Environment Agency

Generic design assessment
UK EPR nuclear power plant design by AREVA NP SAS and Electricité de France SA

Assessment report
Independent dose assessment

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Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

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Author(s): C.A. Robinson, C. Joly, S. Saleh and A. Punt.

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Contractor: Enviros Consulting Ltd

Environment Agency's Project Manager: E.J. Tooley and J.G. Titley

Collaborator(s):
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Executive summary

The Health and Safety Executive and the Environment Agency (the nuclear regulators) are working together to ensure that any new nuclear power stations built in the UK meet the highest standard of safety, security, environmental protection and waste management. Together we have established a generic design assessment (GDA) process to consider the acceptability of the new nuclear power plants. One of the stages in the processes is consideration of the environmental acceptability of the design. This stage has been divided into two main phases, the first addressing generic design matters and the second dealing with applications for specific sites.

In the first phase of the GDA process, we are carrying out detailed assessments of the environmental effects of each design, which will lead to a statement about the acceptability of the design. The statement on acceptability will be non-binding but will give a strong indication of whether a design is likely to be acceptable in principle in the UK with respect to matters that the Environment Agency regulates.

Electricitié de France (EDF) and AREVA NP have submitted their UK EPR nuclear power plant design for evaluation under the GDA arrangements. In their submission, EDF and AREVA carried out assessments of potential doses to members of the public from discharges of radioactive waste to the atmosphere and to the marine environment.

As part of the GDA process, an independent assessment of the potential impact of liquid and gaseous discharges of radioactive wastes from the UK EPR design has been carried out on behalf of the Environment Agency in accordance with the generic design assessment approach outlined in our Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs [Ref. 1]. This assessment takes account of the discharge information, design and the generic site description, provided by EDF and AREVA. The aim of the independent assessment was to:

- Validate and verify the assumptions made by EDF and AREVA in their dose assessments;
- Validate and verify the outcomes of the dose assessments carried out by EDF and AREVA;
- Carry out independent dose assessments to demonstrate that the dose assessments carried out by EDF and AREVA are realistic.

In the EDF and AREVA submission, it is assumed that the UK EPR would be located on the coast. The annual maximum radioactive liquid and atmospheric discharges were used as the basis for assessing doses to the local population and collective doses. A tiered assessment approach was applied by EDF and AREVA to estimate doses to the local population. EDF and AREVA used the Environment Agency's initial radiological assessment approach followed by a more detailed and realistic assessment, using the PC CREAM 98 programme. EDF and AREVA also provided estimates of the collective doses to the UK, European and World populations (truncated at 500 years), estimated using PC CREAM 98. They also predicted doses from expected short-term releases.

As part of the validation and verification activity the approaches applied by EDF and AREVA were reviewed and repeated. EDF and AREVA estimated the annual effective doses to the most exposed members of the local population, arising from the predicted annual maximum radioactive discharge to atmosphere, to be 7.8 µSv/y (to infants). It was possible to repeat the EDF and AREVA assessment outcome.

EDF and AREVA estimated doses from the maximum annual liquid radioactive discharges to the candidates for the representative person from liquid discharges of 17 µSv/y. It was possible to repeat the EDF and AREVA assessment outcome.

EDF and AREVA estimated direct radiation doses of between 1.7 – 4.8 µSv/y, depending on the outdoor occupancy of the age of those considered. Total doses were then estimated by adding the doses to the candidates for the representative person most exposed to atmospheric and marine discharges and from direct radiation. The highest total dose of 25.8 µSv/y was predicted for an adult fisherman assumed to be living within 500 m of the site.

Other aspects of the submission, related to the assessment of the build up of material in the environment, were reviewed but not repeated.

An independent assessment of doses from discharges from the EPR design was also undertaken. The assessment was based on information provided by EDF and AREVA and generic assumptions agreed with the Environment Agency. The following were assessed for liquid and atmospheric discharges:

- the annual dose to the representative person for the facility;
- the potential short-term doses from the maximum anticipated short-term discharges from normal operation;
- collective doses to the UK, European and World populations truncated at 500 years; and
- doses from direct radiation.

The independent assessment predicted doses to representative members of the public from atmospheric discharges is 8.5 μSv/y to local residents who consume locally produced terrestrial foods. The ingestion of carbon-14 in milk accounts for the majority of the dose predicted from aerial discharges. At the maximum liquid discharges, the highest dose to members of the public from marine discharges has been predicted to be around 28 μSv/y to an adult fisherman. The dose arises primarily from carbon-14 in fish.

The dose from direct radiation was independently assessed by basing it on values measured for Sizewell B. The direct radiation dose to members of the public was estimated to be 4 μSv/y. For the purposes of this assessment, this value has been assumed to apply to the UK EPR.

The dose to the representative person from a UK EPR located at a generic coastal site taking account of contributions from atmospheric and liquid discharges and direct radiation, was estimated to be around 31 μSv/y to local adult fishermen, of which 28 μSv/y was due to liquid discharges and 3 μSv/y was from the consumption of locally produced terrestrial foods and no contribution from direct radiation.

The results from the independent assessment were slightly higher than those found by EDF and AREVA because, in the independent assessment, different assumptions about the characteristics of the local marine environment were applied and local residents were assumed to live closer to the site and to produce some vegetables and fruit closer to the site than in the EDF and AREVA assessment.

Doses predicted from the EDF and AREVA assessment and from the independent assessment were low and well below the dose constraint of 300 μSv/y or the proposed constraint for new nuclear power stations of 150 μSv/y.

The independent assessment of collective doses was essentially equivalent to that presented in the EDF and AREVA submission. The estimated doses from short-term releases in the independent assessment (of the order of 5 μSv from a single occurrence) were significantly greater than those in the EDF and AREVA assessment (of 1.5 μSv from a single occurrence). This difference is a reflection of the greater level of simplification and conservatism implicit in the independent assessment of the contribution from terrestrial foods than in that undertaken by EDF and AREVA.

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Introduction

1 The Environment Agency has established a Generic Design Assessment (GDA) process, together with the Health and Safety Executive (HSE), to consider the acceptability of candidate designs for new nuclear power station designs proposed by Requesting Parties (RPs). Electricity de France SA, (EDF) and EDF and AREVA Nuclear Power SAS (referred to as EDF and AREVA in this report) have submitted their UK European Pressurised Water Reactor, (UK EPR) nuclear power plant design for evaluation under the GDA arrangements.

2 As required by the Environment Agency's Process and Information Document [Ref. 1], the EDF and AREVA submission included an assessment of annual individual and collective doses [Ref. 2] arising from potential liquid and gaseous discharges and of potential short-term doses from the maximum anticipated short-term discharges from normal operation [Ref. 3]. These assessments were based on generic design and hypothetical generic site characteristics [Ref. 4].

3 The UK EPR power plant design has been assumed to be located at the coast and EDF and AREVA have defined characteristics of the generic site to encompass the range of conditions likely to occur at any UK coastal nuclear site [Ref. 4]. Generic information on the location of the closest habitation, farms and population centres have also been derived on the basis of information from a range of existing UK nuclear sites [Ref. 4].

4 The EDF and AREVA submission has been critically reviewed and an independent assessment of the impact of expected liquid and gaseous discharges has been undertaken.

Assessments made

5 Independent assessments were undertaken of the EDF and AREVA submission, on behalf of the Environment Agency, in order to:

- Validate and verify the assumptions made by EDF and AREVA in their dose assessments;
- Validate and verify the outcomes of the dose assessments carried out by EDF and AREVA;
- Carry out independent dose assessments to determine whether the dose assessments carried out by EDF and AREVA are realistic.

6 The EDF and AREVA assessment adopted a stepwise approach. The first stage was application of the Environment Agency's Initial Radiological Assessment approach [Ref. 5], followed by a more detailed assessment using PC CREAM. The maximum annual radioactive discharge and other information provided in the EDF and AREVA reports were used in both stages of the assessment [Ref. 2].

7 The EDF and AREVA initial assessment was verified by repeating it using the same assumptions and models. The results were the same as those of EDF and AREVA, within the margins of rounding error. The verification of this stage is considered in more detail in Appendix 1.

8 A review of assumptions and parameters used by EDF and AREVA, in their more detailed dose assessments has been undertaken. This review also informed the approach taken in the independent re-assessment made on behalf of the Environment Agency. The parameters used by EDF and AREVA and on behalf of the Environment Agency are summarised in Appendix 2 and any significant differences are highlighted. Some minor divergences from standard practice were identified, primarily related to the assumed location of the nearest habitation, the potentially inconsistent choice of parameters to represent the local marine compartment and the derivation of different inhalation rates for indoors and outdoors.

9 The EDF and AREVA assessment was made for discharges to atmosphere, liquid discharges to the marine environment and from direct radiation. The results of the EDF and AREVA assessment are summarised in Appendix 2. In our review of the EDF assessment we have

used the term ‘representative person’, rather than ‘critical group’. The Health Protection Agency has recently advised that ‘the terms ‘representative person’, ‘critical group’ and ‘reference person’ are equivalent and refer to those individuals in the population of interest who receive or are expected to receive the highest doses’ [Ref. 5].

10 The independent detailed assessment assessed doses to the potentially most exposed members of the public from discharges to atmosphere, liquid discharges to the marine environment and from direct radiation. An assessment of the potential short-term dose from the maximum anticipated short-term discharge from normal operation was also made. The collective doses arising from annual atmospheric and liquid discharges were also assessed.

Discharge data for all assessments

11 The EDF and AREVA submissions include information on the monthly and annual liquid and gaseous radioactive discharges, based on operating experience. Maximum discharge levels have been proposed by the Requesting Party to include a contingency.

