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****Plant Applicability:** ☐ All AP1000 plants except:
☒ Only the following plants: UKP

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Reference 2-19

AP1000 Generic Design Collective Dose Assessment

This reference provided in Section 2.8 contains Technical Report SERCO/TAS/002730/001 Issue 03 (UKP-GW-GL-031, Revision 0), "AP1000 Generic Design Collective Dose Assessment," prepared by SERCO for the Westinghouse "UK AP1000 Environment Report," UKP-GW-GL-790, Revision 1.

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AP1000 Generic Design
Collective Dose Assessment
Westinghouse Electric Company

Your Reference: Customer Ref

Our Reference: SERCO/TAS/002730/001 Issue 03 (UKP-GW-GL-031, Revision 0)

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Title	AP1000 Generic Design Collective Dose Assessment
Customer	Westinghouse Electric Company
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Our Reference SERCO/TAS/002730/001 Issue 03

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Executive Summary

This document describes calculations undertaken to assess collective doses from atmospheric discharges from the AP1000 design.

Collective doses from the WEC AP1000 design were assessed for UK, EU and world population and truncated at 500 years. The assessment was based on 5 representative coastal sites in the UK. The variation of collective doses between these sites was small.

The highest total collective doses from the AP1000 design are 0.093 manSv for the UK, 0.74 manSv for the EU and 5.2 manSv for world populations. The total collective doses are dominated by doses from atmospheric discharges by about three orders of magnitude.

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Contents

List of Tables

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1 Introduction

This document describes calculations undertaken to assess collective doses from atmospheric and liquid discharges from the AP1000 design.

Radionuclides discharged into the environment have the potential to disperse, allowing exposure of wider populations, albeit at much lower levels of individual exposure than to the individuals within the general population who would be expected to receive the highest doses (the critical group). The collective effective dose has units of man-sieverts (manSv) and can be defined as the sum of all the exposures from a given source to a defined group of people.

The assessment was carried out following guidance provided in Reference [1].

2 Assessment Methodology

2.1 Discharges

Collective doses will arise from discharges of radionuclides to atmosphere and from liquid discharges to the marine environment.

Discharges to the atmosphere were taken from reference [2]. For the purposes of this assessment the discharges were grouped into the following categories [3]:

- Tritium (assumed to be in the form of tritiated water)
- Carbon-14
- Argon-41
- Noble gases – these were assessed as krypton-85
- Iodines – these were assessed as iodine-131
- Particulates – these were assessed as cobalt-60

Liquid discharges to the marine environment were taken from reference [2]. For the purposes of this assessment the discharges were grouped into the following categories:

- Tritium (assumed to be in the form of tritiated water)
- Carbon-14
- Iodines – these were assessed as iodine-131
- All other radionuclides were assessed as cobalt-60

The atmospheric and liquid discharges used in this assessment are provided in Tables 1 and 2 respectively.

2.2 Modelling Approach

Collective doses were calculated using estimated WEC AP1000 design discharges and collective dose per unit discharge factors. The collective dose per unit discharge factors for radionuclides discharged to atmosphere and sea were calculated using the PC CREAM model [4]. PC CREAM is based on a methodology for assessing the radiological consequences of routine releases to the environment published by the European Commission [5]. The collective dose assessment is based on population and food production grids for the atmospheric assessment and seafood catch data for the marine assessment. PC CREAM also contains a model to estimate doses from the global circulation of released radionuclides.

Some radionuclides, owing to the magnitude of their radioactive half-lives and their behaviour in the environment, may become globally dispersed and act as a long term source of irradiation of both the regional and world populations. Such exposures would be in addition to the irradiation of the populations exposed during the initial dispersion of these radionuclides from their points of discharge. Of the radionuclides discharged by the AP1000 design, tritium, carbon-14 and krypton-85 are affected by this characteristic. As a result, the UK and Europe doses presented here are the sum of the so-called 'first pass' dispersion dose and the global circulation component for these radionuclides. Collective doses to the world population from atmospheric discharges were assumed to be equivalent to the first pass dispersion dose for Europe plus the global circulation component for the world population for tritium, carbon-14 and krypton-85.

