of gaseous and aqueous wastes.*

26.3.2.2 Regulatory Context

The sampling and monitoring program that will be developed for the UK HPR1000 will take account of the Radioactive Substances Regulation – Environmental Principles (REPs), Reference [7]. The REPs (Principle RSMDP13) states that 'The best available techniques, consistent with relevant guidance and standards, should be used to monitor and assess radioactive substances, disposals of radioactive wastes and the environment into which they are disposed.'

Permit Conditions Relevant to Sampling and Monitoring

A permit issued under the Environmental Permitting Regulations will contain a number of conditions pertinent to sampling and monitoring in Reference [8]:

- Condition 3.2.1 (a): '*Operators will take samples and conduct measurements, tests, surveys, analyses and calculations to determine compliance with the conditions of this permit*'.
- Condition 3.2.3: '*Monitoring equipment, techniques, personnel and organisations employed for the monitoring of disposals and the environment required by condition 3.2.1 or 3.2.5 shall have either MCERTS certification or MCERTS accreditation (as appropriate), where available, unless otherwise agreed in writing by the Environment Agency'.*
- Condition 3.2.4: '*Permanent means of access shall be provided to enable sampling and monitoring to be carried out in relation to the disposal outlets specified in schedule 3 unless otherwise agreed in writing by the Environment Agency'.*
- Condition 3.2.1 (c): '*The operator shall use the best available techniques when taking such samples and conducting such measurements, tests, surveys, analyses and calculations, and carrying out such environmental monitoring programmes and retrospective dose assessment, unless particular techniques are specified in schedule 3 of this permit or in writing by the Agency'.*

26.3.2.3 Objectives for Sampling and Monitoring

The sampling and monitoring programme will be developed with the following objectives in Reference [9] and [10]:

- to ensure that potential discharges are known by the site operator to be within authorised limits;
- to provide information to demonstrate that the operations giving rise to the effluent and the use of abatement plant (if any) and all associated control and management systems are performing as planned;
- to detect rapidly, give warning and identify the nature and extent of any unplanned releases to the environment to allow suitable remedial activities to be instigated;
- to provide a record of the amount of radioactive material discharged to the

environment in order to demonstrate compliance with the authorised limits on releases.

26.3.2.4 Monitoring and Sampling Methods

There will be three distinct types of sampling and monitoring conducted within and around the UK HPR1000.

a. In-process

In process sampling and monitoring provides information relating the performance of the plant and can provide early indications of sub-optimal performance. The in-process monitoring be designed in the HPR1000 (FCG3) mainly fulfils the monitoring of the following:

- Fuel element (to identify cladding failure);
- Steam generator blowdown water;
- Leakage rate of Steam Generator (monitoring of main steam system);
- Activity of exhaust from Condensate Vacuum System(CVI [CVS]);
- Nuclear Island Vent and Drains System (RPE [VDS]);
- Exhaust from Gaseous Waste Treatment System (TEG [GWTS]);
- Component Cooling Water System (RRI [CCWS]); and,
- Coolant purification filter.

Details on the monitoring systems will be provided at later stages of the GDA process.

b. Effluent

Two final discharge points for radioactive effluent have been identified:

- Gaseous discharges will be released via the stack; and,
- Aqueous discharges will be released via the outfall.

Discharge of liquid radioactive effluent into the environment should be sampled and measured upstream of the discharge point in the storage tanks, and be monitored continuously before the discharge valves. Gaseous discharge routes will be sampled and monitored according to Reference [11]. If dilution brings discharges below limits of detection then sampling may occur closer to the source.

The main focus will be on collecting representative samples for analysis, and ensuring accurate records are obtained of the activity discharged to the environment. The analytes will be those that have associated limits (see T-26.3-6).

The following section outlines some high level suggestions for the type of sampling systems and instrumentation that could be used.

Aqueous Discharges

The Environment Agency's Monitoring Certification Scheme (MCERTS) applies to both the sampling and the resulting analysis of radioactivity from aqueous effluents. For sample collection, MCERTS accredited flow proportional samplers are regularly used throughout the industry and it is proposed that this is what will be employed for the UK HPR1000. These allow representative samples to be collected assuming that the effluent is well mixed prior to discharge. Aqueous effluent is discharged via a batch process and the tanks will be well mixed through the use of a recirculation line prior to discharge to the main outfall. In addition to the collection of the aqueous sample, it is important to determine the flow of the discharge, not only for final sentencing, but also for the correct use of the flow proportional counter. This type of measurement is also covered under MCERTS, so a commitment is made to use an accredited flow meter.

The final sampling method, along with the analytical method will be selected to ensure that the appropriate detection limits can be achieved. The detection limit will need to be at a level where compliance with these limits can be demonstrated.

Gaseous Discharges

Both gaseous and particulate material will be collected to ensure that all the key nuclides identified in T-26.3-6 are sampled or monitored.

The sample will be extracted from the stack at a location where sufficient mixing has occurred to ensure that the sampled effluent is representative of the overall discharge.

Samples will be extracted from the stack isokinetically to ensure particulate material sampled is representative of the main effluent stream. The exact nature and number of sample probes will be determined through the BAT process at later stages of GDA. The sample line from the sample extraction point to the sample collection and monitoring location will be kept as short as possible and will contain a minimum number of bends and horizontal sections as is reasonable to reduce the loss of material.

The final sampling method, along with the analytical methods will be selected to ensure that the appropriate detection limits can be achieved. These detection limits will aim to produce positive results (i.e. not less than values) as far as reasonably achievable along with those dictated by EU2004, Reference [6].

For gaseous radioactive releases, MCERTS only covers the measurement of flow, so a commitment is made to use an accredited flow meter.

Independent Sampling and Monitoring

Arrangements will need to be made for the regulator to collect samples independently and at a time of its choosing. Sampling arrangements will ensure that the standard collection of samples by the operator, used to determine the discharge to the environment, will not be affected. This can either be by the use of a mirror sampling system or through the use of back-up equipment used as redundancy. The exact nature of the sampling

system will be developed at a later stage in the GDA process.

c. Environmental

Radioactive Monitoring

Offsite monitoring of a range of different environmental matrices will be undertaken to calculate a retrospective dose assessment. This is highly dependent on the local site characteristics and habits, which will be defined at the site specific stage. It is outside the scope of the GDA process.

26.3.3 Prospective Radiological Assessment

26.3.3.1 P&ID Requirements

The P&ID sets the following requirements with respect to prospective radiological assessment:

Include:

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

26.3.3.2 Regulatory Context

Environmental Permitting Regulations 2016 (EPR16) (Reference [12]) is the mechanism by which the requirements of the Euratom Basic Safety Standards Directive (BSSD) in Reference [13] are implemented within England and Wales. These requirements are split into two areas:

Optimisation and Dose Limits

There is a requirement to keep exposure of ionising radiation to any member of the public and of the population as a whole ALARA, taking into account economic and social factors.

The total dose to a member of the pubic must not exceed 1 mSv a^{-1}.

Specific Dose Limits

Two maximum dose limits are defined:

- 0.3 mSv a^{-1} from any source from which radioactive discharges are first made on or after 13th May 2000; or,
- 0.5 mSv a^{-1} from the discharges from any single site.

Estimates of doses are to be as realistic as possible (by requiring that Article 45 of BSSD is observed). It should be noted that BSSD has been updated, but that UK legislation has not been updated to reflect the changes.

In addition to the permitting requirements, the UK produced a strategy for discharges in Reference [14] which states that the application of BAT in England and Wales will ensure that discharges from new nuclear power stations constructed in the UK will not exceed those from comparable power stations across the world.

The Health Protection Agency (now known as Public Health England (PHE)), have suggested a dose constraint of 0.15 mSv a^{-1} for any new nuclear power stations in Reference [15]. However, this is not currently enacted into UK legislation.

26.3.3.3 Dose Assessment Methodologies

In order to conduct a meaningful assessment of the impacts of the radioactive discharges from the UK HPR1000, the source term described within Section 26.3.1 was used as the basis for the calculations. Also a number of assumptions were made with respect to the conditions of the Generic Site. The parameters used in this section are based primarily on EA's recommended publications and guidelines, which are generic site data and are suitable for potential sites identified in EN-6. The assumptions made and parameters used for the dose impact assessment will be further developed and justified in the PCER.

Site Assumptions

The main assumptions about the Generic Site are:

- The site is coastal in nature and radioactive discharges will be made to the marine or estuarine environments;
- There are no radioactive discharges to rivers;
- There are no radioactive discharges to groundwater; and,
- There are no radioactive discharges to the sewage network.

Receptors

The human receptors have been taken from the EA's Initial Radiological Assessment Methodology (IRA), Reference [2]. From the assumptions listed above, they will be:

a) Fisherman family who will receive dose from:

- external irradiation from radionuclides deposited in shore sediments
- through the consumption of seafood incorporating radionuclides

b) Local resident family who will receive dose from:

- inhalation of radionuclides in the effluent plume
- external irradiation from radionuclides in the effluent plume and deposited to the ground
- consumption of terrestrial food incorporating radionuclides deposited on the ground.

Appropriate reference organisms have been selected from both the terrestrial and marine ecosystems to determine the impacts on NHS. The pertinent information relating to the two different groups used to undertake the assessment are presented in T-26A-1 to T-26A-10 in Appendix A.

Dose to the Most Exposed Members of the Public

To estimate the dose to the most exposed groups of the general public from the proposed discharge limits the IRA methodology recommended by the EA was used in Reference [2] and [3]. The purpose of the methodology is to:

- Provide a system for undertaking an initial cautious prospective assessment of the dose arising from sources of radioactive waste discharges to the environment; and,
- Identify those sources of discharges for which a more detailed assessment should be undertaken.

The methodology is based on the simple use of dose per unit release (DPUR) values for different radionuclides, release routes and exposure pathways. Where no DPUR values are present then the recommend surrogates provided within IRA were used. Where these were deemed inappropriate then this has been highlighted within the specific sections.

The IRA methodology is applied in the following three main stages:

- Stage 1 – Initial radiological assessment using default data. If assessed dose is > 20 $\mu Sv\ a^{-1}$, then proceed to Stage 2.
- Stage 2 – Initial radiological assessment using refined data. If assessed dose is > 20 $\mu Sv\ a^{-1}$, then proceed to Stage 3.
- Stage 3 – Determine need for separate site-specific assessment.

The generic site is based on a coastal environment. The main pathways that are to be assessed using the IRA approach are air and estuary/coastal. The IRA methodology also allows assessment analysis of both rivers and public sewers. However, neither of the

routes will receive radioactive discharges from the HRP1000 (FCG3) design, so they have not been assessed. In addition to the above, the dose associated with the direct radiation from the facility needs to be taken into account. The IRA methodology rightly states that the DPUR approach cannot be used for this and that measurements, if available, should be used. As there is no data for the UK HPR1000 an estimate of the direct dose has been made which is detailed in a later section of this report.

The three components (aerial, coastal and direct) will then be summed to determine the total estimated dose to the most exposed groups from the operations of the UK HPR1000. This will then determine if the assessment process will need to progress to the next stage.

Stage 1 Assessment

Gaseous

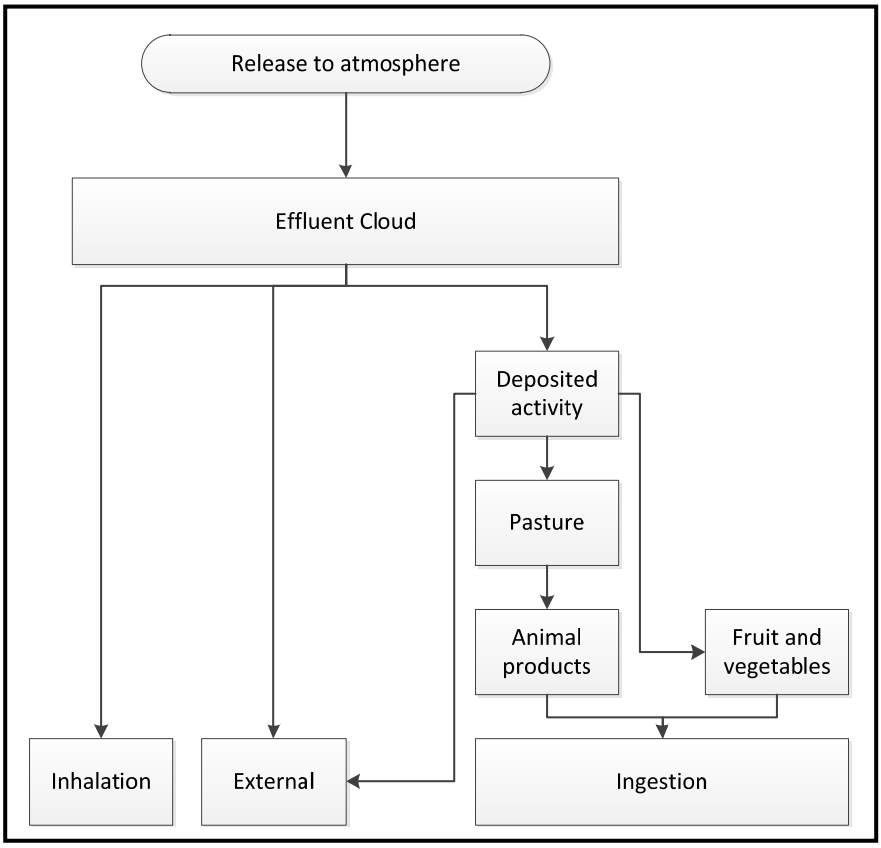
The first stage of the assessment methodology is to use the unmodified DPUR data with the default assumptions as summarised below.

The exposure group for releases to air and relevant exposure pathways is local resident family through:

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

Key assumptions are that:

- The release is at ground level;
- Local resident is located at a distance of 100 m from the release point; and,
- Food is produced at a distance of 500 m from the release point.



F-26.3-2 Flow diagram of gaseous pathways

Where available, the estimated activity from the source term was multiplied by the DPUR values from Table 2 within Reference [2]. There are a number of nuclides within the proposed HPR1000 (FCG3) discharge that do not have DPUR values. The IRA approach suggests surrogate nuclides that can be used when no DPUR values are provided. These are based on the radiation type and half-life. These nuclides and their surrogates are listed in T-26.3-7.

T-26.3-7 A list of the nuclides within the proposed gaseous discharge that do not have corresponding DPUR values within Reference [2], and proposed surrogates

Gaseous Discharged Nuclide with no DPUR	Half Life	IRA proposed surrogate
Kr-87	73.6 min	Kr-79
Kr-88	2.84 hr	Kr-79
Xe-133m	2.19 day	Kr-79
Xe-135	9.14 hr	Kr-79
Xe-138	14 min	Kr-79
Sb-122	2.69 day	I-131
Sb-124	60.2 day	Pb-210

All the nuclides with missing DPUR values use surrogate values. Using the IRA approach Kr-79 should be used as a surrogate for the noble gases. Kr-79 is more appropriate for replacing the noble gases than Am-242 and I-131 of the similar environmental behaviour.

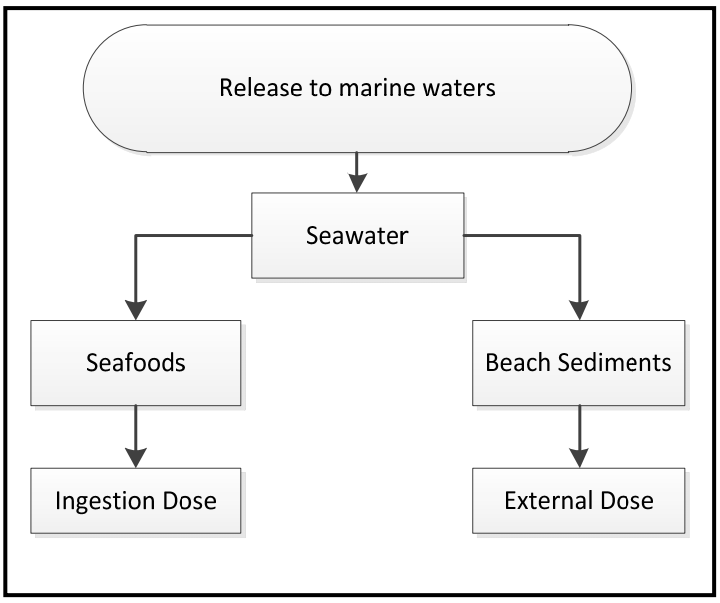
Aqueous

The first stage of the assessment methodology is to use the unmodified DPUR data with the default assumptions as summarised below. The exposure group for releases to an estuary or coastal water and relevant exposure pathways is fisherman family through:

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

Key assumptions are that:

- All shellfish and 50% of the fish are caught from a ‘local compartment’;
- The other 50% of the fish are assumed to be caught in the adjacent regional compartment; and,
- The volumetric exchange rate between local and regional compartments is set at 100 m3 s^{-1}.



F-26.3-3 Flow Diagram of Coastal Pathways

As with the gaseous discharges, the list of proposed discharged nuclides contains ones that do not have corresponding DPUR values within Reference [2]. The nuclides missing DPUR values and the surrogate nuclides used instead are shown in T-26.3-8. The surrogates have been selected using the approached prescribed in IRA, which is based on radiation type and half-life. The suggested surrogate for nuclides with a half-life greater than 10 days is Pb-210. This has dose conversion factors that are orders of magnitude different from those for Sb-124. Cs-137 has a similar half-life to Pb-210 and its dose conversion factors are of a similar order of magnitude to those nuclides with a missing DPUR value, so it was concluded that Cs-137 would be a more realistic surrogate to use for these nuclides.

T-26.3-8 Nuclides with no DPUR values in Reference [2], and the surrogates used in the assessment

Discharged Nuclide	Surrogate
Sb-122	Mn-52
Sb-124	Cs-137

The appropriate total DPUR values (incorporating external and consumption DPUR values) were then multiplied by the proposed discharge data to generate a dose to the most exposed group.

Stage 2 Assessment

The EA's IRA allows for some more realistic parameters to be applied to the discharges at step 2 to make the estimate of dose more representative of the proposed design of the HRP1000 (FCG3).

Gaseous

At stage 1, the assessment methodology assumes that discharges are made at ground level. In reality gaseous discharges will be released through a stack which aids in the dispersion of the effluent. To take account of this, one scaling factor is applied to the food DPUR values while another one is applied to the inhalation and external DPUR values.