12 The annual maximum discharges have been used as the basis for assessment, by EDF and AREVA and for the Environment Agency assessment. In accordance with the information set out by EDF and AREVA in the submission [Ref. 3], atmospheric discharges have been assumed to take place from a single stack which protrudes a few metres above the EPR reactor building; a summary of the annual maximum radioactive discharges to the atmosphere is given in Table 1. The maximum short-term discharges to atmosphere, envisaged to occur under normal operational conditions as a result of outages, start up or when purging the cooling system [Ref. 3], are presented in Table 2. The annual maximum liquid radioactive discharges [Ref. 3] are shown in Table 3.

Assessment methodology

~~13~~ A tiered approach to dose assessment has been applied, by EDF and AREVA and in the independent assessments. The first tier was to apply the Environment Agency’s Initial Radiological Assessment approach [Ref. 6]. This provides radionuclide specific dose per unit release factors derived from generic parameters. This allows conservative estimates of dose to be made in a transparent and consistent manner. This work undertook a verification of this initial assessment stage by repeating the EDF and AREVA assessment, as described in Appendix 1.

14 The next tier of the dose assessment is a more detailed assessment, using a greater degree of specific input data where available. EDF and AREVA undertook a more detailed assessment.

15 This independent assessment work included a critical review of the detailed assessment and supporting reports, submitted by the EDF and AREVA, in order to:

- identify the assessment approach, assumptions and parameters used;
- comment on the applicability of the approach; and,
- determine the basis for an independent assessment.

This review was undertaken using consistency matrices that identified each of the key assessment stages. These matrices are provided in Appendix 2.

16 The detailed assessment undertaken by EDF and AREVA was then repeated in order to determine whether there were any errors in their application. A statement on this stage and a description and explanation of differences in the approach adopted by EDF and AREVA and on behalf of the Environment Agency, and the consequent results, is described in Appendix 2.

17 The next stage of this work was to undertake an independent detailed assessment using an established assessment system, adapted for the UK EPR, and based on dispersion,

environmental transfer and other relevant information from the PC CREAM programme [Ref. 7]. This took into account the review of the EDF and AREVA assessment, and the minor divergences from standard practice identified. These were primarily related to the assumed location of the nearest habitation, inconsistent choice of parameters to represent the local marine compartment and the derivation of different inhalation rates for indoors and outdoors. This assessment was designed to allow the Environment Agency to take an independent view of the outcome of the discharges. The approach and parameters adopted are summarised in the matrices in Appendix 2.

18 The detailed methodology used for the independent assessment of the radiological impact of radioactive discharges, is described in more detail in the appendices, as follows:

- Appendix 3: Radiological assessment of discharges of gaseous radioactive waste to atmosphere using predicted environmental concentrations; obtained from modelling carried out using the PC CREAM model [Ref. 7];
- Appendix 4: Radiological assessment of discharges of liquid radioactive to the marine environment using predicted environmental concentrations; obtained from modelling carried out using the PC CREAM model [Ref. 7];
- Appendix 5: Radiological assessment of collective doses from atmospheric and liquid discharges;
- Appendix 6: Potential doses from anticipated short-term atmospheric releases;
- Appendix 7: A discussion about some of the main uncertainties associated with the dose assessments;
- Appendix 8: The methodology used for the assessment of the potential contribution from direct radiation;
- Appendix 9: Estimated site doses and total doses.

19 It is assumed that no radioactive discharges will be made directly to the freshwater environment from the UK EPR therefore no assessment of doses from the freshwater environment has been made. Furthermore, no release information was provided for site incinerators and it has also been assumed that there are no discharges from this route.

20 Given the generic nature of the site, it has been assumed that there are no current and future discharges from adjacent sources, or from historic discharges from previous operations. The total doses arising from the UK EPR have therefore been used for comparison with the site dose constraint and the annual effective dose limit for members of the public of 1000 μSv/y. If the UK EPR power plant were to be positioned in the vicinity of a present or previous nuclear site, these dose assessments would need to be modified to take account of any additional contributions to radiation dose that might arise from these sources.

Exposure pathways included in the detailed assessments

21 Members of the public can be exposed to radionuclides discharged to atmosphere or to the marine environment by a range of exposure pathways. The exposure pathways considered in the independent assessment were based on information provided by EDF and AREVA on the nature of the generic site [Ref. 4], along with Environment Agency knowledge of the typical nature of nuclear sites gained through radiological assessments of discharges from other sites. Guidance provided by the UK National Dose Assessment Working Group (NDAWG) has also been taken into account. This group provides a technical forum dealing with dose assessment matters for the UK and involves the Environment Agency and other regulatory and advisory organisations. The exposure pathways of members of the public to discharges and direct radiation considered are as follows.

22 For discharges to atmosphere, the EDF and AREVA's detailed assessment and the independent assessment consider:

- ***Internal irradiation*** following inhalation of radionuclides discharged to atmosphere;

- ***Internal irradiation*** from the ingestion of radionuclides incorporated into locally produced foods following deposition of radionuclides discharged to atmosphere;

- ***External irradiation*** from radionuclides in the atmosphere and deposited on the ground following discharge to atmosphere.

23 For discharges of liquids to coastal waters the EDF and AREVA detailed assessment and the independent assessment consider:

- ***External irradiation*** following incorporation of radionuclides into coastal sediment, including exposure to the skin from handling of fishing gear which has come into contact with the sediment.

- ***Internal irradiation*** following the ingestion of radionuclides in marine fish and shellfish caught along the coast, ingestion of seawater while swimming and inhalation of sea spray incorporating radionuclides;

The independent assessment included consideration of ***Internal irradiation*** following the inadvertent ingestion of coastal sediment incorporating radionuclides along the coast, which was not included in the EDF and AREVA assessment.

24 For direct radiation from the site both assessments consider:

- ***External irradiation*** due to direct radiation from the site***.***

Candidates for the representative person

25 Given the nature of this assessment, specific information on the land use and location of members of the public around the generic site are not available. As a consequence, it has been necessary to make some general assumptions about the environment around the generic site. In their submission, EDF and AREVA assumed that the UK EPR nuclear power plant is located at a coastal site and proposed generic assumptions regarding the characteristics of the terrestrial and marine environments that were intended to be conservative and to envelop those of existing UK nuclear sites. In both the EDF and AREVA and the independent assessment, atmospheric dispersion characteristics typical of a coastal site and conservative marine compartment parameters have been applied. Both assessments also assume that commercial fish and shellfish may be sourced at or near to the generic site.

26 For the independent assessment, the modes of radioactive waste discharge, information on generic habits, and radiological assessments for other sites, have been used to identify realistic potential candidates for the representative person. The candidates have been chosen to reflect the residential and other communities in the areas similar to a generic coastal site, as described more fully in Appendices 3 and 4. The candidates for the representative person most exposed to liquid discharges may also be exposed via consumption of terrestrial foods and other atmospheric pathways and vice versa. However, one or the other discharge tends to dominate and the dominant exposure routes have been used to categorise appropriate candidates for the representative person into: local residents, who are primarily exposed to atmospheric discharge pathways; and a local fisherman and family, who are primarily exposed to liquid discharges

27 Candidates for the representative person:

- ***CRP1 Local residents*** For the purposes of the independent assessment, it has been assumed that a family (adults, children and infants) lives in the nearest habitation (assumed to be 100 m from the atmospheric discharge point) and are exposed to atmospheric discharges, direct radiation and to liquid discharges in the marine environment. It has been assumed that members of this family spend most of their time at home, some of which is spent outside. They have been assumed to consume green vegetables, root vegetables and fruit from their garden or other local sources (at 100 m from the atmospheric discharge point) and milk and meat from local farms close to the site (assumed to be located at 500 m from the atmospheric discharge point). They are also assumed to eat small amounts of local fish and shellfish. Generic habit data have been used as the basis for the occupancy and food intakes of the members of this family or families, and these are set out in Appendix 3. The families are assumed to live close enough to the site to be exposed to direct radiation from the site and the estimated direct radiation dose is described in Appendix 8.

- ***CRP2 Fisherman and family*** For the purposes of the independent assessment, it has been assumed that the fishermen and their families are exposed to liquid discharges from the site by spending some time on the intertidal sediments in the area and consuming high levels of locally caught fish and shellfish in addition to small amounts of locally produced foodstuffs (fruit and vegetables), originating from local sources (100 and 500 m from the atmospheric discharge point). These families are assumed to live at sufficient distance from the site to not receive exposure from direct radiation or inhalation of atmospheric releases. Generic habit data have been used to define the occupancy and food intakes of the adults, children and infants and these are set out in Appendix 4.

28 Generic habit data, based on NRPB-W41 [Ref. 8] have been used together with standard dose coefficients for internal and external exposure [Ref. 9, 10]. The sources of other assessment parameters are presented in Appendices 3 and 4.

Results

Individual doses to candidates for the representative person arising from discharges from the UK EPR Nuclear Power Plant

29 The results of the Environment Agency's Initial Radiological Assessment undertaken by EDF and AREVA are presented in Table 4. It proved possible to reproduce the assessment made by EDF and AREVA and therefore the independent initial assessment values given in Table 4 are equivalent to those estimated by EDF and AREVA in their submission.

30 In the detailed assessment, EDF and AREVA estimated the annual effective doses to the most exposed members of the local population, arising from the predicted annual maximum radioactive discharge to atmosphere, to be 7.8 μSv/y (to infants). It was possible to repeat the EDF and AREVA assessment outcome.

31 EDF and AREVA estimated doses from the maximum annual liquid radioactive discharges to the candidates for the representative person of 17 μSv/y. It was possible to repeat the EDF and AREVA assessment outcome.

32 The individual doses to the candidates for the representative person calculated independently using the generic site and habits data are summarised in Table 5. These are for the annual maximum radioactive discharges. At these discharge levels the doses from the UK EPR nuclear power plant to candidates for the representative person amongst the local residents have been predicted to be 8.5 μSv/y (infants), 5.7 μSv/y (children) and 5.3 μSv/y (adults). The highest of these doses was to infants. The highest contribution to dose was from consumption of C-14 in milk. The dose resulting from all discharges to an infant candidate for the representative person, broken down by radionuclide and by pathway, is included in Appendix 3.