Collective doses were calculated for UK, European and World populations, truncated at 500 years. In this context the population of Europe encompasses all European countries which were members of the EU in 1998.

Default PC CREAM model settings were applied with the following exceptions:

- Most of the atmospheric release takes place from the main plant vent which has an effective stack height of 62.4 m. About 12 % of the total release takes place from the turbine building vent which has an effective stack height of 39.8 m. For the purposes of this assessment it was assumed that all discharges occur from a single stack with an effective height of 60 m.
- For the atmospheric assessment an atmospheric stability distribution of '50% category D' was chosen [2].

Collective dose assessments from routine discharges tend to be site specific as they rely on grids of population distribution, agricultural food production and seafood catches that have been established for individual sites. In this instance a collective dose assessment is required for a generic site. Consequently several representative assessments were carried out here to test the distribution of collective doses in England. The following sites were assessed: Dungeness, Hartlepool, Heysham, Hinkley Point and Sizewell [6].

Collective dose per unit discharge for radionuclides discharged from all sites to atmosphere and to the marine environment are shown in Tables 3-7.

3 Results

The collective doses per year of discharge and truncated to 500 years, arising from discharges to atmosphere and from liquid discharges to the marine environment from the AP1000 design are shown in Tables 8-12 for the five sites assessed. Tables 13 and 14 show maximum, averaged and minimum summary statistics of the results for atmospheric and liquid discharges respectively.

Collective doses from discharges to atmosphere ranged from 0.077 manSv to 0.093 manSv for the UK population, from 0.63 manSv to 0.74 manSv for the European population and from 5.1 manSv to 5.2 manSv for the World population between the five sites.

Collective doses from liquid discharges ranged from 0.000021 manSv to 0.00012 manSv for the UK population, from 0.00011 manSv to 0.00023 manSv for the European population and from 0.0015 manSv to 0.0016 manSv for the World population between the five sites.

4 Conclusion

Collective doses from the WEC AP1000 design were assessed for UK, EU and world population. The assessment was based on 5 representative coastal sites in the UK. The variation of collective doses between these sites was small.

The highest total collective doses from the AP1000 design are 0.093 manSv for the UK, 0.74 manSv for the EU and 5.2 manSv for world populations. The total collective doses are dominated by doses from atmospheric discharges by about three orders of magnitude.

5 References

1 Environmental Agency, Scottish Environmental Protection Agency, Northern Ireland Department of Environment, National Radiological Protection Board and Food Standards Agency (2002), Authorisation of Discharges of Radioactive Waste to the Environment, Principals for the Assessment of Prospective Public Doses, http://publications.environment-agency.gov.uk/pdf/PMHO1202BKLH-e-e.pdf

2 R. Hunter-Smith, Assumed Data for Dose Assessments, 63000333-000-00-192-K-003 Revision A1, June 2008.

3 Environment Agency pers. com, Nuclear New Build Assessment Team, Penrith, Cumbria, November 2007

4 A. Mayall, T. Cabianca, C. Attwood, C.A. Fayers, J.G. Smith, J. Penfold, D. Steadman, G. Martin, T.P. Morris, J.R. Simmonds, PC-CREAM Installing and Using the PC System for Assessing the Radiological Impact of Routine Releases, EUR 17791 EN, NRPB-SR296, 1997.

5 J.R. Simmonds, G. Lawson, A. Mayall, Methodology for Assessing the Radiological Consequences of the Routine Releases of Radionuclides to the Environment, European Commission, Luxembourg, EUR 15760 EN, Radiation Protection 72, 1995.

6 R. Hunter-Smith, Characteristics of a Generic Site for a Nuclear Power Station, 63000333-000-00-220-S-006 Revision A1, April 2008.