The current HPR1000 (FCG3) design is to have a stack of 70 m. It has been assumed the effective stack height is 20 m which is still conservative because of building effects on dispersion. This is consistent with the third height rule regularly used in such assessments.

This produces two different scaling factors as described in Reference [2]:

- Food scaling factor of 0.27; and,
- Inhalation and external dose scaling factor of 0.04.

The resulting dose was calculated by multiplying the activity by the appropriate DPUR value and scaling factor for each nuclide and then summing the individual values to obtain the final gaseous dose.

Aqueous

For the Stage 1 assessment the volumetric exchange rate between the local and regional compartments was set at a conservative value of 100 m^3 s^{-1}. The guidance provides a range of values that can be used, which are based in different locations around the UK and reflect the dynamism of those coastal/estuarine environments.

The proposal is to locate the UK HPR1000 in the south east of the UK, and therefore the conservative value for the volumetric exchange value of 130 m^3 s^{-1} provided in the guidance (Reference [2]) has been used within the assessment. This represents a scaling factor of 0.29. The figure was then used to multiple the dose calculated in Step 1 to estimate a more realistic dose.

Stage 3 Assessment

At stage 3, the assessment is to consider detailed site-specific information.

Direct Dose

To complete the assessment to members of the public from the proposed UK HPR1000 design, the direct dose needs to be included within the estimated dose. However, DPUR factors are not appropriate for this exposure pathway. Rather, direct radiation doses would be determined by measurement. It is always difficult to make measurements of direct dose as it has to be distinguished from the dose associated with other discharge routes as well as natural radiation present. There is no data available from similar plants in China, so the direct dose has been estimated using the following conservative approach. It is assumed that the maximum dose rate at outside any building is 1 mSv a^{-1} for public

achieved from direct shine in undesignated area. It is then assumed that the closest individual lives within 100 m of any building and spends 100 % of their time at that location. The individual spends 50% of their time outdoors and 50% with a relative shielding effect of 0.1 for time fraction spent indoors. The resulting dose is calculated as:

$$\text{Direct Dose} = 1/D \times D_{rs} \times [(S_{fo} \times T_{fo}) + (S_{fi} \times T_{fi})]$$

Where:

D = Distance from Building to the exposed group (100 m);

D_{rs} = Dose rate (mSv a^{-1}) in undesignated area;

S_{fo} = Shielding factor for being outdoors (1);

S_{fi} = Shielding factor for being indoors (0.1);

T_{fo} = Time fraction spent outdoors (0.5); and,

T_{fi} = Time fraction spent indoors (0.5).

Using this conservative approach in lieu of any direct dose data generates an estimated direct dose rate of 5.5 µSv a^{-1}, which will be used in the assessment.

Short-term Dose

Aqueous discharges from HPR1000 (FCG3) are made on a batch basis. However, the design prevents any spikes of short term activity being released due to the effluent being held in storage tanks which are sampled prior to final discharge to the environment. If activity values exceed the prescribed levels, then the effluent can be returned to the effluent waste management system to be cleaned up to a level that is acceptable to be released. For this reason, no short term dose assessment of the aqueous effluent discharged to the environment will be undertaken.

The gaseous discharges were assessed in a manner consistent with the methodologies set out in Reference [16] and [17].

The assessment will take into account:

- Inhalation and cloud shine for the period of the passage of the plume; and,
- Ground shine and ingestion for a year following the release.

The gaseous discharge is not constant during an operational cycle. The worst monthly discharge has been used to assess the impacts of short term releases. The discharge occurs during 24 hours assumable, so this will be used as the discharge time for modelling purposes. The source term for the short term release based on data from HPR1000 (FCG3) is provided in T-26.3-9.

T-26.3-9 Release rates for the short-term assessment

	Radionuclides	Release rates(Bq s^{-1})		Radionuclides	Release rates(Bq s^{-1})
1	Kr-85m	4.68E+06	17	Fe-59	1.31E-01
2	Kr-85	4.33E+07	18	Sr-89	3.33E-02
3	Kr-87	4.86E+06	19	Sr-90	1.37E-02
4	Kr-88	9.98E+06	20	Zr-95	1.89E-03
5	Xe-133m	7.31E+07	21	Nb-95	1.16E-03
6	Xe-133	2.45E+06	22	Cs-134	1.28E+01
7	Xe-135	3.84E+07	23	Cs-137	2.50E+01
8	Xe-138	5.44E+06	24	Ba-140	6.00E-02
9	I-131	4.86E+02	25	Ce-141	1.35E-03
10	I-132	2.45E+02	26	La-140	2.31E-03
11	I-133	5.09E+02	27	Ce-144	9.12E-04
12	I-135	2.03E+02	28	Ag-110m	4.61E-02
13	Cr-51	8.56E-01	29	Sb-122	3.03E-02
14	Mn-54	6.41E-02	30	Sb-124	2.85E-02
15	Co-58	3.52E-01	31	H-3	1.15E+07
16	Co-60	2.87E-01	32	C-14	9.68E+05

The aerial dispersion model ADMS-5 was used to calculate activity concentrations in air per unit discharge, deposition rate per unit discharge and the cloud gamma doses for the nuclides shown in the gaseous source term.

It assumed that people are located 100 m from the discharge point and all food production occurs 500 m from the discharge point. The meteorology data is characterised by a single weather stability category D during the 24 hour short-term release, a wind speed of 5 m s^{-1} and a boundary layer depth of 800 m. Food consumption rates have been set as the critical group values in PC CREAM08 to provide a conservative estimate of the dose. It also assumed that all food is produced locally, which again is conservative as an approach.

At this early stage of the process, only the doses to adults will be estimated. As the source term is developed doses to other ages groups will be assessed at future stages of the GDA process.

The doses will then be calculated using the approach outlined in Appendix I of Reference [16], which are summarized below.

Ingestion Dose

$$Dose_{T,n,r} = \sum_{f=1}^{f=F} \sum_{t=1}^{t=T} Dep_{n,r} \times IntAct_{t,f,n} \times IngRate_{t,f} \times DPUI_{n}$$

Where:

$Dose_{T,n,r}$ The individual effective dose (Sv) to the chosen age group received from the consumption, over time (T), for all foods (F) for radionuclide (n) and release (r);

$Dep_{n,r}$ Total deposition (Bq m^{-2}) from the passage of the plume;

$IntAct_{t,f,n}$ Integrated activity concentration per unit deposit (Bq a kg^{-1} per Bq m^{-2}) in food f over time t;

$IngRate_{t,f}$ Ingestion rate (kg a^{-1}) of food f over time t for the chosen age group;

$DPUI_n$ Dose per unit intake (Sv Bq^{-1}) for the radionuclide and chosen age group; and,

Inhalation Dose

$$DoseInh_n(Sv) = Act_n \times H_{inh,n} \times [(Inh_{id} \times T_{id} \times DRF_n) + (Inh_{od} \times T_{od})]$$

$DoseInh_n$ Inhalation dose for nuclide n (Sv);

Act_n Air activity concentration during the passage of the plume (Bq m^{-3});

$H_{ing,n}$ Dose coefficient to calculate committed effective dose for nuclide n (Sv Bq^{-1});

$Inh_{id,od}$ Breathing rate for both indoors (id) and outdoors (od) (m^3 h^{-1});

$T_{id,od}$ Indoor and outdoor exposure time (h); and

DRF_n Dose reduction factor for nuclide n.

Ground Dose

$$Dose_{Dep} = \left(\frac{1-e^{-\lambda_n t}}{\lambda_n}\right) \times GrAct_n \times DC_{ext} \times [(LF_{id} \times F_{id}) + (LF_{od} \times F_{od})]$$

$Dose_{Dep}$ Effective dose (Sv) from the deposit of nuclides n over time t;

λ_n Radioactive decay constant for nuclide n;

t Exposure time (h);

$GrAct_n$ Activity concentration in the ground resulting from the deposition of the plume (Bq m^{-2});

DC_{ext} External dose coefficient (Sv Bq^{-1} m^{-2});

$LF_{id,od}$ Location factor for indoors and outdoors; and,

$F_{id,od}$ Fraction of time spent in Location.

Assessment of Collective Dose

Collective doses are the sum of the doses received by members of the exposed population from all significant exposure pathways from a given source. For the purposes of this assessment an estimate of the collective doses to the populations of UK, Europe and the World will be made and truncated at 500 years as suggested in Principle 12 of the Principles for the Assessment of Prospective Public Doses, Reference [18].

The collective doses to the various populations were estimated from both gaseous and aqueous discharges using PC CREAM08, Reference [19]. Default PC CREAM08 parameters were used for the aqueous discharges, apart from the variation to the local compartment as described in the IRA Stage 2 assessment. The following variations were made to the gaseous discharge assessment set up:

- An atmospheric stability distribution of 50% category D was applied; and,
- An effective stack height of 20 m was used, to be consistent with other assessments for the HPR1000 (FCG3).

There are two components to the collective dose: global circulation and first pass. Only nuclides with significant half-lives contribute to the global circulation such as H-3, C-14 and Kr-85. The dose assumes the populations receiving the dose don't change over time and that they are all adults.

Environmental Accumulation

The proposal is for the UK HPR1000 to have a 60 year operation life time. There is a requirement to assess if over this period, any accumulation of radioactive material in the environment could have the potential to prejudice legitimate users or uses of the land or sea.

PC CREAM08 was used to determine the concentrations in soil and water using parameters consistent with those for the stage 2 of IRA method. The sub models of PC CREAM08, PLUME and FARMLAND are used to calculate the concentrations within the soil after 60 years. The parameters used are shown in T-26.3-10.

T-26.3-10 Model parameters used to determine the accumulation of activity in soils over a 60 year operational period

Parameter	Value used
Duration of discharge	60 years
Effective stack height	20 m
Distance from source	100 m
Wind rose	Uniform
Atmospheric stability category distribution	50% D

For the marine environment seabed sediment and unfiltered seawater activity concentrations were modelled using the DORIS model within PC CREAM08. All inputs were discharged into the local compartment. The parameters used are shown in T-26.3-11 and are based on those of the IRA assessment, with the only alteration being the volumetric mixing ratio being set to 130 m^3 s^{-1} to be consistent with the Stage 2 assessment approach described earlier.

T-26.3-11 Model parameters used to determine the accumulation of activity in seabed sediments and unfiltered seawater over a 60 year operational period

Parameter	Value used
Volume	1×10^8 m^3
Depth	10 m
Coastline length	1×10^4 m
Volumetric exchange rate	4.1×10^9 m^3 a^{-1}
Suspended sediment load	1×10^{-5} t m^{-3}
Sedimentation rate	4.9×10^{-3} t m^{-2} a^{-1}
Sediment density	2.6 t m^{-3}
Diffusion rate	3.15×10^{-2} m^2 a^{-1}

FARMLAND does not predict the transfer of either H-3 or C-14 into soils. A specific activity model was used to estimate the accumulation in soils using a method consistent with that stated in Reference [20]. In particular the equation (2) was used for the H-3 and Equation (26) was used for C-14. All parameters were taken from Reference [20], apart from the following:

- A ratio of 0.167 was used as the amount of moisture in the soil and was derived from the information about wet and dry soils within GRANIS for the H-3

calculation.

- Fraction of stable C was assumed to be 70 gC kg^{-1} taken from the generic wet soil data in GRANIS
- The organic content of the soil was assumed to be 6% as it is felt this is a reasonably representative number to use in this assessment.

Non-human Species

The freely available ERICA assessment tool was used to evaluate the radiological impact on non-human species at the proposed discharge limits. ERICA employs a tiered approach to assessing the risks of the discharge to NHS. It is similar to the IRA approach in that the first two tiers are generic and the third, if required, is more detailed.

The first Tier is based around Environmental Media Concentration Limits (EMCLs), which are defined as the activity concentration of a given radionuclide in media (soil, sediment, water) that will result in a dose-rate to the most exposed reference organism equal to the screening dose-rate, Reference [21]. The output from the tier 1 assessment is in the form of a risk quotient (RQ).

RQ = M/EMCL

Where, M is the activity concentration in the appropriate environment media (e.g. water, soil, sediments and air). These concentrations were those calculated for the 60 year accumulation in the environment.

The model generates an overall RQ, which is a sum of the RQs for the most limiting reference organism for each radionuclide. A default screen level of 10 μGy h^{-1} is used for all ecosystems and organisms.

The second Tier, although still a screening tier, is used to calculate dose rates explicitly and requires more detailed input from the assessor allowing for scrutiny and editing of default parameters in the process. In particular it allows nuclides to be added, which reflects to proposed discharge in a more representative manner. The output is the dose rate per organism for each nuclide and the totals are then compared against an expected and conservative risk quotient. The risk quotient is calculated by dividing the dose rate by the selected screening level. This gives the expected value; the conservative value applies an uncertainty factor, which for this assessment has been selected as 5. This represents a 1% probability of exceeding the dose screening level (assuming the RQ distribution is exponential).

The parameters that were used to run the assessment are provided in T-26A-9 (aqueous) and T-26A-10 (gaseous).

Noble gases cannot be assessed using the latest version of the ERICA tool. The EA R&D128 tool in Reference [22] has recently been updated to contain a greater range of noble gases, Reference [23]. This however, still does not cover all the nuclides discharged

by the HPR1000 (FCG3). Therefore modelled nuclide concentrations in air were summed as per T-26.3-12 to ensure a conservative approach. The kr-88 with the greatest DPUC value was selected to represent the nuclides not present within the model.

T-26.3-12 Doses to the most exposed group using IRAT Stage 1

Nuclide in R&D128	Nuclides used for the air activity concentration
Kr-85	Kr-85
Kr-88	Kr-88 + Kr-85m + Kr-87
Xe-133	Xe-133 + Xe-133m + Xe-135 + Xe-138

26.3.3.4 Dose Assessment Results

Annual Dose to the Most Exposed Members of the Public

Results from the IRAT Stage 1 Assessment for aqueous and gaseous discharges at the proposed limits are shown in T-26.3-13 along with the direct dose.

T-26.3-13 Doses to the most exposed group using IRAT Stage 1

Pathway	Estimated Dose (μSv a^{-1})
Gaseous	68.9
Aqueous	8.4
Direct Dose	5.5
TOTAL	**82.8**

It is clear that the dose exceeds the criterion of 20 μSv a^{-1}. Therefore there is a requirement for a Stage 2 assessment to be conducted. The total dose is driven by the high gaseous dose rate of 68.9 μSv a^{-1}. Nuclide specific results are provided in Appendix B (T-26B-1 and T-26B-2). Noble gases are the major contributor to the aerial dose results besides C-14. And the liquid dose is dominated by C-14 (95.29%).

Using the assumptions outlined in Section 26.3.3.3 a Stage 2 IRAT assessment was conducted and the results are presented in T-26.3-14.

Using an effective stack height of 20 m significantly reduces the gaseous dose down to 6.4 μSv a^{-1} from 68.9 μSv a^{-1}. The aqueous dose is also reduced to 6.5 μSv a^{-1}, by using a more realistic volumetric exchange rate from the local compartment. The Stage 2 assessment results in a total dose of 18.4 μSv a^{-1}.

T-26.3-14 Doses to the most exposed group using IRAT Stage 2

Pathway	**Estimated Dose (μSv a^{-1})**
Gaseous	6.4
Aqueous	6.5
Direct Dose	5.5
TOTAL	**18.4**

The total dose is now below the IRA Methodology value of 20 μSv a^{-1}. Therefore, a Stage 3 assessment has not been conducted at PSR stage.

Dose to the representative person

The dose to a representative person has not been conducted at this stage. The conservative approach of the dose to the most exposed groups produces doses below 20 μSv a^{-1} and it is expected that the source term will be refined at later stages of the GDA process. Therefore the representative person dose will be calculated at the next stage of the GDA process using the defined source term.

Non-human Species

T-26.3-15 summaries the dose associated with gaseous discharges to non-human species. These have been derived from the tier 2 assessment conducted using ERICA, combined with the results from the noble gas calculations taken from the R&D128 assessment. The total dose rate is compared to the screening value (10 μGy h^{-1}) through the use of risk quotients. If these values exceed 1 then there is a risk the screening value could be exceeded. Even when using the conservative risk quotient it is clear that the doses are highly unlikely to exceed to screening value at the propose discharge limits.

T-26.3-15 Doses to NHS resulting from gaseous discharges at the proposed limits

Organism	TOTAL - Dose rate (µGy h^{-1})	Screening Value (µGy h^{-1})	Risk Quotient (expected value)	Risk Quotient (conservative value)
Amphibian	2.15E-03	10	2.15E-04	1.08E-03
Annelid	8.37E-04	10	8.37E-05	4.18E-04
Arthropod - detritivorous	1.53E-03	10	1.53E-04	7.67E-04
Bird	2.07E-03	10	2.07E-04	1.04E-03
Flying insects	8.03E-04	10	8.03E-05	4.01E-04
Grasses & Herbs	1.89E-03	10	1.89E-04	9.45E-04
Lichen & Bryophytes	2.54E-03	10	2.54E-04	1.27E-03
Mammal - large	2.43E-03	10	2.43E-04	1.22E-03
Mammal - small-burrowing	1.91E-03	10	1.91E-04	9.55E-04
Mollusc - gastropod	8.31E-04	10	8.31E-05	4.15E-04
Reptile	2.29E-03	10	2.29E-04	1.14E-03
Shrub	1.73E-03	10	1.73E-04	8.63E-04
Tree	2.21E-03	10	2.21E-04	1.10E-03

T-26C-2 shows the nuclide makeup of the total dose from gaseous discharges, from both different assessment tool used for this section (ERICA and R&D128 V2.0). It is clear that the doses are dominated by C-14, H-3 and Kr-88.

T-26.3-16 summaries the total doses received by a range of non-human species as a result of aqueous discharges at the proposed limits, which have been derived using the ERICA assessment tool. The same screening level was used as with the gaseous doses. All the risk quotients are below 1, even for the conservative approach.