33 The maximum annual liquid radioactive discharges in the independent assessment have been predicted to give rise to doses to candidates for the representative person from local fisherman families of 2.7 μSv/y (infants), 8.3 μSv/y (children) and 27.9 μSv/y (adults). The main pathways were consumption of carbon-14 in fish. The dose resulting from all discharges to adult candidates for the representative person broken down by radionuclide and by pathway is included in Appendix 4.

Individual doses to candidates for the representative person from direct radiation

34 Exposure of the public from direct radiation from nuclear sites in the UK is the responsibility of the HSE. HSE require site operators to measure direct radiation at the site perimeter and estimate exposure to a reference group on an annual basis. The total dose from direct radiation from the UK EPR power plant has been estimated to be 4 μSv/y as outlined in Appendix 8. It is based on measured gamma dose rates for Sizewell B in 2007 [Ref. 11], the only PWR in the UK.

35 EDF and AREVA estimated direct radiation doses of between 1.7 – 4.8 μSv/y, depending on the outdoor occupancy and the age of candidates considered. Total doses were then estimated by adding the doses from direct shine to the doses to candidates for the representative person from atmospheric and marine discharges (below)

Dose to the representative person for the UK EPR Nuclear Power Plant

36 EDF AREVA estimated total dose by adding the doses to the most exposed individuals from atmospheric and marine discharges and from direct shine. The highest total dose of 25.8 μSv/y was predicted for an adult fisherman assumed to be living within 500 m of the site.

37 The independent assessment of the dose to the representative person (adult local fishermen), from discharges at the predicted levels and direct radiation from the UK EPR nuclear power plant design, was 31 μSv/y. Of this around 28 μSv/y was predicted to be from liquid discharges and 3 μSv/y from terrestrial foods. The representative person is assumed to live at sufficient distance from the site that there is no significant contribution from direct shine or from inhalation of the atmospheric discharge plume.

Site dose to the representative person from proposed discharges

38 Site dose is calculated by taking into account the potential combined doses arising from the radioactive source in question (in this case the UK EPR nuclear plant) and from any other sources with which it is co-located. Given the generic nature of the site considered in this assessment, it has been assumed that the UK EPR is the only source located at this site. The site dose is in therefore the dose to the representative person from discharges from UK EPR, 31 μSv/y. Of this around 28 μSv/y was predicted to be from liquid discharges and 3 μSv/y from terrestrial foods

Total dose

39 Total dose is calculated taking into account doses from predicted discharges and radiation from the site along with doses resulting from any residues from previous discharges from this site, and doses from past and future discharges and radiation from other sites (nearby or more distant). The calculation of these contributions to total dose is highly site specific. At this stage, it has been assumed that the UK EPR is located, in isolation, at a site which has not previously been occupied by a source of radioactive discharges and at some distance from any other such sources. In this case, the total dose may therefore be assumed to be equivalent to the total dose from discharges and direct radiation from the UK EPR. If the UK EPR were to be located on a current nuclear licensed site, for example, these assumptions would need to be reviewed.

Collective doses to UK, Europe and the World

40 The collective doses per year of discharge (truncated to 500 years) arising from discharges to the atmosphere and marine environments were calculated as set out in Appendix 5 and are as follows:

- ***Discharges to atmosphere from the UK EPR Nuclear Power Plant at predicted levels*** – 0.09 manSv for the UK, 1.1 manSv for Europe, and 15.8 manSv for the World; and,

- ***Discharges to the sea from the UK EPR Nuclear Power Plant at predicted levels*** – 0.02 manSv for the UK,0.1 manSv for Europe, and 1 manSv for the World; and,

41 The majority of the collective dose from discharges of radioactive waste to both the atmosphere and to the marine environment arises from carbon-14.

Doses from potential short-term releases

42 The doses arising to members of the public as a consequence of potential short-term releases to atmosphere have been calculated as set out in Appendix 5. The dose from a single short term release to atmosphere has been estimated to be in the order of 5 μSv to an adult. This dose estimate was dominated by the contribution from C-14 in terrestrial foods. This result is higher than that presented by EDF and AREVA, due to the less complex and more conservative approach applied to calculate food doses, and due to differences in the assumed location of the exposed individuals (100 m rather than 500 m from the release point).

Discussion

43 At the maximum annual atmospheric and liquid radioactive discharge levels, provided by EDF and AREVA and agreed generic site assumptions, the dose to the representative person, from the UK EPR plant is 31 μSv/y. This value is less than the existing dose constraint of 300 μSv/y, [Ref. 12] or the proposed dose constraint for new nuclear power stations of 150 μSv/y [Ref. 5].

44 To make an assessment of the site and total dose to the representative person for comparison with the site constraint (of 500 Sv/y) and the dose limit for members of the public of 1000 μSv/y [Ref. 12], it is necessary to take account of discharges from all operations on the same site and from all past and current practices. This requires specific information about the location of the reactor which at this stage is not known. It is not appropriate to make the assessment of all sources for comparison with the dose limit . However, doses to the representative person from discharges from the reactor have been assessed as 31 μSv/y, which is well below the site dose constraint of 500 μSv/y.

45 The World collective doses from atmospheric discharges is around 16 manSv per year of discharge, whilst discharges to the marine environment is around 1 manSv per year of discharge. There is no legal dose limit on collective doses.

46 Collective doses may be used to derive the average individual dose to members of different population groups, known as per caput doses. The UK regulatory and advisory agencies have stated that discharges giving rise to per caput doses in the range of nanosieverts per year of discharge can be regarded as miniscule [Ref 13]. The average per caput doses for liquid discharges from the UK EPR nuclear power plant are lower than those for discharges to atmosphere, for which the highest are for the UK population of 1.7 nSv per year of discharge. The average per caput doses for the UK EPR may therefore be regarded as trivial.

47 The potential dose to a representative adult member of the public from a single short-term release to atmosphere was estimated to be of the order of 5 μSv. Although the dose from a single short-term release is low, there is the potential for multiple releases during the course of the year and, at this level, the contribution of short-term releases would be of a similar level as those predicted for continuous discharge. It should be noted, however, that this dose estimate was dominated by the contribution of C-14 in terrestrial foods, and the approach adopted in the independent assessment is likely to be a conservative estimate. Two alternative approaches have been adopted for calculation of food, as discussed in more detail in Appendix 6.

Comparison of EDF and AREVA and our independent assessment

48 The initial radiological and more detailed dose assessment undertaken by EDF and AREVA were repeated using the same assumptions and the results were found to be the same, or within the range of rounding differences.

49 The predicted effective doses to the candidates for representative person estimated by EDF and AREVA and as a result of the independent assessment were compared. The doses to the candidates for representative person of local residents (CRP1) are very similar; the independent assessment results are slightly higher (by around 1 μSv/y) than those predicted by EDF and AREVA. This difference is as a consequence of the location of where people live. This was 100 m from the atmospheric discharge point in the independent assessment and 500 m in the EDF and AREVA assessments. At 500 m, air concentrations and doses are lower than at 100 m.

50 The independent assessment of the predicted effective doses for the candidates for representative person from the local fisherman and family (CRP 2) is higher than the corresponding doses predicted by EDF and AREVA. In the independent assessment CRP2 is assumed not to be located close to the UK EPR plant and therefore not to receive a significant dose from direct shine or inhalation from the plume. The higher dose to the CRP2 is associated with the higher dose prediction for the ingestion of C-14 in fish due to differences in the predicted activity concentrations in the water. These differences arose from the assumptions about the characteristics of the local marine compartment in the independent assessment and EDF and AREVA assessments.

51 The collective doses calculated as part of the independent assessment are essentially identical to those presented in the EDF and AREVA submission. There is a slight difference in the collective dose to the population of Europe from liquid discharges, with the independent assessment lower by around 0.05 manSv due to differences in the specification of the local marine compartment.

52 The independent assessment of predicted doses from short-term releases are greater than those presented by EDF and AREVA, primarily due to the more simplistic and conservative approach used to calculate the contribution from ingestion of terrestrial foods.

Uncertainty in results

53 All assessments show that individual doses are well below the dose constraints. Given the relatively low doses involved, a limited consideration of uncertainty in the results has been made.

54 The potential for a variability and uncertainty in air concentrations has been considered. This may vary by a factor of about 2 in atmospheric concentrations which may be associated with the assumptions about wind direction, as discussed in more detail in Appendix 7. The dose assessment will also be influenced by the choice of distance of the receptor from the release point. In the independent assessment, standard assumptions regarding the habitation and domestic fruit and vegetable production (100 m) and agricultural produce (500 m) were used. Alternative approaches to assessments may adopt the air concentrations where ground level air concentrations are highest. The position at which the maximum air concentration varies with plume release height. For the EDF release height the air concentrations at 100 m and 500 m are around 70% and 50% of those estimated at the location with the maximum air concentration, as discussed in more detail in Appendix 7.

55 The doses have also been presented separately for internal and external exposure, in Appendix 7 to allow that uncertainties in the calculations of each to be considered in more detail if required.

Doses to the foetus and breast fed infants

56 The independent assessment also considered the possibility that pregnant women and breast-feeding infants could be candidates for the representative person. An estimate of doses to the foetus and breast-fed infant during the first few months of life was made. The predicted doses were slightly higher than those to the adult. This assessment is reported in more detail in Appendix 7.

Conclusions

57 An independent assessment was undertaken, on behalf of the Environment Agency, in order to:

- Validate and verify the assumptions made by EDF and AREVA in their dose assessments;
- Validate and verify the outcomes of the dose assessments carried out by EDF and AREVA;
- Carry out independent dose assessments to demonstrate that the dose assessments carried out by EDF and AREVA are realistic.