Tables

Table 1 Estimated atmospheric discharges from the AP1000 design

Radionuclide	Estimated annual discharge (GBq/y)
Tritium	1.80E+03
Carbon-14	2.70E+02
Argon-41	1.30E+03
All remaining noble gases (Kr-85)	6.68E+03
All iodides (I-131)	5.59E-01
All remaining particulates (Co-60)	1.71E-02

Table 2 Estimated liquid discharges from the AP1000 design

Radionuclide	Estimated annual discharge (GBq/y)
Tritium	3.34E+04
Carbon-14	7.00E-05
All iodines (I-131)	7.00E-02
All others (Co-60)	2.24E+00

Table 3 Collective dose per unit discharge from an AP1000 station at Dungeness

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	7.7E-07	2.9E-06	2.9E-06
Tritium Global	1.8E-09	2.3E-08	3.3E-07
Tritium Total	7.7E-07	2.9E-06	3.2E-06
Carbon-14 First Pass	1.8E-04	1.5E-03	1.5E-03
Carbon-14 Global	9.7E-05	1.2E-03	1.8E-02
Carbon-14 Total	2.8E-04	2.7E-03	1.9E-02
Argon-41	1.2E-07	1.4E-07	1.4E-07
Cobalt-60	6.3E-03	1.2E-02	1.2E-02
Krypton-85 First Pass	5.4E-09	1.7E-08	1.7E-08
Krypton-85 Global	1.4E-09	1.8E-08	2.5E-07
Krypton-85 Total	6.8E-09	3.5E-08	2.7E-07
Iodine-131	4.1E-04	4.8E-04	4.8E-04

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	8.7E-11	5.1E-10	5.7E-10
Tritium Global	2.4E-10	1.5E-09	4.3E-08
Tritium Total	3.3E-10	2.0E-09	4.4E-08
Carbon-14 First Pass	8.6E-05	4.9E-04	6.3E-04
Carbon-14 Global	6.0E-05	3.8E-04	1.1E-02
Carbon-14 Total	1.5E-04	8.7E-04	1.2E-02
Cobalt -60	8.4E-06	6.7E-05	6.8E-05
Iodine-131	2.3E-08	1.2E-07	1.2E-07

Table 4 Collective dose per unit discharge from an AP1000 station at Hartlepool

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	9.7E-07	2.4E-06	2.4E-06
Tritium Global	1.8E-09	2.3E-08	3.3E-07
Tritium Total	9.7E-07	2.4E-06	2.7E-06
Carbon-14 First Pass	2.2E-04	1.2E-03	1.2E-03
Carbon-14 Global	9.7E-05	1.2E-03	1.8E-02
Carbon-14 Total	3.2E-04	2.4E-03	1.9E-02
Argon-41	4.5E-07	4.3E-07	4.3E-07
Cobalt-60	9.8E-03	1.2E-02	1.2E-02
Krypton-85 First Pass	6.9E-09	1.5E-08	1.5E-08
Krypton-85 Global	1.4E-09	1.8E-08	2.5E-07
Krypton-85 Total	8.3E-09	3.3E-08	2.7E-07
Iodine-131	7.1E-04	4.8E-04	4.8E-04

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	1.5E-10	4.1E-10	5.0E-10
Tritium Global	2.4E-10	1.5E-09	4.3E-08
Tritium Total	3.9E-10	1.9E-09	4.4E-08
Carbon-14 First Pass	1.2E-04	4.1E-04	6.1E-04
Carbon-14 Global	6.0E-05	3.8E-04	1.1E-02
Carbon-14 Total	1.8E-04	7.9E-04	1.2E-02
Cobalt -60	6.8E-06	2.3E-05	2.5E-05
Iodine-131	3.1E-07	3.3E-07	3.3E-07