T-26.3-16 Doses to NHS resulting from aqueous discharges at the proposed limits

Organism	Total Dose Rate per organism (µGy h^{-1})	Screening Value (µGy h^{-1})	Risk Quotient (expected value)	Risk Quotient (conservative value)
Benthic fish	5.48E-04	10	5.48E-05	2.74E-04
Bird	7.41E-04	10	7.41E-05	3.71E-04
Crustacean	7.42E-04	10	7.42E-05	3.71E-04
Macroalgae	6.60E-04	10	6.60E-05	3.30E-04
Mammal	3.95E-02	10	3.95E-03	1.97E-02
Mollusc - bivalve	9.01E-04	10	9.01E-05	4.51E-04
Pelagic fish	3.30E-04	10	3.30E-05	1.65E-04
Phytoplankton	2.07E-04	10	2.07E-05	1.03E-04
Polychaete worm	2.11E-03	10	2.11E-04	1.06E-03
Reptile	1.10E-03	10	1.10E-04	5.51E-04
Sea anemones & True coral	8.64E-04	10	8.64E-05	4.32E-04
Vascular plant	5.13E-04	10	5.13E-05	2.57E-04
Zooplankton	1.52E-03	10	1.52E-04	7.62E-04

T-26C-1 provides the nuclide makeup of the dose from aqueous discharges. It is clear that the doses are dominated by Fe-59.

Due to all the doses being below the screening level and no risk quotients exceeding 1 it is concluded that there is no risk at a population level from the proposed discharges and no further detailed assessment will be conducted at PSR stage as per recommendations of the ERICA assessment tool.

Environmental Accumulation

It is proposed that the UK HPR1000 is to operate for a total of 60 years, and therefore the accumulation within the environment has been assessed for this period of time as described in Section 26.3.3.3. All parameters were chosen to reflect those used in the Stage 2 assessment.

The unfiltered seawater and seabed sediments concentrations are detailed in T-26E-1. The total activity in unfiltered seawater and seabed sediments has been estimated to be 11.0 Bq l^{-1} and 27.8 Bq kg^{-1} respectively. When the sediment values were compared against the Environmental Permitting Regulations – Radioactive Substances Regulations (EPR-RSR) values in Reference [24], they were all far less than the regulatory values, with the closest being Co-60, which is still 521 times lower than the limit.

The soil concentrations are detailed in T-26E-2. The total activity has been estimated to be 3.01 Bq kg^{-1} following 60 years of continuous discharge. The results were compared against the EPR-RSR (Reference [24]) out of scope values and all are far less than the regulatory values. As these limits are risk driven and the accumulation from the 60 years discharge are well below these, it is concluded that these would not prejudice legitimate users.

Collective Dose

The collective doses resulting from the gaseous discharges at the proposed limits truncated to 500 years are summarised in T-26.3-17.

T-26.3-17 Collective Doses (manSv) resulting from gaseous discharges at the proposed limits

Population	UK	EU	EU12	EU25	World
1st Pass (manSv)	1.77×10^{-1}	8.90×10^{-1}	-	-	-
Global Circulation (manSv)	4.38×10^{-2}	-	2.65×10^{-1}	3.36×10^{-1}	7.36
TOTAL (manSv)	**0.22**	**-**	**1.16**	**1.23**	**7.36**

Details of the assessments can be found in T-26D-1, T-26D-2 and T-26D-3.

The collective doses resulting from the gaseous discharge are dominated by C-14 which contributes to more than 98% of the total dose for both the first pass and global circulation assessments.

The collective doses resulting from the aqueous discharges at the proposed limits truncated to 500 years are summarised in T-26.3-18.

T-26.3-18 Collective Doses (manSv) resulting from aqueous discharges at the proposed limits

Population	UK	EU12	World
1st Pass (manSv)	2.99×10^{-3}	1.81×10^{-2}	2.71×10^{-2}
Global Circulation (manSv)	1.17×10^{-3}	7.03×10^{-3}	1.95×10^{-1}
TOTAL (manSv)	**4.16×10^{-3}**	**2.51×10^{-2}**	**2.22×10^{-1}**

Details of the assessments can be found in T-26D-4, T-26D-5 and T-26D-6.

The collective doses from the aqueous discharge are dominated by C-14.

It is clear that the total collective doses are driven by the gaseous discharges which are orders of magnitude greater than those associated with the aqueous discharges.

Whilst there is no limit for collective doses, the International Atomic Energy Agency

(IAEA) has presented dose criteria which are considered sufficiently low that doses arising from sources or practices that meet these criteria may be exempted from regulatory control. One of the criteria is that collective dose should be less than about 1 manSv per year of practice, Reference [18]. The estimated collective dose to members of the UK is below this value, but the ones for the EU and the World exceed it.

The same guidance states that calculated average annual individual doses for a population group in the nanosievert (nSv y^{-1}) range or below should be ignored in the decision making process as the associated risks are minuscule and the contribution to total doses to individuals will be insignificant, Reference [18]. Using the population values stated in T-26A-7 the average annual individual dose ranges from 0.8 nSv for the world population to 3.9 nSv to the UK.

Short Term Dose

T-26.3-19 provides a summary of the dose to adults from the short term dose associated with a 24 hours discharge from the maximum monthly discharge.

T-26.3-19 Summary of Short Term Dose Assessment

	Dose (μSv)				
Nuclide	**External**	**Direct**	**Ingestion**	**Inhalation**	**TOTAL**
Kr-85m	3.82E-03	0.00E+00	0.00E+00	0.00E+00	3.82E-03
Kr-85	4.39E-04	0.00E+00	0.00E+00	0.00E+00	4.39E-04
Kr-87	1.61E-02	0.00E+00	0.00E+00	0.00E+00	1.61E-02
Kr-88	7.79E-02	0.00E+00	0.00E+00	0.00E+00	7.79E-02
Xe-133m	8.68E-03	0.00E+00	0.00E+00	0.00E+00	8.68E-03
Xe-133	3.98E-04	0.00E+00	0.00E+00	0.00E+00	3.98E-04
Xe-135	4.56E-02	0.00E+00	0.00E+00	0.00E+00	4.56E-02
Xe-138	2.46E-02	0.00E+00	0.00E+00	0.00E+00	2.46E-02
I-131	7.36E-07	7.62E-05	1.06E-06	1.92E-04	2.70E-04
I-132	1.99E-06	2.12E-09	1.77E-11	1.44E-06	3.43E-06
I-133	1.17E-06	8.60E-06	1.27E-08	4.09E-05	5.06E-05
I-135	1.10E-06	5.56E-07	1.81E-10	3.47E-06	5.12E-06
H-3	0.00E+00	0.00E+00	4.28E-01	2.90E-02	4.57E-01
C-14	0.00E+00	0.00E+00	4.05E+00	1.08E-01	4.16E+00
Cr-51	1.26E-10	2.49E-06	9.40E-13	1.76E-09	2.49E-06
Mn-54	1.86E-10	1.25E-06	6.34E-12	5.14E-09	1.25E-06
Co-58	1.37E-09	2.54E-06	6.60E-12	4.11E-08	2.59E-06
Co-60	2.68E-09	8.56E-06	5.19E-11	4.95E-07	9.06E-06
Fe-59	5.27E-10	6.51E-07	5.31E-11	2.80E-08	6.80E-07
Sr-89	1.06E-14	1.76E-07	3.60E-12	1.46E-08	1.90E-07
Sr-90	0.00E+00	3.59E-07	2.59E-11	1.22E-07	4.81E-07

	Dose (μSv)				
Nuclide	**External**	**Direct**	**Ingestion**	**Inhalation**	**TOTAL**
Zr-95	5.56E-12	4.58E-09	5.52E-14	6.20E-10	5.21E-09
Nb-95	3.51E-12	1.58E-09	1.73E-14	9.67E-11	1.68E-09
Cs-134	8.05E-08	2.88E-04	1.26E-07	1.34E-09	2.88E-04
Cs-137	0.00E+00	1.84E-04	1.76E-07	9.95E-10	1.84E-04
Ba-140	4.81E-11	3.58E-08	3.21E-12	1.70E-08	5.28E-08
Ce-141	5.07E-13	4.61E-09	1.82E-14	2.85E-10	4.89E-09
La-140	2.19E-11	4.09E-10	1.20E-14	1.42E-10	5.72E-10
Ce-144	9.32E-14	1.60E-08	1.69E-13	2.69E-09	1.87E-08
Ag-110m	5.16E-10	7.70E-07	1.90E-10	3.07E-08	8.01E-07
Sb-122	6.01E-11	8.60E-09	1.13E-12	1.69E-09	1.03E-08
Sb-124	2.14E-10	1.77E-07	1.18E-11	1.01E-08	1.88E-07
TOTAL	**1.78E-01**	**5.74E-04**	**4.48E+00**	**1.37E-01**	**4.79E+00**

The short term dose is dominated by C-14 from ingestion dose. The nuclide contributes up to 86.74% of the total short term dose.

The short term doses in conjunction with the annual dose should be below the constraint value of 300 μSv a^{-1}. It can be seen even using the conservative assumptions within the short term assessment, when these are added to the annual dose of 4.79 μSv a^{-1}, it produces an estimated dose of 23.19 μSv a^{-1}. It is substantially below any dose limit and annual dose constraints.

Comparison Against Constraints

The main constraint for use in proposed nuclear new build is that the dose to most exposed group does not exceed 300 μSv a^{-1}. Using the Environment Agency's IRA method, the dose at stage 2 of the assessment produced a dose to the most exposed group of 18.4 μSv a^{-1} for a single HPR1000 (FCG3). As well as being below this constraint it is also well below the PHE's proposed value of 150 μSv a^{-1}.

The total collective dose estimates range from between 0.22 to 7.36 manSv. There is no specific limit on collective doses, but there are recommendations that doses should not exceed 1 manSv. There are also recommendations that doses within the nSv range for a population group can be ignored. The values estimated for the HPR1000 (FCG3) range from 0.8 to 3.9 nSv so it is proposed these can be classed as insignificant.

The dose to non-human species is compared against screen level of 10 μGy h^{-1}. The doses estimated are all well below this value and even when the conservative risk quotient was used, the doses were below of the screen level. It is therefore concluded that the impact at a population level to non-human species resulting from the discharge from the HPR1000 (FCG3) is not detrimental.

26.4 Other Environmental Regulations

The GDA process requires an evaluation of a number of non-radiological environmental aspects, impacts, and hazard management issues at the power station site, as follows:

- Water use and abstraction;
- Discharges to surface waters;
- Discharges to groundwater;
- Operation of installations (combustion plant and incinerators);
- Substances subject to the COMAH Regulations; and,
- Fluorinated greenhouse gases (F-Gas) and ozone-depleting substances (ODS).

These topic areas are discussed below.

26.4.1 Water Use and Abstraction

26.4.1.1 P&ID Requirements

The P&ID sets the following requirements with respect to water use and abstraction:

- *Provide details and estimates of fresh water requirements for the design.*
- *Provide details and estimates of cooling water requirements for the design relevant to the generic site. Include consideration of:*
  - *Seawater or river water abstraction;*
  - *Use of conventional cooling towers or hybrid cooling towers;*
  - *Abstraction inlet fish deterrent schemes;*
  - *Fish return systems.*

26.4.1.2 Regulatory Context

There are three main areas of legislative requirements relevant to the abstraction of fresh water in England and Wales:

- The Water Resources Act 1991 (as amended), Reference [25];
- The Eels (England and Wales) Regulations 2009, Reference [26]; and,
- Salmon and Freshwater Fisheries Act 1975, Reference [27].

The Water Resources Act 1991 (Reference [25]) regulates water resources, water quality and pollution, and flood defence. Part II of the Act provides the general structure for the management of water resources with Chapter II addressing the specific aspects of water abstraction and impounding. Subsidiary legislation is provided by the Water Resources (Abstraction and Impounding) Regulations 2006, Reference [28]. Licences are required from the Environment agency for a) impoundment – to create an impoundment structure

such as a sluice, weir or dam, and b) abstraction - to abstract more than 20 cubic metres of water per day for a period of more than 28 days from controlled waters (which include natural waters such as rivers, streams, estuaries, canals, lakes, ponds, ditches and groundwater as far out as the UK territorial limit). Impoundment and abstraction licences are granted for specific site locations.

With specific reference to the passage and protection of fish (and other marine organisms), two additional pieces of legislation are relevant. The Eels Regulations 2009 (Reference [26]) implement Council Regulation (EC) No 1100/2007 of the Council of the European Union, establishing measures for the recovery of the stock of European eel. Under these regulations an operator managing an impoundment structure, water abstraction of more than 20 cubic metres per day or any discharge to a channel, bed or sea (out to six nautical miles) must make provision for: a) an eel pass to allow the free passage of eels, b) the removal of any obstruction, if deemed necessary, c) the use of eel screens to exclude eels from water abstraction and discharge points, and d) if necessary, the use of a by-wash to return excluded eels to the waters they came from. The Salmon and Freshwater Fisheries Act 1975 (Reference [27]) requires similar measures for the protection of migratory salmon and trout.

26.4.1.3 Fresh Water Demand and Supply

The main processes within the UK HPR1000 requiring fresh water are as follows:

- NI Demineralized Water Distribution System (SED [DWDS(NI)]; and,
- CI Demineralized Water Distribution System (SER [DWDS(CI)]).

Potable fresh water will be also required for site personnel (i.e. food preparation, drinking water, washing and showering) for general cleaning (e.g. floors and components) and for external landscaping and emergency fire-fighting purposes.

This Step 2 GDA submission is based on the assumption that all fresh water requirements will be met by the local water company and that fresh water abstraction, and an abstraction licence, will not therefore be required. However, this assumption will not preclude the consideration of other fresh water supply options at later stages of the GDA process. Estimates of total fresh water usage will also be developed at later stages of GDA.

26.4.1.4 Cooling Water Requirements

This Step 2 GDA submission is based on the assumption that the Generic Site is coastal. Cooling to the steam system will be supplied via the once-through Circulating Water System (CRF [CWS]) (see Chapter 11). Seawater will be abstracted via an intake, passed through drum screens, circulating water pumps, and debris filters, and supplied to the steam turbine condensers and the auxiliary cooling system. Downstream of this plant, the now warm water will be routed to the outlet culvert from where it will be returned to sea via an outfall structure.

Cooling for dedicated users within the Nuclear Island will be provided by the Essential Service Water System (SEC [ESWS]), which will exchange heat against the Component Cooling Water System (RRI [CCWS]) (see Chapter 10). The SEC [ESWS] consists of three cooling trains. In each, the seawater will be withdrawn via a dedicated SEC suction line, filtered, and pumped via a shellfish catcher to the RRI [CCWS]/SEC [ESWS] exchanger where it will exchange heat with RRI [CCWS]. Downstream, the warm water will be routed to a discharge canal from where it will be returned to sea via the outfall structure which it shares with CRF [CWS].

26.4.1.5 Consideration of Cooling Towers

Although the use of once-through (sea water abstraction and discharge) cooling system is considered BAT for coastal sites in Reference [29], other potential process waste heat rejection technologies will be considered for the UK HPR1000 design during site-specific stage. These are likely to include:

- Once-through cooling, using cooling towers to cool water before it is discharged to the ultimate heat sink.
- A water recirculation system that uses natural draft (chimney effect) cooling towers for heat rejection, with make-up water to compensate for evaporative losses.
- A water recirculation system that uses mechanical draft (e.g. fan assisted convection) cooling towers for heat rejection, with make-up water to compensate for evaporative losses.
- Closed-circuit cooling towers where the heat load to be rejected is transferred from the process fluid (the fluid being cooled) to a secondary (wet, dry or hybrid) fluid through a heat exchanger.

It should be noted that the options listed above are not considered as part of this submission document.

26.4.1.6 Consideration of Fish Deterrent and Fish Return Systems

The UK HPR1000 sea water intake will need to be sited in order to minimize its impact on surrounding habitats and species, in particular through the entrainment of fish and their juvenile fish. Previous studies in Reference [30] have shown that fish entrainment and impingement (where fish are trapped against screens and either injured or killed) is a complex combination of multiple local factors including: the intake capacity of the plant, physical nature of the water body, climatic conditions and flora/fauna. The issue, along with the design of any systems to mitigate it, is thus highly site specific.

In light of the site-specific nature of the issue it will not be considered further within this GDA submission but will be evaluated at later stages of the process. The later evaluation will consider a number of potential mitigation options including:

- Design of the inlet structure to minimize intake velocities;
- Location of the inlet structure;
- Use of screens and fish return systems;
- Use of physical barriers; and,
- Use of behavioural barriers including electric, bubble, light or sound barriers.

26.4.2 Discharges to Surface Water

26.4.2.1 P&ID Requirements

The P&ID sets the following requirements with respect to discharges to surface water:

Provide a description of how aqueous waste streams will arise, be managed and be disposed of throughout the facility's life-cycle. Include:

- *sources and quantities of contaminants (including disinfectant and biocides), highlighting any priority substances (as specified in the 'Priority Substances' Directive (EU,2008));*
- *identification of the effluent and surface water runoff streams contributing to the overall discharge and how they are controlled;*
- *potential options and associated environmental impact for disposal of each individual effluent stream;*
- *the means of control in the event of detection of unplanned radioactive or other contamination of the discharge;*
- *options for beneficial use of the waste heat produced;*
- *environmental impact of thermal discharges.*

26.4.2.2 Regulatory Context

Discharges of non-radioactive aqueous effluents generated at the generic site will be subject to the Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No. 1154), Reference [12]. These will typically include waste water discharged to drains, trade effluents and sewage wastes, but not normal rain water run-off.

It will, therefore, be necessary to obtain an environmental permit during the site-specific permit application stage. The permit application will need to present sufficient information covering:

- the source of the effluent
- effluent flow rates
- identification of contaminants (including heat).

The application will also need to provide an assessment of the effluent releases to the receiving environment, covering specific aspects such, e.g. protected EU Habitats sites, nationally-designated Special Protection Areas and Special Areas of Conservation and the

global network of protected sites created under the Ramsar, World Heritage and OSPAR Conventions.

26.4.2.3 Effluent Characterization

Information relating to the UK HPR1000's non-radiological aqueous waste streams at the Generic Site will be developed during the GDA process. The information will include a description of the sources of the effluent, and data on volumetric flow rates during different phases of the reactor cycle including: routine power operation, start-up and shutdown, refuelling outage and transients. Information will be provided that identifies the main chemical contaminants in the various effluent streams. The most important of these are expected to be substances such as biocides, disinfectants and corrosion inhibitors, but other substances will be identified and quantified as far as possible. Any contaminants that are identified as being listed on the 'Priority Substances' Directive (Directive 2008/105/EC), Reference [31] and, therefore, which pose a significant risk to (or via) the aquatic environment at the EU level will be highlighted. Furthermore, the means of controlling the streams in the event of detection of unplanned radioactive or other contamination within the discharge will be addressed.