58 EDF and AREVA had adopted a stepwise approach; the Environment Agency Initial Radiological Assessment approach was applied. The maximum annual atmospheric and liquid discharges presented by EDF and AREVA in their submission to the Environment Agency. The results of this process were compared with those presented by EDF and AREVA and found to be effectively equivalent (within the range of rounding errors).

59 The more detailed assessment approach subsequently adopted by EDF and AREVA was then reviewed and compared with established best practice. Some minor divergences from standard practice were identified, primarily related to the assumed location of the nearest habitation, the potentially inconsistent choice of parameters to represent the local marine compartment and the derivation of different inhalation rates for indoors and outdoors. This review was used as an input to the specification of parameters for an independent assessment undertaken on behalf of the Environment Agency.

60 An independent prospective radiological assessment has been undertaken for maximum radioactive discharges predicted for an UK EPR nuclear power plant using the generic site characteristics and parameters agreed with the Environment Agency, identified in Appendix 2. The assessment has considered releases from atmospheric discharges from the PWR plant, liquid discharges and direct radiation.

61 The representative person for discharges and direct radiation from the UK EPR nuclear power plant in a generic environmental setting and for predicted discharges is adult fishermen who receive a dose of around 31 μSv/y with the majority of the dose arising from C-14 in liquid discharges.

62 The doses associated with the predicted discharges from the UK EPR nuclear power plant in a generic environmental setting are less than the existing source dose constraint of 300 μSv/y and the proposed dose constraint for new nuclear power stations of 150 μSv/y.

63 An assessment of the site and total dose to the representative person for comparison with either the site constraint (of 500 Sv/y) or the dose limit for members of the public of 1000 μSv/y [Ref. 12], has not been made. This is because it is necessary to take account of discharges from all operations on the same site and for the site constraint from all other practices including past practises for the dose limit. The assessments made here for the EPR are non-site specific. As the site is not known, what other discharges have been that may affect the assessment doses are also not unknown. Therefore the contribution of past discharges and sources and from discharges of other practices on the same or other sites. If a site specific application is received the dose assessments made will include an assessment of doses from other sources.

64 Collective doses, truncated at 500 years, have been assessed for predicted releases to atmosphere and for liquid discharges to sea. The highest collective doses (to the world population) arise for discharge to atmosphere, and are predicted to be of the order of 16 manSv per year of discharge. The corresponding value for liquid discharges is of the order of 1 manSv. The average per caput doses for all discharges to the UK population are less than 2 nSv per year of discharge. Per caput doses at this level may be regarded as trivial [Ref 13].

65 Potential doses to members of the public from predicted short-term releases could be of the order of 5 μSv. This estimated dose is dominated by the contribution of C-14 in terrestrial foods.

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Table 1 Predicted Maximum Annual Discharges to Atmosphere

Radionuclide	Atmospheric Discharges (TBq/y)
Ar-41	6.53E-01
C-14	9.00E-01
Co-58	8.67E-05
Co-60	1.02E-04
Cs-134	7.96E-05
Cs-137	7.14E-05
H-3	3.00E+00
I-131	1.82E-04
I-133	2.18E-04
Kr-85	3.13E+00
Xe-131m	6.75E-02
Xe-133	1.42E+01
Xe-135	4.46E+00

Table 2 Predicted Short term Discharges to Atmosphere

Radionuclide	Total release in 24 hours Bq	Emission Rate over 24 hours (Bq/s)
Ar-41	1.45E+11	1.68E+06
C-14	1.00E+11	1.16E+06
Co-58	4.34E+07	5.02E+02
Co-60	5.12E+07	5.93E+02
Cs-134	3.98E+07	4.61E+02
Cs-137	3.57E+07	4.13E+02
H-3	3.00E+11	3.47E+06
I-131	1.82E+08	2.11E+03
I-133	2.18E+08	2.52E+03
Kr-85	6.95E+11	8.04E+06
Xe-131m	1.50E+10	1.74E+05
Xe-133	3.16E+12	3.66E+07
Xe-135	9.90E+11	1.15E+07

Table 3 Predicted Maximum Annual Liquid Discharges to the Marine Environment

Radionuclide	Liquid Discharges (TBq/y)
Ag-110m	5.70E-04
C-14	9.50E-02
Co-58	2.07E-03
Co-60	3.00E-03
Cr-51	6.00E-05
Cs-134	5.60E-04
Cs-137	9.45E-04
H-3	7.50E+01
I-131	5.00E-05
Mn-54	2.70E-04
Ni-63	9.60E-04
Sb-124	4.90E-04
Sb-125	8.15E-04
Te-123m	2.60E-04

Table 4 Estimated Doses from Maximum Annual Discharges using Environment Agency Initial Radiological Assessment Approach

	Estimated Dose to the Representative Person (µSv/y)	
	Stage 1	**Stage 2**
Atmospheric Discharges[a]	73	11
Liquid Discharges[b]	60	46

a: Stage 1 release height assumed to be 0 m and Stage 2 20m;
b: Stage 1 volumetric exchange rate 100 m^3/s and at Stage 2 130 m^3/s

Table 5 Summary of Individual Doses to Candidates for the Representative person arising from Discharges and Direct Radiation based on Predicted Maximum Discharges (µSv/y)*

Candidates for Representative person	Age Group	Predicted Doses from UK EPR Nuclear Power Plant Discharges			
		Atmospheric	**Liquid**	**Direct Radiation**	**Total**
CRP1 for gaseous discharges – local resident (high rate terrestrial food consumer	Adult	5.3	2.0	4.0	11
	Child	5.7	1.1	4.0	11
	Infant	8.5	1.1	4.0	14
CRP2 for liquid discharges – local fisherman (high marine exposure)	**Adult**	3.2	28	0	31
	Child	3.8	8.3	0	12
	Infant	4.1	2.7	0	6.8

* Rounded to 2 significant figures

Appendix 1 –Verification of the radiological assessments for the AREVA EPR UK Design

Introduction

A1.1 In accordance with the established principles and guidance for prospective assessment of public doses, a staged approach has been applied to the assessment of the dose to the representative person, by EDF and AREVA and in this independent assessment. EDF and AREVA have used the term ‘critical group’ in their assessment document. The Health Protection Agency has recently advised that ‘the terms ‘representative person’, ‘critical group’ and ‘reference person’ are all equivalent and refer to those individuals in the population of interest who receive or are expected to receive the highest doses’ [Ref. A1.1]. The term ‘representative person’ has been adopted throughout this report.

A1.2 The first stage was the application of the simple and cautious approach provided by the Environment Agency’s Initial Radiological Assessment (IRA) [Ref. A1.2]. This provides dose per unit release values which allow a simple, single step conservative assessment of doses from discharges to be made. It is recommended that if effective doses from this approach are less than 20 µSv/y that no further assessment would be warranted for the purpose of authorising discharge of radioactive waste to the environment.

A1.3 The assumptions about discharges for all stages of the assessment are that the annual maximum radioactive atmospheric and liquid discharges are made. The data were provided in the EDF and AREVA submission, and are included in Tables 1 and 3 [Ref. A1.3]. The short term release assumptions are given in Table 2.

Stage 1 Initial Radiological Assessment

A1.4 In Stage 1 of the Environment Agency’s IRA, dose per unit release values are provided based on the assumption that atmospheric releases are from ground level and that liquid discharges occur into a local marine compartment with a volumetric exchange rate of 100 m^3/s. The results from the application of the relevant dose per unit release values are presented in Tables A1.1 and A1.2 respectively.

A1.5 The total effective dose from atmospheric discharges was estimated to be higher than that reported by the EDF and AREVA by 0.2 µSv/y. This difference is minor and may arise from rounding differences. The effective doses predicted for liquid discharges are identical to those presented by the EDF and AREVA.

Stage 2 Initial Radiological Assessment

A1.6 In Stage 2 of the Environment Agency’s Initial Radiological Assessment, the results of Stage 1 have been amended by factors to allow for an effective stack height of 20 m, in accordance with the approach adopted by EDF and AREVA, and for what is considered to be a more representative volumetric exchange rate of 130 m^3/s. The results from the application of the relevant dose per unit release values are presented in Tables A1.3 and A1.4 respectively.

A1.7 The effective doses estimated for atmospheric discharges in Stage 2 were identical to those presented by EDF and AREVA except for a rounding difference, resulting in a difference in total dose 0.4 µSv/y. The effective doses from liquid discharges were identical to those presented by EDF and AREVA except for a rounding difference, resulting in a difference in total dose of 0.1 µSv/y.

Stage 3 More Detailed Radiological Assessment

A1.8 The results of the EDF and AREVA assessment of doses to candidates for the representative person from the predicted annual maximum atmospheric discharges are presented in Tables A1.5 – A1.10 for ease of reference. EDF and AREVA estimated the annual effective doses to the most exposed members of the local population, arising from the predicted annual maximum radioactive discharge to atmosphere, to be 7.8 μSv/y (to infants). It was possible to repeat the EDF and AREVA assessment outcome.

A1.9 EDF and AREVA estimated doses from the maximum annual liquid radioactive discharges to the marine candidates for the representative person of 17 μSv/y. It was possible to repeat the EDF and AREVA assessment outcome.

A1.10 EDF and AREVA predicted the total effective dose to the representative person to be 25.8 μSv/y. The representative person is affected by both liquid and gaseous discharges and direct radiation. The representative person is assumed to be a member of the local fishing community who also resides at a distance of 500 m from the atmospheric discharge point. The representative person will be exposed to direct radiation, inhalation and ingestion of local seafoods and two terrestrial foods at high rates and other terrestrial foods at average rates.

Short duration releases to atmosphere

A1.11 The results of the EDF and AREVA assessment of potential doses from potential short-term releases from the UK EPR are presented in Tables A1.9. EDF and AREVA estimated the highest effective dose from short-term releases to be 1.46 μSv per discharge to an infant. Around 95% of this dose was estimated to arise from ingestion doses and C-14 was identified as the dominant radionuclide.