Table 5 Collective dose per unit discharge from an AP1000 station at Heysham

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	1.2E-06	2.5E-06	2.5E-06
Tritium Global	1.8E-09	2.3E-08	3.3E-07
Tritium Total	1.2E-06	2.5E-06	2.8E-06
Carbon-14 First Pass	2.1E-04	1.1E-03	1.1E-03
Carbon-14 Global	9.7E-05	1.2E-03	1.8E-02
Carbon-14 Total	3.1E-04	2.3E-03	1.9E-02
Argon-41	2.9E-07	2.3E-07	2.3E-07
Cobalt-60	9.2E-03	1.2E-02	1.2E-02
Krypton-85 First Pass	6.9E-09	1.5E-08	1.5E-08
Krypton-85 Global	1.4E-09	1.8E-08	2.5E-07
Krypton-85 Total	8.3E-09	3.3E-08	2.7E-07
Iodine-131	1.5E-03	8.4E-04	8.4E-04

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	3.1E-10	7.2E-10	7.9E-10
Tritium Global	2.4E-10	1.5E-09	4.3E-08
Tritium Total	5.5E-10	2.2E-09	4.4E-08
Carbon-14 First Pass	2.0E-04	5.3E-04	6.5E-04
Carbon-14 Global	6.0E-05	3.8E-04	1.1E-02
Carbon-14 Total	2.6E-04	9.1E-04	1.2E-02
Cobalt -60	4.6E-05	4.7E-05	4.7E-05
Iodine-131	2.9E-07	3.5E-07	3.5E-07

Table 6 Collective dose per unit discharge from an AP1000 station at Hinkley Point

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	1.2E-06	2.6E-06	2.6E-06
Tritium Global	1.8E-09	2.3E-08	3.3E-07
Tritium Total	1.2E-06	2.6E-06	2.9E-06
Carbon-14 First Pass	2.2E-04	1.3E-03	1.3E-03
Carbon-14 Global	9.7E-05	1.2E-03	1.8E-02
Carbon-14 Total	3.2E-04	2.5E-03	1.9E-02
Argon-41	1.7E-07	1.8E-07	1.8E-07
Cobalt-60	6.9E-03	1.0E-02	1.0E-02
Krypton-85 First Pass	5.7E-09	1.4E-08	1.4E-08
Krypton-85 Global	1.4E-09	1.8E-08	2.5E-07
Krypton-85 Total	7.1E-09	3.2E-08	2.7E-07
Iodine-131	1.7E-03	9.7E-04	9.7E-04

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	3.3E-11	1.6E-10	1.7E-10
Tritium Global	2.4E-10	1.5E-09	4.3E-08
Tritium Total	2.7E-10	1.7E-09	4.3E-08
Carbon-14 First Pass	4.8E-05	2.6E-04	3.6E-04
Carbon-14 Global	6.0E-05	3.8E-04	1.1E-02
Carbon-14 Total	1.1E-04	6.4E-04	1.1E-02
Cobalt -60	5.2E-06	2.3E-05	2.3E-05
Iodine-131	2.6E-08	5.5E-08	5.5E-08

Table 7 Collective dose per unit discharge from an AP1000 station at Sizewell

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	8.5E-07	2.9E-06	2.9E-06
Tritium Global	1.8E-09	2.3E-08	3.3E-07
Tritium Total	8.5E-07	2.9E-06	3.2E-06
Carbon-14 First Pass	2.4E-04	1.5E-03	1.5E-03
Carbon-14 Global	9.7E-05	1.2E-03	1.8E-02
Carbon-14 Total	3.4E-04	2.7E-03	1.9E-02
Argon-41	9.4E-08	1.0E-07	1.0E-07
Cobalt-60	5.3E-03	1.1E-02	1.1E-02
Krypton-85 First Pass	5.0E-09	1.7E-08	1.7E-08
Krypton-85 Global	1.4E-09	1.8E-08	2.5E-07
Krypton-85 Total	6.4E-09	3.5E-08	2.7E-07
Iodine-131	4.8E-04	4.6E-04	4.6E-04