26.4.2.4 Effluent Treatment and Impact Assessment

The GDA submission will ultimately identify reasonably practicable effluent treatment options for each UK HPR1000 aqueous effluent stream (or group of effluents), and will identify the relative environmental impacts of the treatment options using the EA's surface water pollution risk assessment process in Reference [32]. Quantified data on contaminant concentrations and effluent discharge flows will be used to predict maximum concentrations of contaminants in the receiving waters. These values will be compared against environmental quality standards (EQSs) for each contaminant (where published limits exist) and an assessment made as to whether the discharge of each individual substance is regarded as insignificant or potentially significant. BAT will be applied in the selection, storage design and planned use of potential contaminants to reduce the risk of environmental harm as a result of aqueous waste discharges so far as is reasonably practicable. The means to control discharge streams in the event of unplanned radioactive or other contamination being detected will be integrated into the site design and discussed at a later stage of the GDA process. The measures included in the site design will be complemented by the emergency preparedness arrangements during operation to mitigate risk of a major accident to the environment (MATTE).

26.4.2.5 Identification of Options for the Recycling of Waste Heat

The thermal efficiency of the HPR1000 (FCG3) is around 37% and its operation results in the generation of approximately 2,000 MW of waste heat. The overall efficiency of the station can be increased if practical uses can be found for the heat, particularly where their use would displace existing heating requirements. The obvious example is district heating, although others include:

- Heating for agriculture;
- Heating for aquatic farm;
- Use of heat for road surface de-icing in winter; and,
- Seawater desalination.

The practical and economic feasibility of waste heat usage is largely site-specific in nature depending, as it would, on the proximity of potential users, likely heating demand, etc. For this reason the issue of waste heat usage is not considered further within this GDA submission but will be evaluated at later stages of the process.

26.4.2.6 Environmental Impact of Thermal Discharges

Assessment of the impact of the thermal plume resulting from the discharge of warm water from the CRF/SEC outfall structure will be dependent on the plume's dispersion within the receiving waters, the concentrations of contaminants within the plume, and the presence of nearby sensitive habitats.

The behaviour of the plume in the receiving environment is determined by means of dispersion modelling using the outfall's physical characteristics, cooling water flow rate, and the differential temperature (ΔT) with the environment at the point of discharge. However, the modelling also requires information relating to the temperature of the receiving waters, bathymetry and the current and tidal regimes, and prevailing meteorological conditions, all of which (along with information on the presence of nearby sensitive habitats) are site-specific. For this reason the impact of the thermal plume is not evaluated in this submission but will be addressed at later stages of the GDA process.

26.4.3 Discharges to Groundwater

26.4.3.1 P&ID Requirements

The P&ID sets the following requirements with respect to discharges to groundwater:

> *If there will be discharges to groundwater, describe the nature and quantity of those discharges and provide an assessment of the impact on groundwater.*

26.4.3.2 Regulatory Context

All discharges to groundwater will be subject to the Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No. 1154), Reference [12]. Any unauthorised intentional discharge or negligent behaviour that allows transfer of contaminants/pollutants to groundwater sources is a prosecutable offence.

26.4.3.3 Discharges

As currently designed, the HPR1000 (FCG3) does not make routine intentional aqueous

discharges to groundwater sources. This, however, does not take account accidental spills and leaks that could contaminate land and underlying groundwater. Further BAT will be used to develop the design to prevent accidental (unintentional) discharges. These measures incorporated within the UK HPR1000 design will be described during later stages of the GDA process.

26.4.4 Combustion Installations

26.4.4.1 P&ID Requirements

The P&ID sets the following requirements with respect to combustion plant and incinerators:

- *Identify what combustion plant (for example, for standby generation or auxiliary boilers) will be provided.*
  - *If the aggregate rated thermal input of all combustion plant is greater than 50 MW, provide a comparison of the proposed technology against our sector guidance.*
  - *If the aggregate rated thermal input of all combustion plant is greater than 20 MW, describe how greenhouse gas emissions will be monitored.*
- *If the design includes an on-site incinerator with a capacity or 1 tonne or more per hour, provide a comparison of the proposed technology against our sector guidance.*

26.4.4.2 Regulatory Context

Standby Generation or Auxiliary Boilers

All combustion activities (including standby generators and combustion plants) will be subject to the Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No. 1154), Reference [12]. This adopts the equivalent EU Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) (the Industrial Emissions Directive, IED), Reference [33].

An environmental permit will be needed if:

- a single appliance burning fuel has a rated thermal input of ≥ 50MW, or
- two or more appliances burning fuel have an aggregated rated thermal input ≥ 50MW, and are operated at the same time by the same operator (this situation is considered to be equivalent to a single appliance with a rated thermal input ≥ 50MW.

Incineration Plant

The use of incinerators for the burning of non-radioactive wastes is covered by Schedule 1, Part 2, Chapter 5, Section 5.1 of EPR16, Reference [16]. The listing includes the following relevant activity:

- *5.1 Part A (1) (a) The incineration of hazardous waste in a waste incineration plant or waste co-incineration plant with a capacity exceeding 10 tonnes per day.*

- *5.1 Part A (1) (b) The incineration of non-hazardous waste in a waste incineration plant or waste co-incineration plant with a capacity exceeding 3 tonnes per hour.*
- *5.1 Part A (1) (c) The incineration, other than incidentally in the course of burning landfill gas or solid or liquid waste, of any gaseous compound containing halogens.*
- *5.1 Part B (a) The incineration in a small waste incineration plant with an aggregate capacity of 50 kilogrammes or more per hour of the following wastes.*
    - *(i) vegetable waste from agriculture or forestry;*
    - *(ii) vegetable waste from the food processing industry, if the heat generated is recovered;*
    - *(iii) fibrous vegetable waste from virgin pulp production and from production of paper from pulp, if it is co-incinerated at the place of production and the heat generated is recovered;*
    - *(iv) cork waste;*
    - *(v) wood waste with the exception of wood waste which may contain halogenated organic compounds or heavy metals as a result of treatment with wood preservatives or coatings;*
    - *(vi) animal carcasses.*
    - *(b) The cremation of human remains.*

Waste incineration plants which fall into one or more of these relevant activities will require an Environmental Permit to operate.

The burning of radioactive wastes in an incinerator falls under Schedule 23 of EPR16. Concentration limits and dose limits for a wide range of radionuclides in wastes with different source origin are presented. Incineration of radioactive waste will require a separate Environmental Permit for operation.

26.4.4.3 UK HPR1000 Combustion Installations

The UK HPR1000 is provided with the following combustion plant:

- 3 × emergency diesel generators each with a rated output of 8.0 MW; and,
- 2 × fixed station black out (SBO) diesel generators each with a rated output of 3.5 MW.

At the present stage of the design it is anticipated that the combustion plant will have an aggregated gross thermal input in excess of 50 MW_{th}. On this basis it will be necessary to obtain an Environmental Permit for these combustion activities at the site-specific stage.

The UK HPR1000 generic design does not include any requirement for on-site incineration of either general waste (hazardous or non-hazardous) or radioactive waste. It has therefore been assumed that there will be no waste incineration at the Generic Site.

26.4.4.4 Comparison with Sector Guidance Note

From the foregoing discussion, it is concluded that the UK HPR1000 will require ancillary combustion plant (appliances) consisting of diesel generators with an aggregated rated thermal input ≥ 50MW. In order to provide further demonstration that the proposed combustion technology aligns with current good practice, the P&ID (Reference [1]) will require additional comparison against the Environment Agency's '*combustion activities'* guidance, Reference [34].

This will necessitate an assessment of the diesel plant against the following aspects:

- Energy efficiency;
- Avoidance, recovery and disposal of wastes;
- Operational issues;
- Point source emissions to water;
- Point source emissions to air;
- Fugitive emissions; and,
- Monitoring.

The assessment will be undertaken at later stages of the GDA process once candidate diesel units have been identified by CGN and been subjected to technical and commercial evaluation. The technical evaluation will include an assessment against the aspects listed above.

26.4.4.5 Greenhouse Gas Emissions Monitoring

Monitoring Plan

The monitoring and reporting of greenhouse gas (GHG) emissions for the HPR1000 site must be robust, transparent, consistent, accurate and meet the requirements contained in the EU Monitoring and Reporting Regulation (MRR No. 1), Reference [35].

The annual procedure of monitoring, reporting and verification (MRV), together with all the associated processes, is known as the emissions trading system (ETS) compliance cycle, as described in the EU Emissions Trading Directive 2003/87/EC and Commission Regulation (EU) No. 601/2012, Reference [36]. The EU ETS works on the 'cap and trade' principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that total emissions fall. Within the cap, operators receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world.

Industrial installations that generate GHGs, including nuclear stations, covered by the EU ETS are required to have an approved Monitoring Plan for monitoring and reporting

annual GHG emissions. This plan should enable the presentation of plant emission data in a clear, transparent and simple manner, drawing on justifiable data sources, robust metering instruments, and effective control procedures. This plan is an essential part of the permit to operate for the industrial installation.

Every year, operators must submit an emissions report. The data for a given year must be verified by an accredited verifier by 31 March of the following year. Once verified, operators must surrender the equivalent number of allowances by 30 April of that year.

An important aspect of the EU ETS is the development and use of accurate and reliable emissions monitoring methodology. MRR Guidance is provided (Reference [35]) indicating that this can be based on alternative approaches as follows:

- Calculation-based approaches (which still requires a level of measurement to validate the calculations);
- Measurement-based approach (usually based on direct measurement of GHGs);
- Non-tier methodology (also known as "fall-back methodology"; to be used only in certain circumstances)
- Combination of approaches.

Proposed Approach

Section 4.3.1 of the MRR – General Guidance for Installations (Reference [35]), presents a 'Standard Methodology' for the calculation of emissions based on the amount of fuel or process input material consumed times an emission, process or oxidation factor to give the final total emission. It is proposed to use the same 'Standard Methodology' for the generic UK HPR1000, noting that the approach may change later in either the GDA or site specific approval process. The proposed UK HPR100 monitoring process will fully meet the requirements of the EU ETS.

26.4.5 COMAH

26.4.5.1 P&ID Requirements

The P&ID sets the following requirements with respect to COMAH:

Identify any need for on-site storage of substances above the qualifying thresholds in COMAH15.

If a threshold is exceeded, describe the measures taken in the design to prevent a major accident to the environment.

26.4.5.2 Regulatory Context

The COMAH Regulations 2015 (Reference [37]) apply to the prevention and limitation of the effects of major accidents involving dangerous substances, where these substances are stored and processed at a facility above specified thresholds. The substances falling

under the regulations are either named (in Schedule 1 Part 2 of the regulations) – hydrogen is an example – or substances falling within specific 'risk categories' (in Schedule 1 Part 1 of the regulations) such as 'HEALTH HAZARDS', 'PHYSICAL HAZARDS', 'ENVIRONMENTAL HAZARDS', etc. The COMAH Regulations specify two threshold quantities for each listed substance or 'risk category' of substance:

- If a site stores, uses or can produce more than the lower threshold for a dangerous substance but less than the higher threshold it is classified as a Lower Tier (LT) COMAH establishment; and,
- If a site stores, uses or can produce more than the higher threshold it classifies as an Upper Tier (UT) COMAH establishment.

The regulations do not cover radioactive materials.

COMAH applies mainly to the chemical industry, but is also applicable to the nuclear industry. Organisations which manufacture or store dangerous chemicals including: petrochemicals, pharmaceuticals and agrochemicals and explosives, in excess of threshold quantities, are subject to the COMAH regulations, and legally required to:

- *"Take all necessary measures to prevent major accidents involving dangerous substances", and*
- *"Limit the consequences to people and the environment of any major accidents which do occur, and report major accidents to the competent authority".*

Operators must prepare a "Major Accident Prevention Policy" (MAPP) document irrespective of whether the installation is LT or UT. The MAPP document should set out the operator's policy on prevention of major accidents including the aims and principles that are to be adopted and demonstrating that an adequate safety management system is in place. The MAPP document must address the management of the major accident hazards at a particular site and should be specific to that site.

In addition, details (notification) should be sent to the Competent (enforcing) Authority covering:

- Address of installation;
- Names of responsible personnel;
- Name the type and amount of dangerous substances used;
- A description of how the hazardous materials are processed and/or stored.

Once notification is received, Inspectors from the Competent Authority will want to verify the existence of a MAPP, and also the implementation of the safety management system. Any future changes in details should also be notified to the authority. If the site is a UT establishment additional requirements will apply.

26.4.5.3 Chemical Inventory

An inventory of hazardous materials has not yet been prepared either for the HPR1000 (FCG3) or the UK HPR1000.

26.4.5.4 COMAH Assessment

The applicability of COMAH to the UK HPR1000 could not presently be determined due to the lack of information relating to the storage of hazardous materials at the Generic Site. However, the implications of COMAH are well understood by CGN and the issue will be re-evaluated at a later stage of the GDA process.

Should future assessment establish the likelihood of a COMAH threshold being exceeded at the Generic Site, the measures will be taken in the design to protect the environment via notably minimisation of release of dangerous substances into the environment, and to prevent a Major Accident to the Environment (MATTE) and limit their consequences for human health and the environment.

26.4.6 F-Gas and ODS

26.4.6.1 P&ID Requirements

The P&ID sets the following requirements with respect to F-Gas and ODS:

> *Identify whether any equipment included in the design will contain fluorinated greenhouse gases or ozone-depleting substances (as defined in EU, 2014 and EU, 2009, respectively).*
>
> *If so, describe the measures taken in the design to prevent and minimise leakage of such substances.*

26.4.6.2 Regulatory Context

There are two main areas of legislative requirements relevant to the F-Gas and ODS:

- REGULATION (EC) No 1005/2009 on substances that deplete the ozone layer, Reference [38];
- REGULATION (EU) No 517/2014 on fluorinated greenhouse gases, Reference [39].

26.4.6.3 Equipment Using F-Gas and ODS

It is very likely that an aspect of the existing plant design will contain refrigerants for cooling, air conditioning, and fire suppression etc. It is important to identify that the design will not include ODS which are now banned and, if F-Gas, will have a global warming potential (GWP) <2500 to avoid being subject to a ban from 2020. There is also a requirement that measures to ensure leakage is minimised should be considered.

Further detailed information of F-Gas and ODS will be discussed at a later stage of GDA.

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Appendix A

DATA USED FOR DOSE ASSESSMENTS BASED ON GENERIC SITE DESCRIPTION

T-26A-1 Habitat data of local resident family exposure group for IRA assessment

	Infant	Child	Adult
Food Consumption Rates (kg a^{-1})			
Green vegetables	15	35	80
Root vegetables	45	95	130
Fruit	35	50	75
Sheep Meet	3	10	25
Sheep liver	2.75	5	10
Cow meat	10	30	45
Cow liver	2.75	5	10
Milk	320	240	240
Breathing rates (m^3 h^{-1})	0.22	0.64	0.92
Occupancy at habitation (h a^{-1})	8760	8760	8760
Fraction of time spent indoors	0.9	0.8	0.5
Cloud shielding factor	0.2	0.2	0.2
Shielding factor from deposited radionuclides	0.1	0.1	0.1

Data taken from EA IRA Methodology Part 2 in Reference [3]

T-26A-2 Habitat data used for short term assessment

	Infant	Child	Adult
Food Consumption Rates (kg a^{-1})			
Green vegetables	15	35	80
Root vegetables	45	95	130
Fruit	35	50	75
Sheep Meet	3	10	25
Sheep liver	2.75	5	10
Cow meat	10	30	45
Cow liver	2.75	5	10
Milk	320	240	240
Breathing rates (m^3 h^{-1})	0.31	0.87	1.69
Occupancy at habitation (h a^{-1})	8760	8760	8760
Fraction of time spent indoors	0	0	0
Cloud shielding factor	0	0	0
Shielding factor from deposited radionuclides	1	1	1

Data taken from Reference [17].

T-26A-3 Habitat data for fisherman family exposure group

	Infant	Child	Adult	Fraction in compartment	
				Local	Regional
Food Consumption Rates (kg a^{-1})					
Fish	5	20	100	0.5	0.5
Crustaceans	0	5	20	1	0
Molluscs	0	5	20	1	0
Occupancy on beach (h a^{-1})	30	300	2000	1	0

Data taken from EA IRA Methodology Part 2 in Reference [3]

T-26A-4 Local compartment data used in fisherman family assessment

	Step 1	Step 2
Volume (m^3)	1.0×10^8	1.0×10^8
Depth (m)	10	10
Coastline length (km)	10	10
Volumetric exchange rate ($m^3\ a^{-1}$)	3.2×10^9	4.1×10^9
Suspended sediment load ($t\ m^{-3}$)	1.0×10^{-5}	1.0×10^{-5}
Sedimentation rate ($t\ m^{-2}\ a^{-1}$)	4.9×10^{-3}	4.9×10^{-3}
Density of dry sediment particles ($t\ m^{-3}$)	2.6	2.6
Bioturbation rate (coastal water) ($m^2\ a^{-1}$)	3.6×10^{-5}	3.6×10^{-5}
Diffusion rate (sediment diffusion coefficient) ($m^2\ a^{-1}$)	3.15×10^{-2}	3.15×10^{-2}

Data taken from EA IRA Methodology Part 2 in Reference [3]

T-26A-5 Additional data used in local resident family assessment

Parameter	Step 1	Step 2	Short term dose
Relative stack height (m)	0	20	70
Habitation distance from discharge (m)	100	100	100
Food production from discharge point (m)	500	500	500
Surface roughness (m)	0.3	0.3	0.3
Washout coefficient (s^{-1})	1.0×10^{-4}, 0 for noble gases	1.0×10^{-4}, 0 for noble gases	1.0×10^{-4}, 0 for noble gases

Data taken from EA IRA Methodology Part 2 in Reference [3]

T-26A-6 Meteorology data used for terrestrial assessments

Pasquill Stability Category	Frequency of Occurrence (%) used for IRA Stage 1 & 2	Frequency of Occurrence (%) used for Short term	Wind Speed at 10 m (m s^{-1})
A	1		1
B	9		2
C	21		5
D	50		5
E	8		3
F	10		2
G	2		1

Data taken from EA IRA Methodology Part 2 in Reference [3]

T-26A-7 Population data used in collective dose assessment

Country / Region	Population
UK	5.96×10^7
EU12	3.6×10^8
EU25	4.56×10^8
World	1.0×10^{10}

Data taken from Reference [19]

T-26A-8 Reference organisms used in the dose assessment for NHS

Marine Reference Organisms	Terrestrial Reference Organisms
Benthic fish	Amphibian
	Annelid
	Arthropod – detritivorous
Bird	Bird
Crustacean	
Macroalgae	
Mammal	Flying insect
Mollusc - bivalve	Grasses and herbs
	Lichen and bryophytes
Pelagic fish	Mammal – small burrowing
Phytoplankton	Mammal – large
Polychaete worm	Mollusc – gastropod
Reptile	Reptile
Sea anemones/true corals	Shrub
Vascular plant	Tree
Zooplankton	

T-26A-9 Input parameters used in the ERICA assessment for NHS resulting from aqueous discharges

Parameter	Input Source
Nuclides	Source term from T-26.3-2
Organisms	See T-26A-8
Ecosystem	Marine
Dose rate screen value	10 μGy h^{-1}
Uncertainty Factor	5 which gives 1% probability of exceeding the selected dose screening value
Media Concentrations	Taken from the results of the accumulation in the environment results following 60 years of continuous discharge (T-26E-1)
Distribution Coefficients (Kds)	For values not currently present within ERICA, those from IAEA TRS422 were used.
Concentration Factors (CRs)	In addition the ERICA defaults, options 1-10 were selected to derive values. Any gaps where then filled using data from IAEA TRS422 (using best fit organisms) and then if there were still missing data; the maximum value of that organism was used as a conservative approach.
Occupancy Factors	ERICA default values were used

T-26A-10 Input parameters used in the ERICA assessment for NHS resulting from gaseous discharges

Parameter	Input Source
Nuclides	Source term from T-26.3-1 –Noble gases can't be modelled in ERICA, an additional method was used to assess their impacts.
Organisms	See T-26A-8
Ecosystem	Terrestrial
Dose rate screen value	10 μGy h^{-1}
Uncertainty Factor	5 which gives 1% probability of exceeding the selected dose screening value
Media Concentrations	Taken from the results of the accumulation in the environment results following 60 years of continuous discharge (T-26E-2)
Concentration Factors (CRs)	In addition the ERICA defaults, options 1-10 were selected to derive values. Any remaining gaps where then filled using the maximum value of that organism as a conservative approach.
Occupancy Factors	ERICA default values were used.