A1.12 It was possible to repeat this assessment with the same results, with the exception of predicted doses from the ingestion of terrestrial foods. EDF and AREVA adopted an ad-hoc time-dependent modelling approach, which it was not possible to repeat within the scope of this project. The elements of this approach are outlined in more detail in Appendix 2.

Collective Dose

A1.13 The collective dose results included in the EDF and AREVA submission are presented in Table A1.10. The collective dose to the UK was estimated to be 0.11 manSv, while the corresponding values for the European and World populations were estimated to be 1.26 and 16.9 manSv respectively. The per caput dose to all population groups were estimated to be of the order of 2 nSv. It was possible to repeat this assessment, with the same results.

Summary

A1.14 Stages 1 and 2 of the Environment Agency's Initial Radiological Assessment (IRA) [Ref. A1.2] approach were applied for the atmospheric and liquid discharges, for default assumptions and for the stack heights and volumetric exchange rates presented in the EDF and AREVA submission. Some radionuclides not included in the IRA dose calculation were included in the assessment as follows: antimony-124 and tellurium-123m for liquid discharges, and xenon-135 and xenon-131m for atmospheric discharges. Phosphorus-32 and krypton-59 were used as surrogates for these pairs of radionuclides, respectively. The total doses were essentially equivalent to those presented by EDF and AREVA, although some minor rounding differences are noted.

A1.15 The more detailed radiological assessment (Stage 3) was also repeated using the same assumptions and methodology with the same outcome. The collective dose calculations could also be repeated. All elements of the estimate of doses from short-term releases were also repeated, except the contribution from the ingestion of terrestrial foods, which could not be repeated due to the complexity of the approach.

References

A1.1 Health Protection Agency, HPA Advice on the Application of the ICRP's 2007 Recommendations to the UK, HPA, Chilton, (2009).

A1.2 Environment Agency, Initial Radiological Assessment Methodology (Parts 1 and 2), Science Report SC030162/SR1 (2006).

A1.3 EDF and AREVA, UK EPR Pre-Construction Environmental Report, Chapter 11: Radiological Health Impact, Document No. UKEPR-0003-110-Issue 01 (2008).

Table A1.1: Estimated Doses from Stage 1 IRA from UK EPR from EDF and AREVA Maximum Atmospheric Radioactive Discharge (ground level release)

Radionuclide	Surrogate radionuclide	Discharge	Local Habitant Dose	% Contribution
		Bq/y	μSv/y	
Tritium	-	3.00E+12	2.9E+00	3.96%
Carbon-14	-	9.00E+11	6.1E+01	84.12%
Argon-41		6.53E+11	2.1E+00	2.87%
Cobalt-58		8.67E+07	2.7E-02	0.04%
Cobalt-60		1.02E+08	1.1E+00	1.58%
Krypton-85		3.13E+12	4.1E-02	0.06%
Iodine-131		1.82E+08	8.2E-01	1.13%
Iodine-133		2.18E+08	3.8E-02	0.05%
Xenon-133		1.42E+13	9.9E-01	1.37%
Caesium-134	-	7.96E+07	3.4E-01	0.46%
Caesium-137		7.14E+07	5.0E-01	0.69%
Krypton-79*	-	4.53E+12	2.7E+00	3.67%
Xenon-135*	Krypton-79	4.46E+12	2.63E+00	3.6%
Xenon-131m*	Krypton-79	6.75E+10	3.98E-02	0.1%
Total dose			73	μSv/y

* For the purpose of this assessment, the sum of discharges of xenon-135 and xenon-131m was used as input for krypton-79 in the initial assessment system. The dose to local inhabitant and percentage contribution to total dose from these radionuclides was 2.7μSv/y and 3.6% respectively, approximately equal to the sums of the values for the individual radionuclides as presented in the EDF and AREVA report (reproduced in the table above in italics)

Table A1.2: Estimated Doses from Stage 1 IRA from UK EPR from EDF and AREVA Maximum Liquid Radioactive Discharge (100 m^3/s volumetric exchange rate)

Radionuclide	Surrogate radionuclide	Discharge	Fisherman dose	% Contribution
		Bq/y	μSv/y	
Tritium	-	7.5E+13	6.7E-02	0.11%
Carbon-14	-	9.5E+10	4.4E+01	72.85%
Chromium-51		6.0E+07	3.6E-05	0.00%
Manganese-54		2.7E+08	6.2E-02	0.10%
Cobalt-58		2.1E+09	1.4E-01	0.24%
Cobalt-60		3.0E+09	8.4E+00	14.00%
Nickel-63		9.6E+08	3.5E-03	0.01%
Silver-110m		5.7E+08	2.3E+00	3.80%
Antimony-125		8.2E+08	2.4E-02	0.04%
Iodine-131	-	5.0E+07	1.3E-04	0.00%
Caesium-134		5.6E+08	6.7E-02	0.11%
Caesium-137	-	9.5E+08	1.4E-01	0.24%
Phosphorus-32*		7.5E+08	5.1E+00	8.50%
*Antimony-124**	*Phosphorus-32*	*4.9E+08*	*3.33E+00*	*5.6%*
*Tellurium-123m**	*Phosphorus-32*	*2.6E+08*	*1.77E+00*	*3.0%*
Total dose			**60**	**μSv/y**

* For the purpose of this assessment, the sum of discharges of antimony-124 and tellurium123m was used as input for the surrogate radionuclide (phosphorus-32) in the initial radiological assessment system. The dose to fisherman and percentage contribution to total dose from these radionuclides was 5.1μSv/y and 8.6% respectively, approximately equal to the sums of the values for the individual radionuclides as presented in the EDF and AREVA report (reproduced in the table above in italics).

Table A1.3: Estimated Doses from Stage 2 IRA from UK EPR from EDF and AREVA Maximum Atmospheric Radioactive Discharge (effective stack height 20 m)*

Radionuclide	Surrogate radionuclide	Discharge	Local Habitant Dose	% Contribution
		Bq/y	**µSv/y**	
Tritium	-	3.00E+12	3.3E-01	2.94%
Carbon-14	-	9.00E+11	1.0E+01	92.04%
Argon-41		6.53E+11	8.4E-02	0.73%
Cobalt-58		8.67E+07	1.2E-03	0.01%
Cobalt-60		1.02E+08	4.7E-02	0.42%
Krypton-85		3.13E+12	1.6E-03	0.01%
Iodine-131		1.82E+08	2.3E-01	2.06%
Iodine-133		2.18E+08	5.8E-03	0.05%
Xenon-133		1.42E+13	4.0E-02	0.35%
Caesium-134	-	7.96E+07	2.4E-02	0.21%
Caesium-137		7.14E+07	2.7E-02	0.24%
Krypton-79**	-	4.53E+12	1.1E-01	0.94%
*Xenon-135***	*Krypton-79*	*4.46E+12*	*1.05E-01*	
*Xenon-131m***	*Krypton-79*	*6.75E+10*	*1.59E-03*	
Total dose			**11**	**µSv/y**

* Scaling factors: 0.04 (inhalation and external dose); 0.31 (food).
**For the purpose of this assessment, the sum of discharges of xenon-135 and xenon-131m was used as input for krypton-79 on the initial radiological assessment system. The total dose to local inhabitant by these radionuclides was 0.11 µSv/y. The EDF and AREVA reports did not provide % contribution of radionuclides to total dose for stage 2 assessments.

Table A1.4: Estimated Doses from Stage 2 IRA from UK EPR from EDF and AREVA Maximum Liquid Radioactive Discharge (volumetric exchange rate 130 m^3/s)*

Radionuclide	**Surrogate radionuclide**	**Discharge**	**Fisherman dose**	**% Contribution**
		Bq/y	**μSv/y**	
Tritium	-	7.5E+13	5.1E-02	0.11%
Carbon-14	-	9.5E+10	3.4E+01	72.85%
Chromium-51		6.0E+07	2.8E-05	0.00%
Manganese-54		2.7E+08	4.8E-02	0.10%
Cobalt-58		2.1E+09	1.1E-01	0.24%
Cobalt-60		3.0E+09	6.5E+00	14.00%
Nickel-63		9.6E+08	2.7E-03	0.01%
Silver-110m		5.7E+08	1.8E+00	3.80%
Antimony-125		8.2E+08	1.8E-02	0.04%
Iodine-131	-	5.0E+07	9.6E-05	0.00%
Caesium-134		5.6E+08	5.2E-02	0.11%
Caesium-137	-	9.5E+08	1.1E-01	0.24%
Phosphorus-32*		7.5E+08	3.9E+00	8.50%
*Antimony-124**	*Phosphorus-32*	*4.9E+08*	*2.56E+00*	
*Tellurium-123m**	*Phosphorus-32*	*2.6E+08*	*1.36E+00*	
Total dose			**46**	**μSv/y**

* For the purpose of this assessment, the sum of discharges of antimony-124 and tellurium-123m was entered as phosphorus-32 discharges in the initial radiological assessment system. The total dose to fisherman from these radionuclides was 3.9 μSv/y, approximately equal to the sums of the values for the individual radionuclides as presented in the EDF and AREVA report (reproduced in the table above in italics). The RP reports did not provide % contribution of radionuclides to total dose for Stage 2 assessments.