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv per GBq/y		
Tritium First Pass	1.8E-10	7.3E-10	8.2E-10
Tritium Global	2.4E-10	1.5E-09	4.3E-08
Tritium Total	4.2E-10	2.2E-09	4.4E-08
Carbon-14 First Pass	1.5E-04	6.4E-04	8.5E-04
Carbon-14 Global	6.0E-05	3.8E-04	1.1E-02
Carbon-14 Total	2.1E-04	1.0E-03	1.2E-02
Cobalt -60	1.9E-05	7.1E-05	7.3E-05
Iodine-131	3.6E-07	4.7E-07	4.7E-07

Table 8 Collective dose results for discharges from an AP1000 station at Dungeness

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	1.4E-03	5.3E-03	5.8E-03
Carbon-14	7.5E-02	7.4E-01	5.2E+00
Argon-41	1.6E-04	1.8E-04	1.8E-04
Cobalt-60	1.1E-04	2.1E-04	2.1E-04
Krypton-85	4.5E-05	2.3E-04	1.8E-03
Iodine-131	2.3E-04	2.7E-04	2.7E-04
Total	**7.7E-02**	**7.4E-01**	**5.2E+00**

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	1.1E-05	6.7E-05	1.5E-03
Carbon-14	1.0E-08	6.1E-08	8.1E-07
Cobalt-60	1.9E-05	1.5E-04	1.5E-04
Iodine-131	1.6E-09	8.4E-09	8.4E-09
Total	**3.0E-05**	**2.2E-04**	**1.6E-03**

Table 9 Collective dose results for discharges from an AP1000 station at Hartlepool

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	1.7E-03	4.4E-03	4.9E-03
Carbon-14	8.6E-02	6.6E-01	5.1E+00
Argon-41	5.9E-04	5.6E-04	5.6E-04
Cobalt-60	1.7E-04	2.1E-04	2.1E-04
Krypton-85	5.5E-05	2.2E-04	1.8E-03
Iodine-131	4.0E-04	2.7E-04	2.7E-04
Total	**8.8E-02**	**6.6E-01**	**5.1E+00**

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	1.3E-05	6.4E-05	1.5E-03
Carbon-14	1.3E-08	5.5E-08	8.1E-07
Cobalt-60	1.5E-05	5.2E-05	5.6E-05
Iodine-131	2.2E-08	2.3E-08	2.3E-08
Total	**2.8E-05**	**1.2E-04**	**1.5E-03**

Table 10 Collective dose results for discharges from an AP1000 station at Heysham

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	2.2E-03	4.5E-03	5.1E-03
Carbon-14	8.3E-02	6.3E-01	5.0E+00
Argon-41	3.8E-04	3.0E-04	3.0E-04
Cobalt-60	1.6E-04	2.1E-04	2.1E-04
Krypton-85	5.5E-05	2.2E-04	1.8E-03
Iodine-131	8.4E-04	4.7E-04	4.7E-04
Total	**8.6E-02**	**6.3E-01**	**5.1E+00**

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	1.8E-05	7.4E-05	1.5E-03
Carbon-14	1.8E-08	6.4E-08	8.2E-07
Cobalt-60	1.0E-04	1.1E-04	1.1E-04
Iodine-131	2.0E-08	2.5E-08	2.5E-08
Total	**1.2E-04**	**1.8E-04**	**1.6E-03**

Table 11 Collective dose results for discharges from an AP1000 station at Hinkley Point

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	2.2E-03	4.7E-03	5.3E-03
Carbon-14	8.6E-02	6.8E-01	5.1E+00
Argon-41	2.2E-04	2.3E-04	2.3E-04
Cobalt-60	1.2E-04	1.7E-04	1.7E-04
Krypton-85	4.7E-05	2.1E-04	1.8E-03
Iodine-131	9.5E-04	5.4E-04	5.4E-04
Total	**8.9E-02**	**6.9E-01**	**5.1E+00**