Appendix B

STAGE 1 AND STAGE 2 DOSE ASSESSMENT RESULTS

T-26B-1 Dose results from Stage 1 aerial assessment

Radionuclide	DPUR nuclide used	Discharge (Bq a^{-1})	Total DPUR (µSv a^{-1} per Bq a^{-1})	Dose (µSv a^{-1})	% Contribution to dose
H-3	H-3	4.98E+12	9.60E-13	4.78E+00	6.93%
C-14	C-14	4.18E+11	6.80E-11	2.84E+01	41.2%
Cr-51	Cr-51	3.70E+05	4.50E-12	1.67E-06	0.00%
Mn-54	Mn-54	2.77E+04	9.70E-10	2.69E-05	0.00%
Co-58	Co-58	1.52E+05	3.10E-10	4.71E-05	0.00%
Fe-59	Fe-59	5.66E+04	3.00E-10	1.70E-05	0.00%
Co-60	Co-60	1.24E+05	1.20E-08	1.49E-03	0.00%
Kr-85m	Kr-85m	2.02E+12	3.60E-13	7.27E-01	1.05%
Kr-85	Kr-85	1.87E+13	1.30E-14	2.43E-01	0.35%
Kr-87	Kr-79	2.10E+12	5.90E-13	1.24E+00	1.80%
Kr-88	Kr-79	4.31E+12	5.90E-13	2.54E+00	3.69%
Sr-89	Sr-89	1.44E+04	1.50E-10	2.16E-06	0.00%
Sr-90	Sr-90	5.91E+03	1.40E-09	8.27E-06	0.00%
Zr-95	Zr-95	8.17E+02	4.80E-10	3.92E-07	0.00%
Nb-95	Nb-95	5.01E+02	1.40E-10	7.01E-08	0.00%
I-131	I-131	2.10E+08	4.50E-09	9.45E-01	1.37%
I-132	I-132	1.06E+08	1.50E-11	1.59E-03	0.00%
I-133	I-133	2.20E+08	1.80E-10	3.96E-02	0.06%
Xe-133	Xe-133	1.06E+12	7.00E-14	7.42E-02	0.11%
Xe-133m	Kr-79	3.16E+13	5.90E-13	1.86E+01	27.0%
Cs-134	Cs-134	5.51E+06	4.20E-09	2.31E-02	0.03%
I-135	I-135	8.75E+07	3.00E-11	2.63E-03	0.00%
Xe-135	Kr-79	1.66E+13	5.90E-13	9.79E+00	14.21%
Cs-137	Cs-137	1.08E+07	7.00E-09	7.56E-02	0.11%
Xe-138	Kr-79	2.35E+12	5.90E-13	1.39E+00	2.01%
Ba-140	Ba-140	2.59E+04	2.40E-10	6.22E-06	0.00%
Ce-141	Ce-141	5.83E+02	8.20E-11	4.78E-08	0.00%
La-140	La-140	1.00E+03	4.60E-11	4.60E-08	0.00%
Ce-144	Ce-144	3.94E+02	9.00E-10	3.55E-07	0.00%
Ag-110m	Ag-110m	1.99E+04	2.90E-09	5.77E-05	0.00%
Sb-122	I-131	1.31E+04	4.50E-09	5.90E-05	0.00%
Sb-124	Cs-137	1.23E+04	7.00E-09	8.61E-05	0.00%

T-26B-2 Dose results from Stage 1 liquid assessment

Radionuclide	DPUR nuclide used	Discharge (Bq a^{-1})	Total DPUR (µSv a^{-1} per Bq a^{-1})	Dose (µSv a^{-1})	% Contribution to dose
Sr-89	Sr-89	3.19E+06	1.50E-12	4.79E-06	0.00%
Sr-90	Sr-90	6.40E+04	6.10E-12	3.90E-07	0.00%
Zr-95	Zr-95	1.54E+05	8.70E-11	1.34E-05	0.00%
Nb-95	Nb-95	1.31E+05	2.20E-11	2.88E-06	0.00%
Ru-103	Ru-103	1.64E+05	8.80E-12	1.44E-06	0.00%
Ru-106	Ru-106	4.56E+04	4.80E-11	2.19E-06	0.00%
I-131	I-131	2.29E+09	2.50E-12	5.73E-03	0.07%
Cs-134	Cs-134	4.98E+08	1.20E-10	5.98E-02	0.71%
Cs-137	Cs-137	7.29E+08	1.50E-10	1.09E-01	1.30%
Ba-140	Ba-140	5.76E+06	5.00E-12	2.88E-05	0.00%
La-140	La-140	7.04E+05	1.50E-12	1.06E-06	0.00%
Ce-141	Ce-141	1.67E+05	1.70E-12	2.84E-07	0.00%
Ce-144	Ce-144	9.67E+04	1.50E-11	1.45E-06	0.00%
Cr-51	Cr-51	1.39E+08	6.00E-13	8.34E-05	0.00%
Mn-54	Mn-54	1.16E+07	2.30E-10	2.67E-03	0.03%
Fe-59	Fe-59	2.27E+07	4.90E-11	1.11E-03	0.01%
Co-58	Co-58	5.21E+07	6.90E-11	3.59E-03	0.04%
Co-60	Co-60	5.01E+07	2.80E-09	1.40E-01	1.7%
Ag-110m	Ag-110m	8.20E+06	4.00E-09	3.28E-02	0.4%
Sb-122	Mn-52	1.52E+06	2.00E-11	3.04E-05	0.00%
Sb-124	Cs-137	3.52E+06	1.50E-10	5.28E-04	0.01%
H-3	H-3	4.48E+13	8.90E-16	3.99E-02	0.47%
C-14	C-14	1.74E+10	4.60E-10	8.00E+00	95.29%

T-26B-3 Dose results from Stage 2 aerial assessment

Radionuclide	DPUR nuclide used	Discharge (Bq a^{-1})	Food DPUR (µSv a^{-1} per Bq a^{-1})	External DPUR (µSv a^{-1} per Bq a^{-1})	Inhalation DPUR (µSv a^{-1} per Bq a^{-1})	Dose (µSv a^{-1})	% Contribution to dose
H-3	H-3	4.98E+12	2.70E-13	0.00E+00	6.90E-13	5.00E-01	8.21%
C-14	C-14	4.18E+11	3.30E-11	6.40E-17	3.50E-11	4.31E+00	70.7%
Cr-51	Cr-51	3.70E+05	1.30E-13	3.50E-12	8.30E-13	7.71E-08	0.00%
Mn-54	Mn-54	2.77E+04	2.80E-11	9.10E-10	3.40E-11	1.26E-06	0.00%
Co-58	Co-58	1.52E+05	4.40E-12	2.70E-10	3.60E-11	2.04E-06	0.00%
Fe-59	Fe-59	5.66E+04	1.60E-11	2.00E-10	8.30E-11	8.85E-07	0.00%
Co-60	Co-60	1.24E+05	5.30E-11	1.10E-08	2.20E-10	5.74E-05	0.00%
Kr-85m	Kr-85m	2.02E+12	0.00E+00	3.60E-13	0.00E+00	2.91E-02	0.48%
Kr-85	Kr-85	1.87E+13	0.00E+00	1.30E-14	0.00E+00	9.72E-03	0.16%
Kr-87	Kr-79	2.10E+12	0.00E+00	5.90E-13	0.00E+00	4.96E-02	0.81%
Kr-88	Kr-79	4.31E+12	0.00E+00	5.90E-13	0.00E+00	1.02E-01	1.67%
Sr-89	Sr-89	1.44E+04	2.20E-11	1.60E-14	1.30E-10	1.60E-07	0.00%
Sr-90	Sr-90	5.91E+03	6.40E-10	3.20E-15	8.00E-10	1.21E-06	0.00%
Zr-95	Zr-95	8.17E+02	1.20E-12	3.70E-10	1.10E-10	1.60E-08	0.00%
Nb-95	Nb-95	5.01E+02	6.30E-13	1.10E-10	3.40E-11	2.97E-09	0.00%
I-131	I-131	2.10E+08	4.10E-09	3.80E-11	3.90E-10	2.36E-01	3.87%
I-132	I-132	1.06E+08	0.00E+00	1.30E-11	2.10E-12	6.40E-05	0.00%
I-133	I-133	2.20E+08	7.20E-11	7.60E-12	9.70E-11	5.20E-03	0.09%
Xe-133	Xe-133	1.06E+12	0.00E+00	7.00E-14	0.00E+00	2.97E-03	0.05%
Xe-133m	Kr-79	3.16E+13	0.00E+00	5.90E-13	0.00E+00	7.46E-01	12.24%

Radionuclide	DPUR nuclide used	Discharge (Bq a^{-1})	Food DPUR (µSv a^{-1} per Bq a^{-1})	External DPUR (µSv a^{-1} per Bq a^{-1})	Inhalation DPUR (µSv a^{-1} per Bq a^{-1})	Dose (µSv a^{-1})	% Contribution to dose
Cs-134	Cs-134	5.51E+06	4.70E-10	3.60E-09	1.50E-10	1.53E-03	0.03%
I-135	I-135	8.75E+07	1.90E-12	7.80E-12	2.00E-11	1.42E-04	0.00%
Xe-135	Kr-79	1.66E+13	0.00E+00	6.40E-14	0.00E+00	4.25E-02	0.70%
Cs-137	Cs-137	1.08E+07	3.80E-10	6.50E-09	1.00E-10	3.96E-03	0.06%
Xe-138	Kr-79	2.35E+12	0.00E+00	5.90E-13	0.00E+00	5.55E-02	0.91%
Ba-140	Ba-140	2.59E+04	2.80E-12	1.20E-10	1.10E-10	2.58E-07	0.00%
Ce-141	Ce-141	5.83E+02	8.00E-13	8.90E-12	7.20E-11	2.01E-09	0.00%
La-140	La-140	1.00E+03	3.30E-13	2.10E-11	2.50E-11	1.93E-09	0.00%
Ce-144	Ce-144	3.94E+02	2.40E-11	1.60E-11	8.60E-10	1.64E-08	0.00%
Ag-110m	Ag-110m	1.99E+04	3.10E-10	2.40E-09	1.70E-10	3.71E-06	0.00%
Sb-122	I-131	1.31E+04	4.10E-09	3.80E-11	3.90E-10	1.47E-05	0.00%
Sb-124	Cs-137	1.23E+04	3.80E-10	6.50E-09	1.00E-10	4.51E-06	0.00%

T-26B-4 Dose results from Stage 2 liquid assessment

Radionuclide	DPUR nuclide used	Discharge (Bq a^{-1})	Total DPUR (µSv a^{-1} per Bq a^{-1})	Dose (µSv a^{-1})	% Contribution to dose
Sr-89	Sr-89	3.19E+06	1.50E-12	3.68E-06	0.00%
Sr-90	Sr-90	6.40E+04	6.10E-12	3.00E-07	0.00%
Zr-95	Zr-95	1.54E+05	8.70E-11	1.03E-05	0.00%
Nb-95	Nb-95	1.31E+05	2.20E-11	2.22E-06	0.00%
Ru-103	Ru-103	1.64E+05	8.80E-12	1.11E-06	0.00%
Ru-106	Ru-106	4.56E+04	4.80E-11	1.68E-06	0.00%
I-131	I-131	2.29E+09	2.50E-12	4.40E-03	0.07%
Cs-134	Cs-134	4.98E+08	1.20E-10	4.60E-02	0.71%
Cs-137	Cs-137	7.29E+08	1.50E-10	8.41E-02	1.30%
Ba-140	Ba-140	5.76E+06	5.00E-12	2.22E-05	0.00%
La-140	La-140	7.04E+05	1.50E-12	8.12E-07	0.00%
Ce-141	Ce-141	1.67E+05	1.70E-12	2.18E-07	0.00%
Ce-144	Ce-144	9.67E+04	1.50E-11	1.12E-06	0.00%
Cr-51	Cr-51	1.39E+08	6.00E-13	6.42E-05	0.00%
Mn-54	Mn-54	1.16E+07	2.30E-10	2.05E-03	0.03%
Fe-59	Fe-59	2.27E+07	4.90E-11	8.56E-04	0.01%
Co-58	Co-58	5.21E+07	6.90E-11	2.77E-03	0.04%
Co-60	Co-60	5.01E+07	2.80E-09	1.08E-01	1.7%
Ag-110m	Ag-110m	8.20E+06	4.00E-09	2.52E-02	0.4%
Sb-122	Mn-52	1.52E+06	2.00E-11	2.34E-05	0.00%
Sb-124	Cs-137	3.52E+06	1.50E-10	4.06E-04	0.01%
H-3	H-3	4.48E+13	8.90E-16	3.07E-02	0.47%
C-14	C-14	1.74E+10	4.60E-10	6.16E+00	95.29%

Appendix C

DOSE TO NHS RESULTS

T-26C-1 Dose to NHS resulting from aqueous discharges

	Dose Rate (µGy h^{-1})												
Nuclide	**Benthic fish**	**Bird**	**Crustacean**	**Macroalgae**	**Mammal**	**Mollusc - bivalve**	**Pelagic fish**	**Phytoplankton**	**Polychaete worm**	**Reptile**	**Sea anemones & True coral**	**Vascular plant**	**Zooplankton**
Ag-110m	3.97E-06	1.10E-05	1.61E-05	8.16E-07	3.76E-05	7.22E-06	4.44E-06	4.06E-06	4.79E-06	3.72E-05	1.94E-07	1.01E-06	5.54E-07
Ba-140	3.59E-08	1.10E-07	5.19E-08	3.64E-08	2.01E-07	9.78E-08	1.66E-08	2.91E-08	4.48E-08	1.99E-07	6.60E-08	2.40E-08	2.37E-08
C-14	2.09E-04	2.09E-04	1.72E-04	1.58E-04	2.09E-04	7.75E-05	2.09E-04	2.87E-05	1.19E-03	2.09E-04	2.03E-04	1.55E-04	1.19E-03
Ce-141	9.19E-10	3.28E-09	5.16E-10	3.20E-09	3.88E-09	3.39E-09	5.30E-10	1.03E-08	3.82E-09	3.88E-09	6.31E-10	6.45E-10	7.41E-09
Ce-144	7.68E-09	1.34E-08	3.84E-09	2.33E-08	1.41E-08	1.92E-08	2.34E-09	9.13E-09	3.07E-08	1.41E-08	1.40E-08	7.84E-09	1.27E-08
Co-58	5.12E-06	2.76E-07	4.68E-06	3.64E-06	8.95E-07	4.48E-06	2.33E-06	2.99E-07	8.22E-06	8.68E-07	3.41E-06	3.32E-06	6.45E-07
Co-60	1.30E-04	7.17E-07	1.29E-04	1.37E-04	2.31E-06	1.37E-04	5.96E-06	8.51E-07	2.73E-04	2.28E-06	1.35E-04	1.35E-04	1.60E-06
Cr-51	9.97E-08	3.63E-07	8.20E-08	9.14E-07	6.63E-07	3.58E-07	3.38E-08	6.34E-07	4.23E-07	6.52E-07	3.45E-07	9.36E-07	1.31E-07
Cs-134	3.92E-05	1.22E-05	3.74E-05	4.16E-05	1.50E-05	4.06E-05	1.93E-06	1.58E-07	8.29E-05	3.21E-05	4.35E-05	4.00E-05	1.36E-06
Cs-137	6.56E-05	1.57E-05	6.27E-05	7.17E-05	1.25E-05	6.87E-05	2.65E-06	1.67E-07	1.43E-04	2.64E-05	7.50E-05	6.76E-05	2.74E-06
H-3	9.08E-05	9.08E-05	9.08E-05	9.05E-05	9.08E-05	9.08E-05	9.08E-05	9.05E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05
I-131	4.10E-07	3.89E-04	1.77E-06	1.48E-04	6.67E-04	3.34E-04	4.33E-07	1.93E-05	3.06E-04	6.67E-04	3.06E-04	9.52E-07	9.61E-05
La-140	1.18E-07	1.38E-07	6.73E-08	8.11E-08	2.85E-07	9.70E-08	1.24E-07	1.78E-08	9.10E-08	2.83E-07	8.34E-08	9.67E-08	5.37E-08
Mn-54	2.60E-06	4.09E-07	6.00E-06	2.82E-06	1.48E-06	2.96E-06	1.81E-07	3.35E-08	5.29E-06	1.48E-06	2.61E-06	3.51E-06	3.01E-08
Nb-95	3.24E-09	8.87E-10	3.23E-09	3.68E-09	2.69E-09	3.88E-09	2.91E-11	2.87E-10	7.29E-09	2.59E-09	3.81E-09	3.70E-09	6.35E-09
Sb-124	1.45E-07	2.23E-06	8.71E-08	4.68E-08	4.77E-06	9.48E-08	1.43E-07	4.50E-08	7.85E-07	4.71E-06	2.69E-08	5.32E-08	1.32E-07
Ru-103	1.27E-10	6.39E-09	3.89E-10	3.15E-09	1.25E-08	4.39E-09	1.08E-10	1.37E-08	4.32E-09	1.25E-08	1.07E-10	3.30E-09	7.00E-08