Table A1.5: Effective Dose from Atmospheric Discharges (EDF and AREVA, Stage 3 Assessment)

	Inhalation Dose (μSv/y)	Ingestion of terrestrial food dose (μSv/y)	External exposure to plume dose(μSv/y)	External exposure to deposited radionuclides dose (μSv/y)	Total Dose (μSv/y)
Adult	0.24	3.6	0.047	0.039	4.0
Child	0.19	4.2	0.03	0.02	4.4
Infant	0.13	7.7	0.024	0.013	7.8

Table A1.6: Effective Dose from Liquid Discharges (EDF and AREVA, Stage 3 Assessment)*

	Ingestion of sea food dose (μSv/y)	External Exposure (μSv/y)	Total Dose (μSv/y)
Adult	14	3.2	17
Child	4.2	0.48	4.7
Infant	1.4	0.048	1.5

*Maximum dose from inhalation of seaspray estimated to be very low ~ 2 10^{-9} μSv/y.

Table A1.7: Effective Doses from Direct Radiation (EDF and AREVA, Stage 3 Assessment)

	Annual effective dose to most exposed members of the public from direct radiation (μSv/y)		
	Adult	**Child**	**Infant**
Direct radiation	4.8	2.5	1.7

Table A1.8: Total Effective Dose to the Representative Person (EDF and AREVA, Stage 3 Assessment)

	Fishing family (μSv/y)	Farming Family (μSv/y)	Direct Radiation (μSv/y)	Total Dose (μSv/y)
Adult	17	4	4.8	25.8
Child	4.7	4.4	2.5	11.6
Infant	1.5	7.8	1.7	11.0

Table A1.9: Effective Dose to Local Inhabitants from Potential Short-term Releases (EDF and AREVA Assessment)

Radionuclide Group	Effective Dose per Discharge (µSv) for 24 hour scenario		
	Adult	Child	Infant
Fission and activation products	0.144	0.079	0.059
Iodines	0.009	0.011	0.023
Noble gases	0.033	0.020	0.015
Tritium	0.020	0.022	0.044
C-14	0.659	0.758	1.32
Total short-term dose	0.864	0.889	1.46

Table A1.10: Collective and per Caput Doses from UK EPR (EDF and AREVA Assessment)

		UK	Europe	World
Collective dose (ManSv)	Atmospheric Discharges	0.09	1.11	15.80
	Liquid Discharges	0.02	0.15	1.10
	Total	0.11	1.26	16.90
Average per caput dose (nSv)		2.0	1.8	1.7

Appendix 2 – Review of assessment of AREVA EPR UK Design; assessment approach and summary of key independent parameters

Introduction

A2.1 Following the initial radiological assessment (the results of which are presented in Appendix 1), the first stage of this work was to undertake a detailed critical review of the approach and parameters used in the assessments presented for consideration by EDF and AREVA [Ref. A2.1]. This review was undertaken using matrices for each assessment process. The criteria and approaches used were compared with the latest regulatory and advisory body guidance. Supporting notes and comments and decisions regarding the approaches to be adopted during the subsequent independent assessment outlined in this report are noted in Tables A2.1 to A2.7 and key points noted below.

A2.2 This work has not assessed the validity of maximum annual discharges provided by EDF and AREVA. The validation of the dose assessments submitted by EDF and AREVA is discussed in Appendix 1.

Review Findings

A2.3 The EDF and AREVA assessment for the UK EPR power plant was based on an assumption of 70% stability category D [Ref. A2.1]. For the independent assessment, a value of 60% category D was used as this is considered to be the most conservative assumption consistent with potential coastal sites.

A2.4 In the EDF and AREVA assessment, the candidates for representative person for atmospheric releases and the origin of terrestrial foods were both assumed to be located at 500 m from the discharge point [Ref. A2.1]. For the purposes of the independent assessment, the candidates for representative person were assumed to be located at 100 m whilst agricultural terrestrial foods were assumed to be grown at 500 m. These assumptions are consistent with those applied in the Environment Agency Initial Radiological Assessment methodology Reference A2.2, except for the additional assumption made in the independent assessment that green and root vegetables and domestic fruit are derived from 100 m.

A2.5 Habit data for the candidates for the representative person from atmospheric pathways were based on the top two approach in both the EDF and AREVA and the independent assessments. In this approach, the two terrestrial foods giving rise to the highest doses are assumed to be consumed at high rates while other foods are consumed at average rates. In the EDF and AREVA approach, 50% of those terrestrial foods consumed at average rates were assumed to be of local origin. In the independent assessment, all terrestrial food intakes are assumed to be derived locally.

A2.6 For the assessment of marine discharges, EDF and AREVA specified a range of marine compartment characteristics. The internal consistency of these parameters was unclear. As a consequence, the marine compartment characteristics for a potential coastal UK site with the lowest volumetric exchange rate was used in the independent assessment of 4 10^9 m^3/y (or around 126 m^3/s), The EDF and AREVA assessment included consideration of the following additional pathways: inhalation of seaspray and external exposure from handling fishing nets. These pathways have also been included in the independent assessment, together with the inadvertent ingestion of sediment and seawater during leisure activities, which were not specifically identified in the EDF and AREVA approach.

A2.7 The EDF and AREVA approach included derivation of higher inhalation rates for periods spent outdoors, derived from information from Reference A2.3 (ICRP 66). This level of complexity in the assessment was not considered necessary for a generic assessment. Generic inhalation rate assumptions, from NRPB-W41 [Ref. A2.4] were used in the independent assessment.

A2.8 The direct radiation dose was calculated by EDF and AREVA on the basis of the dose limit for members of the public and the distance from the site. The validity of this approach is questionable, as outlined in more detail in Table A2.3. As a consequence, dose rates measured in the vicinity of Sizewell B (the only PWR currently operating in the UK) were used to estimate the potential direct radiation contribution from the UK EPR, in the independent assessment, as outlined in more detail in Appendix 8.

A2.9 The EDF and AREVA approach to assess the contribution of terrestrial foods from short term releases to atmosphere was relatively complex and involved the implementation of the FARMLAND model within a software tool. This involved modelling the different stages of deposition, radioactive decay and food production. Repetition of such an approach was beyond the scope of the independent assessment. For the purposes of the independent assessment, a simple method based on the application of factors included in the HPA methodology [Ref. A2.14] has been applied.

A2.10 PC CREAM [Ref A2.5] was used to assess collective doses in the EDF and AREVA and independent assessments. The basis for these assessments were similar (to the UK, European and World populations, truncated at 500 years). In the independent assessment, the range of collective doses from atmospheric and liquid discharges were assessed for the potential sites submitted for the Strategic Siting Assessment. The results from the potential site that gave the highest dose are presented. The assumptions on effective stack height and stability categories were consistent with those used for the individual assessment, outlined above. For liquid radioactive discharges, the marine compartment characteristics of each potential site were applied, and that giving the highest collective dose are reported.

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Table A2.1: Summary and Review of EDF and AREVA Approach for Assessment of Individual Dose - Discharges to Atmosphere

Section	Criteria	EDF and Areva Approach	Comments on EDF and AREVA Approach	Independent Approach
Discharges	Discharge assumptions	Annual maximum discharges assumed to be continuous, and uniform for 50 years.	Maximum and typical discharges are presented – maximum values are used in the assessment	Based on annual maximum discharge values provided by EDF and Areva.
	Release Points	Effective stack height of 20 m (for all stages of assessment)	Physical stack height: 60 m, protruding several metres above building. Entrainment in the wake of reactor building gives effective release height of 1/3 building height).	Effective stack height based on 1/3 physical (20 m) [Ref A2. 7].
	Incineration release	None	Not considered	Not considered
Receptor Points and pathways	Habits of the candidates for representative person	Habitation: 500 m from release,	Suitably conservative but highest air concentration at 150 – 200 m, depending on the stability category used.	Habitation at 100 m in line with Environment Agency Initial Radiological Assessment approach [Ref. A2.3]. Values scaled from PC CREAM [Ref, A2.2] data for 300 m on the basis of dispersion curves in NRPB-W63 [Ref. A2.8]
		Food origin: 500 m from release	Suitably conservative – more realistic to assume food derived over wider area.	Production of fruit and vegetables at 100m other terrestrial foods at 500 m (in accordance with EA Initial Radiological Assessment).
Exposure Pathways	Internal and external exposure	External	Standard assumptions: Cloud and from deposit Location factor for cloud gamma: 0.2 and 0.1 for deposited gamma.	Similar generic data.applied
		Inhalation	Includes resuspension following deposition; inhalation rates derived from Reference A1.4.	Similar generic data.applied
		Ingestion	Terrestrial foods – excluding grain (NB: milk products are included in the calculations, but not in identification of which foods are in the top 2). Doses dominated by cow's milk and root vegetables (milk products included in calculation).	Milk products and grain not included, in line with the EA Initial Radiological Assessment Reference A2.2].

Section	Criteria	EDF and Areva Approach	Comments on EDF and AREVA Approach	Independent Approach
Modelling of Environmental Concentrations	Meterology	Uniform windrose; 70% Pasquill Category D	Typical of coastal UK (ref. NRPB-R91) [Ref. A2.9]	60% Stability Category D chosen as most conservative of existing potential sites.
	Deposition	Standard deposition and washout coefficients	Standard values used deposition velocity: 1E-3; 1E-2 m/s (inorganic iodine); zero for noble gases. Washout: 1E-4 s^{-1} for 1 µm particles. [Ref: A2.10]	Similar generic data applied.
		Surface roughness: 0.3	Representative of agricultural areas (ref.-R72) [Ref. A2.10]	Similar generic data applied
Habits Data	Occupancy	Occupancy	100%	100%
		Indoor occupancy	0.5, 0.8, 0.9 factors for adult, child and infant respectively. Consistent with conservative interpretation of Reference A2.4 (farmer and higher value for child). NB: The standard assumption for indoor occupancy for child is 0.9. However, allowance for 0.8 where more conservative assumptions are appropriate.	Similar generic data applied, consistent with the EA Initial Radiological Assessment [Reference A2.2].
	Intakes	Inhalation	Indoor/outdoor inhalation rates derived from NRPB-W41 [Ref. 2,4] and ICRP Publication No. 66 [Ref.A2.3].	Generic inhalation rates from NRPB-W41 used [Ref. 2.4].
		Terrestrial foods	Top two approach adopted. 100% of critical foods assumed to be locally produced; but 50% of other foods locally sourced and consumed at average rates. This is a departure from normal practice, which would be to assume 100% local origin of all terrestrial foods for the candidates for the representative person from atmospheric discharges (with the exception of grain, pig, milk products)	Independent assessment: Top two 100% locally produced critical foods and others foods at average rates 100% locally produced.