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	9.1E-06	5.5E-05	1.4E-03
Carbon-14	7.6E-09	4.5E-08	8.0E-07
Cobalt-60	1.2E-05	5.2E-05	5.2E-05
Iodine-131	1.8E-09	3.9E-09	3.9E-09
Total	**2.1E-05**	**1.1E-04**	**1.5E-03**

Table 12 Collective dose results for discharges from an AP1000 station at Sizewell

a) Atmospheric discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	1.5E-03	5.3E-03	5.8E-03
Carbon-14	9.1E-02	7.4E-01	5.2E+00
Argon-41	1.2E-04	1.3E-04	1.3E-04
Cobalt-60	9.1E-05	1.9E-04	1.9E-04
Krypton-85	4.3E-05	2.3E-04	1.8E-03
Iodine-131	2.7E-04	2.6E-04	2.6E-04
Total	**9.3E-02**	**7.4E-01**	**5.2E+00**

b) Liquid discharges

Radionuclide	UK	Europe	World
	manSv		
Tritium	1.4E-05	7.4E-05	1.5E-03
Carbon-14	1.5E-08	7.1E-08	8.3E-07
Cobalt-60	4.3E-05	1.6E-04	1.6E-04
Iodine-131	2.5E-08	3.3E-08	3.3E-08
Total	**5.7E-05**	**2.3E-04**	**1.6E-03**

Table 13 Collective dose statistics for AP1000 discharges to atmosphere

Radionuclide	UK (manSv)			Europe (manSv)			World (manSv)		
	Min	Average	Max	Min	Average	Max	Min	Average	Max
Tritium	1.4E-03	1.8E-03	2.2E-03	4.4E-03	4.8E-03	5.3E-03	4.9E-03	5.4E-03	5.8E-03
Carbon-14	7.5E-02	8.4E-02	9.1E-02	6.3E-01	6.9E-01	7.4E-01	5.0E+00	5.1E+00	5.2E+00
Argon-41	1.2E-04	2.9E-04	5.9E-04	1.3E-04	2.8E-04	5.6E-04	1.3E-04	2.8E-04	5.6E-04
Cobalt-60	9.1E-05	1.3E-04	1.7E-04	1.7E-04	2.0E-04	2.1E-04	1.7E-04	2.0E-04	2.1E-04
Krypton-85	4.3E-05	4.9E-05	5.5E-05	2.1E-04	2.2E-04	2.3E-04	1.8E-03	1.8E-03	1.8E-03
Iodine-131	2.3E-04	5.4E-04	9.5E-04	2.6E-04	3.6E-04	5.4E-04	2.6E-04	3.6E-04	5.4E-04
Total	**7.7E-02**	**8.7E-02**	**9.3E-02**	**6.3E-01**	**6.9E-01**	**7.4E-01**	**5.1E+00**	**5.1E+00**	**5.2E+00**

Table 14 Collective dose statistics for AP1000 discharges to sea

Radionuclide	UK (manSv)			Europe (manSv)			World (manSv)		
	Min	Average	Max	Min	Average	Max	Min	Average	Max
Tritium	9.1E-06	1.3E-05	1.8E-05	5.5E-05	6.7E-05	7.4E-05	1.4E-03	1.5E-03	1.5E-03
Carbon-14	7.6E-09	1.3E-08	1.8E-08	4.5E-08	5.9E-08	7.1E-08	8.0E-07	8.1E-07	8.3E-07
Cobalt-60	1.2E-05	3.8E-05	1.0E-04	5.2E-05	1.0E-04	1.6E-04	5.2E-05	1.1E-04	1.6E-04
Iodine-131	1.6E-09	1.4E-08	2.5E-08	3.9E-09	1.9E-08	3.3E-08	3.9E-09	1.9E-08	3.3E-08
Total	**2.1E-05**	**5.1E-05**	**1.2E-04**	**1.1E-04**	**1.7E-04**	**2.3E-04**	**1.5E-03**	**1.6E-03**	**1.6E-03**