	Dose Rate (µGy h^{-1})												
Nuclide	**Benthic fish**	**Bird**	**Crustacean**	**Macroalgae**	**Mammal**	**Mollusc - bivalve**	**Pelagic fish**	**Phytoplankton**	**Polychaete worm**	**Reptile**	**Sea anemones & True coral**	**Vascular plant**	**Zooplankton**
Ru-106	2.97E-10	1.40E-08	8.96E-10	6.68E-09	1.56E-08	1.18E-08	2.48E-10	4.32E-09	1.08E-08	1.56E-08	2.81E-10	8.99E-09	6.67E-08
Sr-89	5.60E-09	3.70E-08	1.12E-08	5.90E-09	3.70E-08	3.20E-08	5.64E-09	7.59E-09	8.48E-10	3.70E-08	1.87E-08	8.59E-10	8.46E-09
Sr-90	5.50E-10	1.60E-09	6.29E-10	1.39E-09	1.65E-09	1.84E-09	2.41E-10	3.47E-10	1.40E-09	1.65E-09	1.69E-09	4.66E-10	3.11E-10
Zr-95	7.23E-09	1.49E-10	7.01E-09	9.29E-09	3.35E-10	1.10E-08	1.27E-10	2.21E-08	1.86E-08	3.35E-10	7.79E-09	8.67E-09	1.83E-08
Fe-59	7.04E-07	8.30E-06	2.21E-04	5.81E-06	3.84E-02	1.37E-04	1.22E-05	6.18E-05	8.31E-06	2.79E-05	4.80E-06	1.56E-05	1.41E-04
Sb-122	2.36E-08	3.31E-07	1.28E-08	8.00E-09	4.36E-07	1.75E-08	2.31E-08	6.51E-09	1.49E-07	4.33E-07	4.19E-09	9.08E-09	2.59E-08
TOTAL	**3.97E-06**	**1.10E-05**	**1.61E-05**	**8.16E-07**	**3.76E-05**	**7.22E-06**	**4.44E-06**	**4.06E-06**	**4.79E-06**	**3.72E-05**	**1.94E-07**	**1.01E-06**	**5.54E-07**

T-26C-2 Dose to NHS resulting from gaseous discharges

	Dose Rate (µGy h^{-1})												
Nuclide	**Amphibian**	**Annelid**	**Arthropod – detritivorous**	**Bird**	**Flying insects**	**Grasses & Herbs**	**Lichen & Bryophytes**	**Mammal – large**	**Mammal – small-burrowing**	**Mollusc – gastropod**	**Reptile**	**Shrub**	**Tree**
Ag-110m*	3.16E-09	3.33E-09	3.24E-09	1.49E-09	1.21E-09	1.53E-09	1.20E-09	1.74E-09	3.23E-09	1.29E-09	3.01E-09	1.10E-09	1.72E-09
Ba-140*	1.75E-10	1.76E-10	1.77E-10	1.15E-09	6.77E-11	6.65E-11	7.11E-11	4.00E-11	1.68E-10	6.96E-11	1.62E-10	9.30E-11	6.89E-11
C-14*	1.17E-03	3.75E-04	3.76E-04	1.21E-03	3.76E-04	7.78E-04	7.87E-04	1.21E-03	1.21E-03	3.76E-04	1.21E-03	7.78E-04	1.18E-03
Ce-141*	2.02E-13	2.02E-13	2.00E-13	1.45E-13	8.97E-14	1.05E-13	1.02E-13	4.37E-14	1.95E-13	1.38E-13	1.87E-13	9.49E-14	7.52E-14
Ce-144*	1.26E-12	1.23E-12	1.14E-12	2.83E-12	4.75E-13	7.79E-13	6.54E-13	3.95E-13	1.22E-12	2.06E-12	1.17E-12	6.42E-13	4.14E-13
Co-58*	2.39E-09	2.40E-09	2.40E-09	9.28E-10	9.23E-10	8.79E-10	9.29E-10	7.75E-10	2.32E-09	9.25E-10	2.23E-09	8.32E-10	7.46E-10
Co-60*	1.10E-07	1.08E-07	1.08E-07	4.11E-08	4.17E-08	4.01E-08	4.17E-08	3.52E-08	1.03E-07	4.18E-08	1.02E-07	3.76E-08	3.28E-08
Cr-51*	5.97E-11	6.12E-11	6.09E-11	2.64E-11	2.52E-11	2.56E-11	2.67E-11	1.23E-11	5.69E-11	2.59E-11	5.46E-11	2.37E-11	2.03E-11
Cs-134*	1.40E-06	1.33E-06	1.35E-06	6.90E-07	5.25E-07	6.70E-07	1.02E-06	3.68E-06	2.16E-06	5.15E-07	1.34E-06	7.73E-07	5.22E-07
Cs-137*	9.73E-06	8.22E-06	8.52E-06	5.73E-06	3.56E-06	7.03E-06	1.48E-05	3.21E-05	2.27E-05	3.32E-06	9.70E-06	1.02E-05	3.52E-06
Fe-59*	7.45E-10	6.39E-10	6.54E-10	2.16E-09	2.66E-10	3.19E-10	5.47E-10	1.69E-09	1.02E-09	2.55E-10	6.41E-10	5.61E-10	3.82E-10
H-3*	4.50E-04	4.50E-04	4.50E-04	4.50E-04	4.22E-04	4.50E-04	4.49E-04	4.50E-04	4.50E-04	4.50E-04	4.50E-04	4.50E-04	4.50E-04
I-131*	1.44E-06	1.25E-06	1.33E-06	8.02E-07	6.52E-07	5.57E-07	5.51E-07	8.26E-07	1.40E-06	5.90E-07	1.34E-06	4.35E-07	5.79E-07
I-132*	4.67E-08	4.37E-08	4.43E-08	2.27E-08	1.86E-08	1.71E-08	1.72E-08	2.36E-08	4.42E-08	1.78E-08	4.39E-08	1.51E-08	1.75E-08
I-133*	2.75E-07	2.35E-07	2.48E-07	1.54E-07	1.19E-07	9.98E-08	9.78E-08	1.60E-07	2.67E-07	1.04E-07	2.61E-07	7.95E-08	1.05E-07
I-135*	7.81E-08	7.35E-08	7.54E-08	3.64E-08	3.18E-08	2.85E-08	2.88E-08	3.90E-08	7.66E-08	3.01E-08	7.39E-08	2.47E-08	2.90E-08
La-140*	6.42E-17	5.59E-17	5.62E-17	3.23E-17	2.12E-17	2.07E-17	2.14E-17	1.29E-17	5.35E-17	2.13E-17	6.13E-17	1.95E-17	1.69E-17
Mn-54*	1.61E-09	1.61E-09	1.65E-09	6.25E-10	6.27E-10	5.91E-10	6.46E-10	3.10E-10	1.54E-09	6.25E-10	1.47E-09	8.41E-10	5.37E-10
Nb-95*	2.86E-12	2.88E-12	2.85E-12	1.15E-12	1.11E-12	1.04E-12	1.09E-12	6.19E-13	2.73E-12	1.15E-12	2.59E-12	9.72E-13	8.54E-13
Sb-122*	2.89E-12	3.07E-12	2.96E-12	1.05E-12	1.15E-12	1.23E-12	1.82E-12	5.67E-13	2.74E-12	1.27E-12	2.63E-12	1.17E-12	1.09E-12

	Dose Rate (µGy h^{-1})												
Nuclide	**Amphibian**	**Annelid**	**Arthropod – detritivorous**	**Bird**	**Flying insects**	**Grasses & Herbs**	**Lichen & Bryophytes**	**Mammal – large**	**Mammal – small-burrowing**	**Mollusc – gastropod**	**Reptile**	**Shrub**	**Tree**
Sb-124*	2.90E-10	2.99E-10	2.97E-10	1.09E-10	1.13E-10	1.11E-10	1.24E-10	6.01E-11	2.78E-10	1.15E-10	2.68E-10	1.05E-10	9.58E-11
Sr-89*	1.22E-10	5.75E-12	2.15E-11	1.21E-10	2.56E-11	6.54E-11	2.72E-10	1.64E-10	1.64E-10	7.71E-12	3.88E-11	1.50E-11	4.84E-11
Sr-90*	1.11E-08	4.93E-10	1.72E-09	1.11E-08	2.06E-09	5.72E-09	2.11E-08	1.55E-08	1.48E-08	6.47E-10	3.49E-09	1.31E-09	4.44E-09
Zr-95*	8.88E-12	8.87E-12	8.86E-12	3.70E-12	3.33E-12	3.38E-12	3.61E-12	1.64E-12	8.19E-12	3.33E-12	8.26E-12	3.11E-12	2.73E-12
Kr-85[∞]	8.20E-08	4.90E-11	4.80E-07	4.30E-08	1.20E-10	2.80E-07	4.20E-07	8.70E-07	1.40E-08	1.20E-11	1.70E-07	6.80E-08	4.30E-08
Kr-88[∞]	4.80E-04	1.40E-07	6.50E-04	3.70E-04	1.50E-07	6.10E-04	1.20E-03	6.80E-04	2.10E-04	1.00E-07	5.70E-04	4.50E-04	5.40E-04
Xe-133[∞]	3.80E-05	9.90E-09	4.50E-05	3.10E-05	1.10E-08	4.30E-05	8.30E-05	5.00E-05	9.80E-06	8.20E-09	4.10E-05	3.70E-05	3.50E-05
TOTAL	**2.15E-03**	**8.37E-04**	**1.53E-03**	**2.07E-03**	**8.03E-04**	**1.89E-03**	**2.54E-03**	**2.43E-03**	**1.91E-03**	**8.31E-04**	**2.29E-03**	**1.73E-03**	**2.21E-03**

[*] Data from ERICA assessment tool

[∞] Data from R&D 128 SCK-CEN Release Version 2 assessment tool

Appendix D

COLLECTIVE DOSE RESULTS

T-26D-1 Collective dose (manSv) to UK from gaseous first pass

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Ag-110m (1.99E+4 Bq/y)	1.86E-11	1.53E-14	1.30E-09	9.39E-09	1.78E-09	1.33E-12	4.40E-10	4.95E-10	6.93E-11	6.32E-12	1.03E-10	1.35E-11	2.19E-10	1.42E-08	0.00E+00	2.80E-08
Ba-140 (2.59E+4 Bq/y)	1.54E-12	1.28E-13	1.11E-09	5.91E-10	9.05E-11	5.84E-13	1.76E-10	3.32E-15	2.73E-17	2.65E-13	1.96E-14	5.99E-13	3.15E-14	7.95E-11	0.00E+00	2.05E-09
La-140 (Ba-140)(FD)	2.86E-12	4.11E-14	3.50E-11	8.09E-12	2.76E-12	6.26E-15	4.34E-13	2.85E-50	2.10E-45	5.76E-18	1.46E-16	1.98E-17	2.50E-16	2.66E-14	0.00E+00	4.92E-11
La-140 (Ba-140)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.05E-14	2.02E-11	5.33E-48	3.19E-43	8.16E-15	8.38E-15	2.65E-14	1.30E-14	5.14E-13	0.00E+00	2.09E-11
C-14 (4.18E+11 Bq/y)	0.00E+00	5.02E-08	1.03E-02	0.00E+00	0.00E+00	0.00E+00	7.61E-03	1.11E-01	1.98E-02	5.50E-04	2.93E-05	1.63E-03	6.53E-05	1.60E-02	0.00E+00	1.67E-01
Ce-141 (5.83E+2 Bq/y)	1.50E-14	1.18E-15	1.59E-11	9.72E-13	1.85E-12	1.07E-14	1.86E-12	3.75E-15	1.62E-17	1.92E-16	2.33E-15	3.98E-16	3.54E-15	1.49E-13	0.00E+00	2.08E-11
Ce-144 (3.94E+2 Bq/y)	2.61E-15	2.59E-16	1.22E-10	3.53E-12	3.61E-11	1.28E-13	1.38E-11	1.37E-12	1.53E-14	7.51E-15	8.13E-14	2.05E-14	1.66E-13	9.97E-13	0.00E+00	1.78E-10
Pr-144 (Ce-144)(FD)	4.13E-15	1.07E-14	5.97E-14	1.04E-16	4.21E-15	1.58E-19	4.20E-142	0.00E+00	0.00E+00	8.22E-252	7.07E-103	2.14E-226	2.27E-102	2.80E-120	0.00E+00	7.88E-14
Pr-144m (Ce-144)(FD)	8.47E-16	0.00E+00	0.00E+00	5.29E-17	7.26E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.01E-16
Co-58 (1.52E+5 Bq/y)	5.03E-11	7.09E-14	2.09E-09	7.72E-09	2.08E-10	1.66E-12	6.70E-10	1.60E-10	9.08E-13	2.11E-13	1.19E-12	4.25E-13	1.78E-12	4.84E-11	0.00E+00	1.10E-08
Co-60 (1.24E+5 Bq/y)	1.05E-10	1.04E-13	1.07E-08	2.71E-07	6.93E-10	1.76E-11	3.32E-09	5.75E-09	3.23E-10	3.23E-12	1.73E-11	7.27E-12	2.91E-11	2.62E-10	0.00E+00	2.92E-07

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Cr-51 (3.70E+5 Bq/y)	3.93E-12	0.00E+00	1.17E-10	2.43E-10	5.21E-13	7.52E-14	5.89E-11	5.56E-14	7.63E-17	1.65E-12	1.02E-13	3.32E-12	1.50E-13	4.80E-12	0.00E+00	4.33E-10
Cs-134 (5.51E+6 Bq/y)	2.91E-09	1.40E-11	3.13E-07	3.78E-06	9.44E-08	4.03E-10	9.40E-07	8.98E-06	1.70E-06	2.84E-07	1.52E-08	4.88E-07	1.96E-08	2.91E-06	0.00E+00	1.95E-05
Cs-137 (1.08E+7 Bq/y)	0.00E+00	2.72E-11	4.28E-07	1.44E-05	3.20E-07	1.54E-09	1.49E-06	1.56E-05	3.02E-06	4.76E-07	2.54E-08	7.61E-07	3.04E-08	4.40E-06	0.00E+00	4.10E-05
Ba-137m (Cs-137)(FD)	2.19E-09	1.51E-11	0.00E+00	8.73E-12	1.54E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E-09
Fe-59 (5.66E+4 Bq/y)	2.27E-11	7.52E-14	1.79E-09	2.17E-09	1.55E-10	1.29E-12	5.32E-10	3.74E-11	6.87E-14	1.42E-13	2.49E-11	2.91E-13	5.04E-11	1.98E-11	0.00E+00	4.81E-09
H-3 (4.98E+12 Bq/y)	0.00E+00	0.00E+00	1.66E-03	0.00E+00	0.00E+00	0.00E+00	5.28E-04	2.07E-04	1.34E-03	2.22E-05	1.18E-06	6.59E-05	2.64E-06	2.49E-03	0.00E+00	6.32E-03
I-131 (2.10E+8 Bq/y)	9.96E-09	2.06E-10	4.51E-06	1.27E-06	6.98E-07	1.53E-08	2.45E-05	1.72E-12	1.09E-11	2.65E-07	2.37E-08	8.07E-07	4.97E-08	7.98E-05	0.00E+00	1.12E-04
Xe-131m (I-131)(FD)	5.20E-12	2.83E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.02E-12
Xe-131m (I-131)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-132 (1.06E+8 Bq/y)	1.11E-08	1.38E-10	1.10E-08	1.76E-08	5.24E-09	1.83E-12	4.40E-25	0.00E+00	0.00E+00	2.50E-42	9.39E-25	3.60E-38	7.32E-24	1.76E-23	0.00E+00	4.51E-08
I-133 (2.20E+8 Bq/y)	1.44E-08	5.25E-10	8.28E-07	2.06E-07	1.91E-07	9.65E-10	1.92E-08	3.32E-80	7.73E-66	1.43E-12	9.28E-12	1.96E-11	4.28E-11	4.90E-08	0.00E+00	1.31E-06
Xe-133 (I-133)(FD)	5.26E-11	4.00E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.66E-11
Xe-133m (I-133)(FD	8.94E-11	2.61E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E-10