Section	Criteria	EDF and Areva Approach	Comments on EDF and AREVA Approach	Independent Approach
Dose to Candidates for the representative person (gaseous discharges)		Dose per unit intakes	Stage 2: ICRP 72 [Ref. A2.11]	Similar generic data applied.
		External dose coefficients	FGR 12 [Ref. A2.10]	Similar source of generic data applied. Some minor differences in individual factors.

Table A2.2: Summary and Review of EDF and AREVA Approach for Assessment of doses to candidates for representative person for liquid discharges to the marine environment

Section	**Criteria**	**EDF and Areva Approach**	**Comments on the EDF and AREVA Approach**	**Independent Approach**
Discharges	Discharge assumptions	Maximum discharge of tritium, C-14, iodine (I-131) and fission and activation products assumed.	Maximum and typical discharges are presented – maximum values are used in the assessment	Maximum discharge values used.
		Assumed to be continuous, uniform – maximum at 50 years.	Suitably conservative and in accordance with established practice	Similar approach applied
Exposure Pathways	Internal and external exposure	External	External irradiation on beach sediments (3 age groups); handling fishing gear (adults only).	Similar generic assumptions assumed
		Inhalation	Seaspray while at beach (an assumption of 1 m distance from sea assumed – although this is not stated in the report).	Similar generic assumptions assumed
		Ingestion	Ingestion of fish, crustacea and molluscs (100% caught in local compartment). Reference A2.2 methodology based on fish caught 50% in local and 50% in regional compartment.	Similar approach: 100% fish, crustacean and molluscs derived from local compartment.
Habits	Occupancy	In local compartment	100%	Similar approach applied
		Beach occupancy	Rates from NRPB-W41 [Ref. A2.4] used (2000, 300 and 30 h/y for adults, children and infants respectively).	Similar generic assumptions assumed
	Intakes	Inhalation	Inhalation rates higher than the representative values derived from ICRP Publication 66 [Reference A2.3] (adult value based on heavy exercise worker based on 7 hours light exercise and 1 hour heavy exercise. Appropriate for application for working hours. Values for children and infants are significantly greater than those recommended in NRPB-W41 [Reference A2.4] and are taken from ICRP 66 [Ref. A2.3]. The assumptions underlying	Standard inhalation rates from NRPB-W41 [Reference A2.4] applied.

Section	Criteria	EDF and Areva Approach	Comments on the EDF and AREVA Approach	Independent Approach
			these values are unclear. Information in Chapter 10 of Reference A2.1 suggests general breathing rate of 0.87 m^3/h (not sleeping) and 0.31 m^3/h for infants (as opposed to 1.12 and 0.35 m^3/h suggested for beach occupancy).	
		Ingestion	Ingestion rates for marine foods based on NRPB-W41 [Reference A2.4]	Similar generic assumptions applied.
Modelling of Environmental Concentrations	Water Concentrations	In detailed assessment: Combination of compartment parameters applied	Considered to be most restrictive assumptions. Regional compartment: Cumbrian waters chosen as having lowest flow with parameters chosen for other regional compartments – lowest dispersion and highest activity concentrations. Potential for inconsistency between parameters applied for different areas. Furthermore, not all parameters chosen are necessarily the most restrictive (in terms of dose) for the proposed sites.	Marine compartment characteristics derived from the potential site with the lowest volumetric exchange rate, considered likely to give rise to the highest doses to candidates for representative person from liquid discharges (Hartlepool).

Table A2.3: Summary and Review of EDF and AREVA Approach for Assessment of Individual Dose – Direct Dose Assessment

Section	Criteria	EDF and Areva Approach	Comments on EDF and AREVA Approach	Independent Approach
		Based on the use of the public dose limit of 1 mSv/y.	Maximum dose rate outside buildings based on 1 mSv/y and dose rate at perimeter fence based on 1/r relationship (more restrictive than $1/r^2$) assuming distance of 100 m. Inappropriate application of dose limit. Under UK regulations maximum dose from single new source = 0.3 mSv (or 0.1 mSv if HPA recommendations accepted). Furthermore, these values would relate to total dose (although inclusion of direct shine to be determined).	Most recent or averaged data for Sizewell B (i.e. without contribution from the Magnox A site). The appropriate value in RIFE 13 (for 2007): 4 µSv [Ref. A2.13]

Table A2.4: Summary and Review of EDF and AREVA Approach for Assessment of Individual Dose – Short-term Releases

Section	Criteria	EDF and AREVA Approach	Comments on the EDF and AREVA Approach	Independent Approach
General approach	Discharges	Only assumed for gaseous discharges	No short-term liquid discharges considered to be regular short-term releases occurring repeatedly which can be modelled as continuous. Approach reasonable. Consultation with HPA also indicated that potential for significantly non-homogeneous impacts from liquid discharges less than for atmospheric releases.	Atmospheric discharges only considered. Following discussion pending consultation with HPA and NDAWG.
	Radionuclide	Same as for the long term assessment	No comment	Same data applied for independent assessment
	Methodology	Based on NRPB-W54 [Ref A6.1]. Modelling using ADMS 4 [Ref. A2.15]	Suitable methodology for assessing short term discharges to atmosphere	NRPB-W54 method applied where possible for independent assessment
Dispersion modelling of Environmental concentrations	Stack height, diameter and location	60 m 2.5 m Stack assumed to be adjacent to building (stack upwind and downwind of building modelled to determine worst case)	Inconsistent with stack height assumption for longer-term releases as the effect of the building taken into account explicitly within ADMS [Ref. A2.15]	It was assumed that the stack will protrude 3m above the nearby building as reflected in section 1.2.1 of the EDF AREVA document [Ref. 2]. Therefore, stack height of 63 m modelled for independent assessment. Upwind and downwind location modelled, results presented for worst case
	Building dimensions	L=60 m W=60 m H =60 m	No comment	Same data applied for independent assessment
	Exit velocity	7 m/s	No comment	Same data applied for independent assessment

Section	Criteria	EDF and AREVA Approach	Comments on the EDF and AREVA Approach	Independent Approach
	Emission rates	Assessment based on maximum monthly discharge occurring over a 24 hour period	24-hour period is longer than the short-term release scenarios presented in NRPB-W54 (30 mins and 12 hours). Not considered to significantly affect results as assumption that monthly discharge occurring in 24-hours is conservative. Modelled in ADMS assuming 1 hour averaging time and wind angle used to represent meandering of wind direction over period of 24 hours (see below).	Similar approach used for independent assessment.
	Stability	Stability category D, boundary layer depth 800m	Stability category follows approach in NRPB-W54	Same approach applied for independent assessment
	Wind speed	Wind speed of 5 m/s	Within the range of wind speeds listed in NRPB-W54 (3 – 5m/s). 5 m/s corresponds to Case 1, which may lead to lower air concentrations and deposition than the Realistically Cautious Case	3 m/s used to represent Realistically Cautious Case from NRPB-W54 for independent assessment
	Wind direction	Towards receptor To characterise meandering effects of wind direction over 24 hour period, wind angle utilised in meteorological data used in the ADMS modelling – calculated using standard calculation	Consistent with NRPB-W54 Suitable approach	Same data applied for independent assessment
	Deposition	Dry and wet deposition modelled simultaneously and not independently using ADMS	Approach suitable	Same approach applied for independent assessment

Section	Criteria	EDF and AREVA Approach	Comments on the EDF and AREVA Approach	Independent Approach
	Rainfall	Rainfall determined assuming rainfall coefficient of 0.0001 s^{-1}	Clarification of rate used for the wet deposition was requested to determine if corresponds with value of 0.1 mm/hr for Realistically Cautious Case set out in NRPB-W54	Rainfall rate of 0.1 mm/hr utilised for independent assessment, default ADMS co-efficient constants A and B used
	Radioactive decay	No information provided on whether radioactive decay was modelled	Clarification on approach to modelling radioactive decay for the short term assessment was requested	No decay assumed for independent assessment due to relatively short distance and travel times
	Receptors	Receptor at 500 m downwind from release point	Location consistent with the continuous release assumptions and consistent with initial assessment approach.	Receptor at 100 m and 500 m downwind of release point modelled for independent assessment
Date		1 July	Most conservative for all foods	Implicit in multiplication factors applied.
Pathways	External dose	For the period of passage and deposition in year following release	Approach reasonable – application of FGR 12 coefficients [Ref. A2.12] and taking account of radioactive decay.	Simpler approach using dose rate parameters from NRPB-W54, for comparison purposes.
	Inhalation	For period of plume passage	Approach reasonable - resuspension likely to be minimal	Similar approach applied
	Ingestion of foods	In the year following release	Approach reasonable	
Environmental Modelling	Food concentration s	Ingestion dose in 1st year for release of all nuclides except H-3 and C-14, using software implementation of FARMLAND [Ref. A1.5]. Cropping, grazing, decay and preparation assumptions applied.	General approach reasonable but complex application of model beyond the scope of independent assessment	Generic normalised factors for assessing doses from food consumption for a short term release of 4.32 10^4 MBq over a 30 minute duration on 1 July, included in NRPB-W54 [Ref. A2.14].
	Tritium and C-14	Specific activity model Relevant Bq/kg per Bq/m^3 factors taken from Environment Agency Initial Assessment Methodology.	Reasonable	Similar approach applied