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
)																
Xe-133 (I-133)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135 (8.75E+7 Bq/y)	1.14E-08	1.39E-10	5.30E-08	5.44E-08	1.60E-08	2.44E-11	8.34E-14	1.22E-238	2.51E-191	8.40E-22	1.62E-16	8.81E-20	1.03E-15	2.43E-13	0.00E+00	1.35E-07
Xe-135 (I-135)(FD)	8.98E-10	5.98E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.58E-10
Xe-135m (I-135)(FD)	3.05E-09	3.83E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.09E-09
Xe-135 (I-135)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85 (6.74E+11 Bq/y)	7.06E-07	4.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.07E-06
Kr-85m (2.02E+12 Bq/y)	4.83E-05	4.06E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.24E-05
Kr-85 (Kr-85m)(FD)	6.84E-11	4.28E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.96E-10
Kr-85 (Kr-85m)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87 (2.10E+12 Bq/y)	7.10E-05	8.27E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.92E-05
Rb-87 (Kr-87)(FD)	0.00E+00	3.22E-21	2.59E-17	0.00E+00	4.54E-17	6.91E-19	5.93E-16	2.53E-15	1.48E-15	4.15E-17	2.21E-18	1.14E-16	4.57E-18	3.47E-15	0.00E+00	8.31E-15
Rb-87 (Kr-87)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Kr-88 (4.31E+12 Bq/y)	8.31E-04	9.13E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.40E-04
Rb-88 (Kr-88)(FD)	2.75E-04	6.38E-05	1.78E-04	1.50E-05	3.52E-05	1.03E-09	2.83E-128	0.00E+00	0.00E+00	7.31E-232	4.97E-87	6.19E-207	1.41E-86	1.36E-104	0.00E+00	5.67E-04
Rb-88 (Kr-88)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140 (1.00E+3 Bq/y)	6.66E-13	9.46E-15	8.06E-12	2.51E-12	8.58E-13	1.95E-15	1.78E-13	1.12E-50	6.56E-46	7.55E-19	1.92E-17	3.17E-18	4.00E-17	4.28E-15	0.00E+00	1.23E-11
Mn-54 (2.77E+4 Bq/y)	7.91E-12	0.00E+00	3.58E-10	4.84E-09	6.17E-13	3.82E-13	1.51E-10	1.87E-10	1.71E-11	1.12E-12	2.37E-12	2.21E-12	3.52E-12	2.86E-11	0.00E+00	5.59E-09
Nb-95 (5.01E+2 Bq/y)	1.30E-13	4.49E-17	6.42E-12	1.01E-11	4.25E-14	4.38E-15	1.39E-12	4.06E-14	2.30E-16	1.19E-18	7.12E-20	2.40E-18	1.06E-19	4.30E-16	0.00E+00	1.81E-11
Sb-122 (1.31E+4 Bq/y)	1.77E-12	1.42E-13	1.02E-10	1.11E-11	1.92E-11	3.08E-14	6.78E-12	5.13E-35	6.81E-33	3.56E-15	8.85E-14	1.21E-14	1.74E-13	7.77E-13	0.00E+00	1.42E-10
Sb-124 (1.23E+4 Bq/y)	7.52E-12	9.26E-14	6.75E-10	9.62E-10	2.02E-10	5.18E-13	1.76E-10	2.92E-11	1.62E-13	1.71E-12	9.79E-12	3.15E-12	1.34E-11	1.29E-11	0.00E+00	2.09E-09
Sr-89 (1.44E+4 Bq/y)	4.14E-16	1.80E-13	7.53E-10	4.44E-14	3.62E-10	5.56E-13	2.10E-10	2.17E-11	3.53E-13	3.29E-13	1.91E-14	7.88E-13	3.38E-14	1.21E-10	0.00E+00	1.47E-09
Sr-90 (5.91E+3 Bq/y)	0.00E+00	1.89E-14	1.83E-09	1.40E-16	7.41E-10	6.47E-12	6.18E-09	1.02E-08	2.35E-09	6.64E-12	3.54E-13	2.98E-11	1.19E-12	4.12E-09	0.00E+00	2.55E-08
Y-90 (Sr-90)(FD)	9.38E-21	1.22E-14	7.42E-12	5.30E-20	9.50E-13	1.66E-15	2.87E-13	1.18E-36	2.27E-34	6.57E-19	1.66E-18	1.84E-18	2.71E-18	1.68E-14	0.00E+00	8.69E-12
Xe-133 (1.06E+12 Bq/y)	1.73E-05	1.35E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.86E-05
Xe-133m (3.16E+13	3.55E-04	1.08E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.64E-04

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Bq/y)																
Xe-133 (Xe-133m) (FD)	3.30E-05	2.59E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.56E-05
Xe-133 (Xe-133m) (SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135 (1.66E+13 Bq/y)	9.56E-04	6.68E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-03
Cs-135 (Xe-135)(FD)	0.00E+00	7.80E-16	2.32E-11	0.00E+00	6.58E-12	5.69E-13	9.49E-11	7.94E-10	2.18E-10	4.69E-11	2.50E-12	6.52E-11	2.61E-12	3.81E-10	0.00E+00	1.64E-09
Cs-135 (Xe-135)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138 (2.35E+12 Bq/y)	1.32E-05	5.57E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E-05
Cs-138 (Xe-138)(FD)	4.01E-05	1.43E-06	1.05E-05	3.71E-06	2.00E-06	9.99E-11	8.08E-75	0.00E+00	0.00E+00	1.17E-132	3.74E-53	1.13E-121	9.33E-56	2.29E-65	0.00E+00	5.78E-05
Cs-138 (Xe-138)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-95 (8.17E+2 Bq/y)	2.05E-13	1.04E-15	3.36E-11	5.76E-11	2.79E-12	2.62E-14	4.50E-12	8.63E-13	1.56E-15	5.26E-18	2.99E-19	9.36E-18	3.95E-19	1.94E-15	0.00E+00	9.96E-11
Nb-95 (Zr-95)(FD)	1.72E-15	5.97E-19	8.54E-14	1.01E-13	4.28E-16	4.40E-17	1.06E-14	3.30E-16	2.30E-18	2.76E-20	1.66E-21	4.66E-20	2.06E-21	8.21E-18	0.00E+00	2.00E-13
Nb-95m (Zr-95)(FD)	1.26E-15	1.76E-16	4.08E-13	1.02E-13	2.20E-14	1.04E-16	1.11E-14	6.22E-32	4.99E-31	1.85E-21	3.12E-22	4.70E-21	4.91E-22	1.25E-17	0.00E+00	5.45E-13
Nb-95 (Zr-95)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E-15	8.00E-13	3.38E-14	6.73E-16	2.71E-18	1.62E-19	4.81E-18	2.12E-19	1.53E-16	0.00E+00	8.37E-13

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Total	**2.64E-03**	**2.71E-04**	**1.22E-02**	**3.87E-05**	**3.86E-05**	**1.94E-08**	**8.17E-03**	**1.11E-01**	**2.12E-02**	**5.73E-04**	**3.06E-05**	**1.70E-03**	**6.80E-05**	**1.86E-02**	**0.00E+00**	**1.77E-01**

T-26D-2 Collective dose (manSv) to EU from gaseous first pass

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Ag-110m (1.99E+4 Bq/y)	3.27E-11	2.54E-14	2.16E-09	1.37E-08	2.60E-09	1.94E-12	6.79E-10	1.02E-09	1.41E-10	8.40E-12	1.38E-10	4.57E-11	5.43E-10	1.26E-08	1.10E-07	1.44E-07
Ba-140 (2.59E+4 Bq/y)	2.59E-12	2.06E-13	1.79E-09	8.40E-10	1.29E-10	8.30E-13	2.64E-10	6.51E-15	5.34E-17	3.44E-13	2.55E-14	1.95E-12	7.51E-14	6.83E-11	5.77E-12	3.10E-09
La-140 (Ba-140)(FD)	9.97E-12	1.27E-13	1.09E-10	2.30E-11	7.85E-12	1.78E-14	1.61E-12	1.82E-49	1.07E-44	1.02E-17	2.70E-16	1.24E-16	1.11E-15	3.91E-14	2.95E-29	1.51E-10
La-140 (Ba-140)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-13	3.03E-11	1.04E-47	6.24E-43	1.06E-14	1.09E-14	8.63E-14	3.11E-14	4.42E-13	3.56E-28	3.09E-11
C-14 (4.18E+11 Bq/y)	0.00E+00	1.29E-07	2.65E-02	0.00E+00	0.00E+00	0.00E+00	2.36E-02	5.59E-01	8.82E-02	1.04E-03	5.83E-05	9.95E-03	2.89E-04	2.40E-02	1.34E-01	8.67E-01
Ce-141 (5.83E+2 Bq/y)	2.54E-14	1.94E-15	2.62E-11	1.41E-12	2.67E-12	1.54E-14	2.84E-12	7.56E-15	3.26E-17	2.53E-16	3.09E-15	1.33E-15	8.67E-15	1.31E-13	2.15E-13	3.35E-11
Ce-144 (3.94E+2 Bq/y)	4.45E-15	4.31E-16	2.03E-10	5.16E-12	5.27E-11	1.87E-13	2.14E-11	2.81E-12	3.12E-14	9.99E-15	1.09E-13	6.96E-14	4.13E-13	8.88E-13	8.00E-12	2.95E-10
Pr-144 (Ce-144)(FD)	7.39E-15	1.78E-14	9.99E-14	1.53E-16	6.19E-15	2.32E-19	6.55E-142	0.00E+00	0.00E+00	1.09E-251	9.47E-103	7.40E-226	5.73E-102	2.52E-120	0.00E+00	1.31E-13
Pr-144m (Ce-144)(FD)	1.43E-15	0.00E+00	0.00E+00	7.74E-17	1.06E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-15
Co-58 (1.52E+5 Bq/y)	8.78E-11	1.17E-13	3.46E-09	1.12E-08	3.02E-10	2.41E-12	1.03E-09	3.26E-10	1.84E-12	2.79E-13	1.59E-12	1.43E-12	4.41E-12	4.29E-11	1.99E-10	1.67E-08
Co-60 (1.24E+5 Bq/y)	1.87E-10	1.74E-13	1.78E-08	3.96E-07	1.01E-09	2.57E-11	5.14E-09	1.18E-08	6.60E-10	4.31E-12	2.32E-11	2.47E-11	7.26E-11	2.34E-10	2.54E-09	4.35E-07
Cr-51 (3.70E+5 Bq/y)	6.69E-12	0.00E+00	1.91E-10	3.51E-10	7.52E-13	1.08E-13	8.97E-11	1.12E-13	1.53E-16	2.17E-12	1.36E-13	1.11E-11	3.67E-13	4.21E-12	4.98E-12	6.63E-10
Cs-134 (5.51E+6 Bq/y)	5.11E-09	2.34E-11	5.22E-07	5.53E-06	1.38E-07	5.88E-10	1.45E-06	1.85E-05	3.47E-06	3.77E-07	2.04E-08	1.66E-06	4.88E-08	2.59E-06	2.68E-05	6.11E-05

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Cs-137 (1.08E+7 Bq/y)	0.00E+00	4.53E-11	7.13E-07	2.11E-05	4.68E-07	2.25E-09	2.31E-06	3.21E-05	6.17E-06	6.34E-07	3.41E-08	2.59E-06	7.58E-08	3.93E-06	4.38E-05	1.14E-04
Ba-137m (Cs-137)(FD)	3.83E-09	2.52E-11	0.00E+00	1.28E-11	2.25E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.87E-09
Fe-59 (5.66E+4 Bq/y)	3.98E-11	1.24E-13	2.96E-09	3.15E-09	2.24E-10	1.87E-12	8.15E-10	7.58E-11	1.39E-13	1.87E-13	3.31E-11	9.78E-13	1.24E-10	1.75E-11	4.85E-11	7.48E-09
H-3 (4.98E+12 Bq/y)	0.00E+00	0.00E+00	4.26E-03	0.00E+00	0.00E+00	0.00E+00	1.63E-03	1.04E-03	5.96E-03	4.18E-05	2.36E-06	4.02E-04	1.17E-05	3.73E-03	1.51E-03	1.86E-02
I-131 (2.10E+8 Bq/y)	1.32E-08	2.68E-10	5.89E-06	1.62E-06	8.92E-07	1.95E-08	3.26E-05	2.53E-12	1.78E-11	3.14E-07	2.77E-08	2.08E-06	9.52E-08	5.75E-05	2.90E-07	1.01E-04
Xe-131m (I-131)(FD)	1.89E-11	1.01E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.90E-11
Xe-131m (I-131)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-132 (1.06E+8 Bq/y)	1.20E-08	1.49E-10	1.20E-08	1.90E-08	5.66E-09	1.98E-12	5.28E-25	0.00E+00	0.00E+00	3.01E-42	1.12E-24	4.35E-38	8.46E-24	9.99E-24	0.00E+00	4.87E-08
I-133 (2.20E+8 Bq/y)	1.76E-08	6.32E-10	9.97E-07	2.44E-07	2.27E-07	1.15E-09	2.40E-08	4.22E-80	1.12E-65	1.64E-12	1.05E-11	4.12E-11	6.96E-11	3.18E-08	2.05E-38	1.54E-06
Xe-133 (I-133)(FD)	1.53E-10	1.15E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E-10
Xe-133m (I-133)(FD)	2.22E-10	6.30E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.85E-10
Xe-133 (I-133)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135 (8.75E+7 Bq/y)	1.27E-08	1.55E-10	5.91E-08	6.02E-08	1.76E-08	2.70E-11	9.95E-14	1.33E-238	3.23E-191	9.50E-22	1.82E-16	1.38E-19	1.36E-15	1.43E-13	6.77E-111	1.50E-07
Xe-135 (I-135)(FD)	1.28E-09	8.34E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-09
Xe-135m (I-135)(FD)	3.38E-09	4.23E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.42E-09

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Xe-135 (I-135)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85 (6.74E+11 Bq/y)	1.82E-06	1.12E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.30E-05
Kr-85m (2.02E+12 Bq/y)	5.26E-05	4.40E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.70E-05
Kr-85 (Kr-85m)(FD)	2.25E-10	1.39E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.61E-09
Kr-85 (Kr-85m)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87 (2.10E+12 Bq/y)	7.67E-05	8.99E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.57E-05
Rb-87 (Kr-87)(FD)	0.00E+00	5.59E-21	4.51E-17	0.00E+00	6.88E-17	1.05E-18	9.80E-16	6.14E-15	3.23E-15	5.53E-17	2.98E-18	4.15E-16	1.20E-17	3.21E-15	3.60E-14	5.02E-14
Rb-87 (Kr-87)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-88 (4.31E+12 Bq/y)	8.85E-04	9.72E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.94E-04
Rb-88 (Kr-88)(FD)	2.90E-04	6.71E-05	1.87E-04	1.60E-05	3.76E-05	1.10E-09	3.09E-128	0.00E+00	0.00E+00	7.51E-232	5.08E-87	9.25E-207	1.77E-86	7.53E-105	0.00E+00	5.97E-04
Rb-88 (Kr-88)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140 (1.00E+3 Bq/y)	9.68E-13	1.32E-14	1.12E-11	3.19E-12	1.09E-12	2.47E-15	2.34E-13	1.77E-50	1.06E-45	8.87E-19	2.24E-17	8.34E-18	7.83E-17	3.13E-15	2.59E-30	1.67E-11
Mn-54 (2.77E+4 Bq/y)	1.39E-11	0.00E+00	5.95E-10	7.06E-09	9.01E-13	5.58E-13	2.34E-10	3.84E-10	3.49E-11	1.49E-12	3.19E-12	7.48E-12	8.76E-12	2.55E-11	2.34E-10	8.61E-09
Nb-95 (5.01E+2 Bq/y)	2.25E-13	7.38E-17	1.06E-11	1.45E-11	6.15E-14	6.33E-15	2.13E-12	8.21E-14	4.63E-16	1.57E-18	9.47E-20	8.03E-18	2.60E-19	3.78E-16	7.21E-16	2.76E-11
Sb-122	2.69E-12	2.09E-13	1.49E-10	1.47E-11	2.54E-11	4.07E-14	9.32E-12	8.76E-35	1.18E-32	4.32E-15	1.07E-13	3.45E-14	3.67E-13	6.02E-13	6.43E-22	2.03E-10

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
(1.31E+4 Bq/y)																
Sb-124 (1.23E+4 Bq/y)	1.32E-11	1.53E-13	1.12E-09	1.40E-09	2.93E-10	7.53E-13	2.70E-10	5.95E-11	3.27E-13	2.27E-12	1.31E-11	1.06E-11	3.30E-11	1.14E-11	4.54E-11	3.27E-09
Sr-89 (1.44E+4 Bq/y)	7.22E-16	2.98E-13	1.24E-09	6.44E-14	5.25E-10	8.07E-13	3.22E-10	4.41E-11	7.13E-13	4.36E-13	2.54E-14	2.65E-12	8.31E-14	1.07E-10	3.51E-10	2.60E-09
Sr-90 (5.91E+3 Bq/y)	0.00E+00	3.14E-14	3.05E-09	2.05E-16	1.08E-09	9.46E-12	9.56E-09	2.11E-08	4.80E-09	8.85E-12	4.77E-13	1.01E-10	2.97E-12	3.68E-09	4.10E-08	8.44E-08
Y-90 (Sr-90)(FD)	3.31E-20	4.30E-14	2.62E-11	1.71E-19	3.07E-12	5.38E-15	1.27E-12	8.94E-36	1.34E-33	1.29E-18	3.46E-18	1.27E-17	1.34E-17	2.78E-14	1.97E-23	3.06E-11
Xe-133 (1.06E+12 Bq/y)	3.59E-05	2.79E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.87E-05
Xe-133m (3.16E+13 Bq/y)	6.23E-04	1.88E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.11E-04
Xe-133 (Xe-133m)(FD)	1.80E-04	1.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.94E-04
Xe-133 (Xe-133m)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135 (1.66E+13 Bq/y)	1.14E-03	7.86E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.21E-03
Cs-135 (Xe-135)(FD)	0.00E+00	1.84E-15	5.48E-11	0.00E+00	1.40E-11	1.21E-12	2.39E-10	3.32E-09	7.55E-10	6.72E-11	3.61E-12	3.13E-10	8.71E-12	4.18E-10	4.80E-09	1.00E-08
Cs-135 (Xe-135)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138 (2.35E+12 Bq/y)	1.71E-05	6.93E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.78E-05
Cs-138 (Xe-138)(FD)	4.43E-05	1.60E-06	1.18E-05	4.01E-06	2.17E-06	1.08E-10	8.99E-75	0.00E+00	0.00E+00	1.24E-132	3.96E-53	1.16E-121	9.61E-56	1.17E-65	0.00E+00	6.39E-05

	Collective Dose (manSv)														
Nuclide	**Gamma from Plume**	**Beta from Plume**	**Inhalation of Plume**	**Gamma from Ground**	**Beta from Ground**	**Resuspension**	**Green vegetables**	**Grain**	**Root vegetables**	**Sheep meat**	**Sheep liver**	**Cow meat**	**Cow liver**	**Cow milk**	**Cow milk products**	**Total**
Cs-138 (Xe-138)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr-95 (8.17E+2 Bq/y)	3.57E-13	1.72E-15	5.57E-11	8.37E-11	4.05E-12	3.81E-14	6.92E-12	1.76E-12	3.16E-15	6.97E-18	4.00E-19	3.15E-17	9.76E-19	1.72E-15	7.29E-15	1.53E-10
Nb-95 (Zr-95)(FD)	8.16E-15	2.52E-18	3.60E-13	3.91E-13	1.65E-15	1.70E-16	5.95E-14	3.15E-15	1.67E-17	6.30E-20	4.09E-21	3.66E-19	1.18E-20	1.59E-17	2.64E-17	8.24E-13
Nb-95m (Zr-95)(FD)	4.89E-15	6.41E-16	1.49E-12	3.42E-13	7.35E-14	3.49E-16	5.14E-14	4.92E-31	3.07E-30	3.72E-21	6.67E-22	3.32E-20	2.50E-21	2.12E-17	6.68E-24	1.96E-12
Nb-95 (Zr-95)(SD)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E-15	1.23E-12	6.88E-14	1.36E-15	3.58E-18	2.17E-19	1.62E-17	5.24E-19	1.35E-16	2.57E-16	1.30E-12
Total	**3.34E-03**	**3.88E-04**	**3.10E-02**	**4.90E-05**	**4.15E-05**	**2.48E-08**	**2.53E-02**	**5.60E-01**	**9.42E-02**	**1.08E-03**	**6.08E-05**	**1.04E-02**	**3.01E-04**	**2.78E-02**	**1.36E-01**	**8.90E-01**

T-26D-3 Collective dose (manSv) from gaseous global circulation

	Collective Dose (manSv)			
Nuclide	**UK**	**EU12**	**EU25**	**World**
Ag-110m (1.99E+4 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba-140 (2.59E+4 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14 (4.18E+11 Bq/y)	4.38E-02	2.65E-01	3.36E-01	7.36E+00
Ce-141 (5.83E+2 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce-144 (3.94E+2 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-58 (1.52E+5 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-60 (1.24E+5 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cr-51 (3.70E+5 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-134 (5.51E+6 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137 (1.08E+7 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fe-59 (5.66E+4 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H-3 (4.98E+12 Bq/y)	9.70E-06	5.86E-05	7.43E-05	1.63E-03
I-131 (2.10E+8 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-132 (1.06E+8 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133 (2.20E+8 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135 (8.75E+7 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85 (6.74E+11 Bq/y)	1.04E-06	6.26E-06	7.94E-06	1.70E-04
Kr-85m (2.02E+12 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87 (2.10E+12 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-88 (4.31E+12 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
La-140 (1.00E+3 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn-54 (2.77E+4 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nb-95 (5.01E+2 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-122 (1.31E+4 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-124 (1.23E+4 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-89 (1.44E+4 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90 (5.91E+3 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133 (1.06E+12 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m (3.16E+13 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135 (1.66E+13 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138 (2.35E+12 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Zr-95 (8.17E+2 Bq/y)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	**4.38E-02**	**2.65E-01**	**3.36E-01**	**7.36E+00**

T-26D-4 Collective dose (manSv) to UK from aqueous discharges

	Collective Dose (manSv)					
Radionuclide	**Fish**	**Crustaceans**	**Molluscs**	**Beach Sediment Gammas**	**Global Circulation**	**Total**
Ag-110m (8.20E+6 Bq/y)	2.34E-08	1.12E-07	1.63E-06	2.88E-10	0.00E+00	1.76E-06
Ba-140 (5.76E+6 Bq/y)	2.53E-11	8.13E-12	1.20E-09	2.21E-12	0.00E+00	1.24E-09
La-140 (Ba-140)	1.18E-11	1.81E-10	1.34E-09	6.96E-11	0.00E+00	1.60E-09
C-14 (1.74E+10 Bq/y)	1.17E-03	2.30E-04	1.56E-03	0.00E+00	1.16E-03	4.12E-03
Ce-141 (1.67E+5 Bq/y)	3.18E-14	1.67E-12	2.47E-11	6.90E-13	0.00E+00	2.71E-11
Ce-144 (9.76E+4 Bq/y)	1.97E-13	7.86E-12	1.16E-10	2.38E-12	0.00E+00	1.27E-10
Co-58 (5.21E+7 Bq/y)	2.54E-09	4.93E-08	1.82E-07	5.31E-09	0.00E+00	2.39E-07
Co-60 (5.01E+7 Bq/y)	2.10E-08	2.58E-07	9.51E-07	2.23E-07	0.00E+00	1.45E-06
Cr-51 (1.39E+8 Bq/y)	1.55E-10	8.53E-10	1.01E-08	1.20E-10	0.00E+00	1.12E-08
Cs-134 (4.98E+8 Bq/y)	2.70E-06	2.80E-07	2.00E-06	6.88E-08	0.00E+00	5.04E-06
Cs-137 (7.29E+8 Bq/y)	4.47E-06	3.07E-07	2.12E-06	1.31E-07	0.00E+00	7.03E-06
Fe-59 (2.27E+7 Bq/y)	3.92E-09	6.99E-08	3.10E-06	1.24E-09	0.00E+00	3.18E-06
H-3 (4.48E+13 Bq/y)	4.17E-06	9.37E-07	6.47E-06	0.00E+00	9.03E-06	2.06E-05
I-131 (2.29E+9 Bq/y)	6.12E-08	2.55E-07	1.89E-06	1.44E-11	0.00E+00	2.20E-06
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	7.52E-13	0.00E+00	7.52E-13
La-140 (7.04E+5 Bq/y)	1.35E-13	9.06E-12	6.71E-11	2.14E-12	0.00E+00	7.84E-11
Mn-54 (1.16E+7 Bq/y)	2.84E-10	5.60E-10	4.14E-07	4.25E-09	0.00E+00	4.19E-07

	Collective Dose (manSv)					
Radionuclide	**Fish**	**Crustaceans**	**Molluscs**	**Beach Sediment Gammas**	**Global Circulation**	**Total**
Nb-95 (1.31E+5 Bq/y)	4.97E-14	8.15E-13	3.02E-11	5.59E-12	0.00E+00	3.66E-11
Ru-103 (1.64E+5 Bq/y)	1.28E-13	9.53E-12	1.41E-09	4.88E-14	0.00E+00	1.42E-09
Ru-106 (4.56E+4 Bq/y)	1.69E-12	3.30E-11	4.74E-09	5.47E-14	0.00E+00	4.78E-09
Sb-122 (1.52E+6 Bq/y)	4.21E-11	1.72E-11	1.02E-10	3.06E-14	0.00E+00	1.61E-10
Sb-124 (3.52E+6 Bq/y)	2.64E-09	1.84E-10	1.09E-09	1.91E-11	0.00E+00	3.93E-09
Sr-89 (3.19E+6 Bq/y)	1.07E-11	1.35E-11	5.00E-11	6.69E-16	0.00E+00	7.42E-11
Sr-90 (6.40E+4 Bq/y)	1.87E-11	4.08E-12	1.40E-11	1.13E-17	0.00E+00	3.68E-11
Zr-95 (1.54E+5 Bq/y)	3.73E-14	8.42E-13	1.56E-10	1.22E-11	0.00E+00	1.69E-10
Nb-95 (Zr-95)	2.02E-14	7.52E-14	2.77E-12	1.29E-11	0.00E+00	1.58E-11
Total	**1.18E-03**	**2.33E-04**	**1.58E-03**	**4.34E-07**	**1.17E-03**	**4.16E-03**

T-26D-5 Collective dose (manSv) to EU12 from aqueous discharges

	Collective Dose (manSv)					
Radionuclide	**Fish**	**Crustaceans**	**Molluscs**	**Beach Sediment Gammas**	**Global Circulation**	**Total**
Ag-110m (8.20E+6 Bq/y)	1.46E-07	8.69E-07	1.01E-05	2.92E-10	0.00E+00	1.12E-05
Ba-140 (5.76E+6 Bq/y)	1.90E-10	6.32E-11	7.41E-09	2.21E-12	0.00E+00	7.67E-09
La-140 (Ba-140)	8.76E-11	1.41E-09	8.25E-09	6.96E-11	0.00E+00	9.82E-09
C-14 (1.74E+10 Bq/y)	6.25E-03	1.74E-03	9.91E-03	0.00E+00	6.97E-03	2.49E-02
Ce-141 (1.67E+5 Bq/y)	2.37E-13	1.30E-11	1.52E-10	6.90E-13	0.00E+00	1.66E-10
Ce-144 (9.76E+4 Bq/y)	1.46E-12	6.11E-11	7.15E-10	2.38E-12	0.00E+00	7.80E-10
Co-58 (5.21E+7 Bq/y)	1.88E-08	3.84E-07	1.12E-06	5.32E-09	0.00E+00	1.53E-06
Co-60 (5.01E+7 Bq/y)	1.51E-07	2.01E-06	5.87E-06	2.24E-07	0.00E+00	8.25E-06
Cr-51 (1.39E+8 Bq/y)	1.15E-09	6.64E-09	6.22E-08	1.20E-10	0.00E+00	7.01E-08
Cs-134 (4.98E+8 Bq/y)	1.55E-05	2.15E-06	1.25E-05	7.00E-08	0.00E+00	3.02E-05
Cs-137 (7.29E+8 Bq/y)	2.37E-05	2.33E-06	1.34E-05	1.37E-07	0.00E+00	3.96E-05
Fe-59 (2.27E+7 Bq/y)	2.87E-08	5.44E-07	1.91E-05	1.24E-09	0.00E+00	1.97E-05
H-3 (4.48E+13 Bq/y)	2.20E-05	7.13E-06	4.10E-05	0.00E+00	5.45E-05	1.25E-04
I-131 (2.29E+9 Bq/y)	4.60E-07	1.98E-06	1.16E-05	1.44E-11	0.00E+00	1.41E-05
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	7.52E-13	0.00E+00	7.52E-13
La-140 (7.04E+5 Bq/y)	1.02E-12	7.05E-11	4.13E-10	2.14E-12	0.00E+00	4.87E-10
Mn-54 (1.16E+7 Bq/y)	2.08E-09	4.36E-09	2.55E-06	4.26E-09	0.00E+00	2.56E-06
Nb-95	3.70E-13	6.34E-12	1.86E-10	5.59E-12	0.00E+00	1.98E-10

	Collective Dose (manSv)					
Radionuclide	**Fish**	**Crustaceans**	**Molluscs**	**Beach Sediment Gammas**	**Global Circulation**	**Total**
(1.31E+5 Bq/y)						
Ru-103 (1.64E+5 Bq/y)	9.26E-13	7.42E-11	8.69E-09	4.89E-14	0.00E+00	8.77E-09
Ru-106 (4.56E+4 Bq/y)	1.01E-11	2.55E-10	2.97E-08	5.57E-14	0.00E+00	2.99E-08
Sb-122 (1.52E+6 Bq/y)	3.18E-10	1.34E-10	6.26E-10	3.06E-14	0.00E+00	1.08E-09
Sb-124 (3.52E+6 Bq/y)	1.87E-08	1.43E-09	6.71E-09	1.91E-11	0.00E+00	2.69E-08
Sr-89 (3.19E+6 Bq/y)	7.67E-11	1.05E-10	3.09E-10	6.70E-16	0.00E+00	4.90E-10
Sr-90 (6.40E+4 Bq/y)	9.87E-11	3.10E-11	8.89E-11	1.18E-17	0.00E+00	2.19E-10
Zr-95 (1.54E+5 Bq/y)	2.77E-13	6.55E-12	9.60E-10	1.22E-11	0.00E+00	9.79E-10
Nb-95 (Zr-95)	1.45E-13	5.84E-13	1.71E-11	1.29E-11	0.00E+00	3.07E-11
Total	**6.32E-03**	**1.75E-03**	**1.00E-02**	**4.42E-07**	**7.03E-03**	**2.51E-02**

T-26D-6 Collective dose (manSv) to the World from aqueous discharges

	Collective Dose (manSv)					
Radionuclide	**Fish**	**Crustaceans**	**Molluscs**	**Beach Sediment Gammas**	**Global Circulation**	**Total**
Ag-110m (8.20E+6 Bq/y)	2.63E-07	1.28E-06	1.09E-05	2.94E-10	0.00E+00	1.25E-05
Ba-140 (5.76E+6 Bq/y)	3.30E-10	9.27E-11	7.97E-09	2.21E-12	0.00E+00	8.39E-09
La-140 (Ba-140)	1.53E-10	2.06E-09	8.87E-09	6.96E-11	0.00E+00	1.12E-08
C-14 (1.74E+10 Bq/y)	1.35E-02	2.58E-03	1.07E-02	0.00E+00	1.93E-01	2.20E-01
Ce-141 (1.67E+5 Bq/y)	4.13E-13	1.90E-11	1.64E-10	6.90E-13	0.00E+00	1.84E-10
Ce-144 (9.76E+4 Bq/y)	2.54E-12	8.96E-11	7.69E-10	2.38E-12	0.00E+00	8.63E-10
Co-58 (5.21E+7 Bq/y)	3.28E-08	5.62E-07	1.21E-06	5.32E-09	0.00E+00	1.81E-06
Co-60 (5.01E+7 Bq/y)	2.64E-07	2.94E-06	6.31E-06	2.24E-07	0.00E+00	9.74E-06
Cr-51 (1.39E+8 Bq/y)	2.00E-09	9.73E-09	6.69E-08	1.20E-10	0.00E+00	7.87E-08
Cs-134 (4.98E+8 Bq/y)	2.85E-05	3.17E-06	1.35E-05	7.03E-08	0.00E+00	4.52E-05
Cs-137 (7.29E+8 Bq/y)	4.75E-05	3.45E-06	1.45E-05	1.40E-07	0.00E+00	6.55E-05
Fe-59 (2.27E+7 Bq/y)	5.02E-08	7.97E-07	2.06E-05	1.24E-09	0.00E+00	2.14E-05
H-3 (4.48E+13 Bq/y)	4.34E-05	1.05E-05	4.42E-05	0.00E+00	1.52E-03	1.61E-03
I-131 (2.29E+9 Bq/y)	8.00E-07	2.91E-06	1.25E-05	1.44E-11	0.00E+00	1.62E-05
Xe-131m (I-131)	0.00E+00	0.00E+00	0.00E+00	7.52E-13	0.00E+00	7.52E-13
La-140 (7.04E+5 Bq/y)	1.77E-12	1.03E-10	4.44E-10	2.14E-12	0.00E+00	5.51E-10
Mn-54 (1.16E+7 Bq/y)	3.63E-09	6.39E-09	2.74E-06	4.26E-09	0.00E+00	2.76E-06
Nb-95 (1.31E+5 Bq/y)	6.44E-13	9.29E-12	2.00E-10	5.59E-12	0.00E+00	2.15E-10
Ru-103 (1.64E+5 Bq/y)	1.62E-12	1.09E-10	9.34E-09	4.89E-14	0.00E+00	9.45E-09
Ru-106 (4.56E+4 Bq/y)	1.83E-11	3.75E-10	3.19E-08	5.60E-14	0.00E+00	3.23E-08
Sb-122 (1.52E+6 Bq/y)	5.53E-10	1.96E-10	6.73E-10	3.06E-14	0.00E+00	1.42E-09
Sb-124 (3.52E+6 Bq/y)	3.29E-08	2.10E-09	7.21E-09	1.91E-11	0.00E+00	4.22E-08
Sr-89 (3.19E+6 Bq/y)	1.35E-10	1.54E-10	3.31E-10	6.70E-16	0.00E+00	6.20E-10

	Collective Dose (manSv)					
Radionuclide	**Fish**	**Crustaceans**	**Molluscs**	**Beach Sediment Gammas**	**Global Circulation**	**Total**
Sr-90 (6.40E+4 Bq/y)	2.00E-10	4.59E-11	9.59E-11	1.21E-17	0.00E+00	3.41E-10
Zr-95 (1.54E+5 Bq/y)	4.82E-13	9.60E-12	1.03E-09	1.22E-11	0.00E+00	1.05E-09
Nb-95 (Zr-95)	2.55E-13	8.57E-13	1.84E-11	1.29E-11	0.00E+00	3.24E-11
Total	**1.37E-02**	**2.60E-03**	**1.08E-02**	**4.45E-07**	**1.95E-01**	**2.22E-01**

Appendix E

ACCUMULATION IN THE ENVIRONMENT

T-26E-1 Activity concentration in unfiltered seawater and seabed sediments resulting from 60 years of continuous aqueous releases at proposed limits

Nuclide	Unfiltered seawater (Bq l^{-1})	Seabed sediment (Bq kg^{-1})
H-3	1.10E+01	1.90E+01
C-14	4.16E-03	8.07E+00
Mn-54	1.24E-06	1.11E-02
Cr-51	1.81E-05	8.15E-03
Co-58	5.31E-06	1.20E-02
Fe-59	3.09E-06	2.22E-03
Co-60	5.91E-06	1.92E-01
Sr-89	6.83E-07	1.72E-05
Sr-90	1.55E-08	1.27E-05
Nb-95	1.22E-08	5.32E-05
Zr-95	1.30E-08	3.65E-05
Ru-103	3.44E-08	2.26E-07
Ag-110m	1.92E-06	2.18E-04
Sb-122	1.12E-07	1.55E-07
Sb-124	7.67E-07	2.30E-05
I-131	3.16E-04	8.38E-05
Cs-134	1.15E-04	9.16E-02
Cs-137	1.72E-04	4.21E-01
Ba-140	8.87E-07	2.68E-05
La-140	2.61E-08	2.07E-06
Ce-141	1.33E-08	2.00E-05
Ce-144	8.44E-09	9.96E-05
Ru-106	1.09E-08	5.61E-07

T-26E-2 Activity concentration in soils resulting from 60 years of continuous gaseous releases at proposed limits

Nuclide	Soil Activity (Bq kg^{-1})
H-3	2.33E+00
C-14	6.43E-01
Cr-51	3.93E-06
Mn-54	3.66E-06
Co-58	4.61E-06
Fe-59	1.02E-06
Co-60	8.33E-05
Kr-85m	0.00E+00
Kr-85	0.00E+00
Kr-87	0.00E+00
Kr-88	0.00E+00
Sr-89	2.98E-07
Sr-90	1.43E-05
Zr-95	2.21E-08
Nb-95	6.94E-09
I-131	6.03E-03
I-132	3.52E-05
I-133	6.62E-04
Xe-133	0.00E+00
Xe-133m	0.00E+00
Cs-134	1.59E-03
I-135	8.34E-05
Xe-135	0.00E+00
Cs-137	2.64E-02
Xe-138	0.00E+00
Ba-140	1.20E-07
Ce-141	7.35E-09
La-140	4.69E-14
Ce-144	4.81E-08
Ag-110m	2.16E-06
Sb-122	1.24E-08
Sb-124	3.12E-07