Section	Criteria	EDF and AREVA Approach	Comments on the EDF and AREVA Approach	Independent Approach
Habits of candidates for representative person	Occupancy	100% at location; Indoor occupancy of 0.5, 0.8, 0.9 factors used for adults, children and infants respectively	Reasonable approach	Same generic assumptions applied.
	Intake by inhalation	Inhalation rates based on References ICRP Publication 66 [Ref. A2.3] and NRPB-W41 [Ref. A2.4] to derive indoor and outdoor inhalation rates.	Complex approach. NRPB-W41 applied high rate inhalation rates for maximum 30 minute and 12 hour durations.	Standard inhalation rates applied from NRPB-W41, given longer duration of assumed release.
	Intakes of terrestrial foods	Top 2 approach with 100 and 50% fractions of local food for critical rate in average rate foods respectively. Milk and root vegetables assumed to be critical and 100% local; 50% and average consumption of other terrestrial foods. Ingestion rates derived from NRPB-W41 [Ref. A2.4].	Standard conservative assumption would be to assume 100% ingestion of local foods.	Food ingestion multiplication factors origin at 1 km from release point and top 2 approach implicitly assumed. Alternative approach of using equilibrium transfer factors and radioactive decay also applied.
Dose calculation	External (plume)	24 hour exposure for Indoor/outdoor locations used. Standard (ADMS) dose coefficients for immersion.	Use of immersion coefficients from ADMS inconsistent with approach for annual exposures.	Dose rate factors for immersion based on FGR 12 [Ref. A2.10]
	External (deposit)	Calculation for the year following release; concentrations on the ground derived from ADMS. Radioactive decay over the year and occupancy and location factors for indoor and outdoor occupancy taken into account; dose coefficients for deposit derived from FGR 12 [Ref. A2.12]	Approach and calculations reasonable	Simple generic factors derived from NRPB-W54 [Ref. A2.14] applied.
	Inhalation	Exposure during passage of plume (24 hours) taken into account breathing rate (indoor/outdoor average) modified by indoor/outdoor occupancy and reduction factor of 0.5 for depositing radionuclides indoors.	Reasonable approach; differentiation of internal and external inhalation rates more complex than necessary for a generic assessment.	Standard inhalation rates were used from NRPB-W41; other aspects of the assessment similar [Ref. A2.4].

Section	Criteria	EDF and AREVA Approach	Comments on the EDF and AREVA Approach	Independent Approach
	Ingestion	In the year following release From ADMS atmospheric concentration, TIC in food (Bq/kg per Bq/m^3); preparation factor, ingestion rate and dose coefficient for ingestion.	General approach reasonable	Generic normalised factors for assessing doses from food consumption for a short term release of $4.32\ 10^4$ MBq over a 30 minute duration on 1 July, included in NRPB-W54 [Ref. A2.14].

Table A2.5: Summary and Review of EDF and AREVA Approach for Assessment of Individual Dose – Total Dose

Section	Criteria	EDF and AREVA Approach	Comments on the EDF and AREVA Approach	Independent Approach
Total dose to representative person	Combination of habits	No exposure to fishing gear, seaspray or beach sediments. Marine food consumption based on average consumption of marine foods from local compartment.	External dose and seaspray not included	Combination of habits agreed with Environment Agency. Terrestrial food derived from 500 m at average consumption rates. Independent assessment: Some (non-occupational) beach occupancy (external dose and seaspray would seem appropriate for farmer)
		Marine food consumers who consume local terrestrial foods	Assumed consumption of up to 50% terrestrial foods from local sources – but not exposed to plume, or deposits from atmospheric discharges. Location of local terrestrial foods unclear	Independent assessment: origin at 500 m from atmospheric discharge point.
		Local resident exposed to both atmospheric and liquid discharges	Most exposed from both discharges. Located at 500 m.	

Table A2.6: Summary and Review of EDF and AREVA Approach for Assessment of Collective Dose – Discharges to Atmosphere

Section	Criteria	EDF and AREVA Approach	Comments on EDF and AREVA Approach	Independent Approach
Location		The maximum collective dose arising from potential sites	Approach reasonable; the location of the site is not presented.	Maximum of assessments of collective dose for the 5 potential sites listed by DECC with reference to EDF applied; Hinkley Point, Sizewell, Heysham, Hartlepool, Dungeness [Ref. A2.17]
Discharges	Discharge assumptions	1 year's discharge	Appropriate	Similar approach.
	Effective release height	20 m	Consistent with individual dose calculation	Similar approach
Meteorology		Uniform wind rose	Appropriate	
		70% Category D	Considered to be typical of UK coastal site.	60% chosen as most conservative value for existing protential coastal sites (and consistent with individual assessment)
Receptor Points and pathways		Standard deposition, surface roughness assumptions	Consistent with individual assessment and standard practice	Similar approach
	Population and agricultural grids	UK, Europe and World truncated at 500 y. included in PC CREAM [Ref. A2.10].	Best approach currently available	Similar approach

Table A2.7: Summary and Review of EDF and AREVA Approach for Assessment of Collective Dose – Liquid Discharges to the Marine Environment

Section	Criteria	EDF and AREVA Approach	Comments on EDF and AREVA Approach	Independent Approach
Discharges	Marine compartment	North Sea/ North Sea West regional compartment No specific site assumed – but conservative choice for each marine box characteristic implied.	Inconsistent parameter assumptions.	Highest doses presented (Irish Sea South West (Hartlepool) characteristics.
Interpretation of results		Calculation of per caput dose and comparison with Joint Agencies' guidance on values [Ref. A1.18] < nanoSv trivial – all around 2 nSv. 16 manSv to the world population.	Reasonable approach	Similar approach adopted

Appendix 3 –Independent radiological assessment of discharges to atmosphere

Introduction

A3.1 According to information provided by EDF and AREVA, discharges of radioactive wastes to atmosphere from the UK EPR Generic Design Nuclear Plant are assumed to be made from a single release point which is the stack on the EPR reactor building. The methodology used to assess doses from the atmospheric releases from these release points is described in this Appendix.

A3.2 The radiological assessment was made on the basis of the maximum predicted discharges of the full list of radionuclides presented in the EDF and AREVA submissions [Ref. A3.1].

A3.3 This work is based on predicted discharges to atmosphere as presented by EDF and AREVA. The validity of these predictions has not been assessed.

Discharges to Atmosphere

A3.4 Details of the atmospheric discharge points on the UK EPR Generic Design Nuclear Plant are provided in Table A3.1 and predicted maximum levels of activity discharged are provided in Table A3.2. The main discharge point is assumed to be from a stack located on the UK EPR reactor building. According to EDF and AREVA information, the building will be of the order of 60 m high and the stack protrudes a few metres above the building. It is therefore assumed to be in the wake of the reactor building. For the purposes of this assessment, the stack has been assumed to have an effective stack height of 1/3rd of the building height (20 metres), in accordance with the approach outlined in NPRB-R157 [Ref. A3.2].

Receptor Points and Candidate Representative persons

A3.5 For the purposes of this assessment, candidates for the representative person affected by atmospheric discharges (CRP1) has been identified to be potential local residents living close to the proposed power plant. Generic habit data have been applied, on the basis of the Environment Agency Initial Radiological Assessment Methodology [Ref. A3.3] and NRPB-W41 [Ref. A3.4], to represent those members of the public likely to be the most exposed individuals to atmospheric discharges from the UK EPR nuclear power plant.

A3.6 On the basis of information provided by EDF and AREVA, the UK EPR nuclear power plant is assumed to be located at a coastal site. It is therefore assumed that commercial fishing is in operation, for fish and shellfish along the coast, where the liquid discharges from the site are made. Fishing families may also receive exposures from atmospheric discharges from locally derived terrestrial foods.

A3.7 The following candidate for representative person were chosen to reflect the residential, farming and working communities in the area closest to the UK EPR nuclear power plant.

- ***CRP1 Local residents.*** For the purposes of this assessment, it is assumed that families (adults, children (10 years) and infants (1 year)) living in the nearest habitation (assumed to be located at approximately 100 m from the discharge point), are exposed to atmospheric discharges, direct radiation and, to a lesser extent, to liquid discharges in the marine environment. It is assumed that members of this family spend most of their time at home, some of which is spent outside. They consume green vegetables, root vegetables and fruit from their garden or other local source (100 m from the discharge point) and milk and meat from local farms close to the site, whose livestock graze approximately 500 m from the discharge point. Some local fish and shellfish are also consumed. Generic habit data for people in this group were derived from NRPB-W41 [Ref. A3.4].

A3.8 Each age group in CRP1 was assumed to consume 2 terrestrial foods at critical rates, in accordance with the approach recommended where no site-specific information is available in guidance from the National Dose Assessment Working Group (NDAWG) [Ref. A3.5]. Generic assumptions regarding the proportion of time spent indoors and outdoors were assumed, from NRPB-W41 [Ref. A3.4]; higher than average outdoor occupancy rates for adults and children were considered appropriate for a farming family.

Exposure Pathways

A3.9 The exposure pathways considered were:

- internal exposure to radionuclides from ingestion of local fruit and vegetable produce (green vegetable and root vegetable), cow and sheep meat and cow milk;
- internal exposure via inhalation of radionuclides from the plume and secondary inhalation of radionuclides deposited on the ground and resuspended; and,
- external doses from exposure to the plume (‘cloudshine’) and beta and gamma radiation from radionuclides deposited on the ground (‘groundshine’).

A3.10 Assessment of exposure to direct radiation from the site was taken into account where appropriate (Appendix 7).

Modelling of Environmental Concentrations

A3.11 Air concentrations and deposition at 100 m (local residence) and 500 m (local farmland) from the site relevant to the assessment of exposure of candidates for representative person for gaseous discharges were assessed.

A3.12 The Gaussian plume atmospheric dispersion model, PLUME, in PC-CREAM 98 [Ref A3.6] was used to calculate air activity concentrations (dispersion factors) and ground deposition values for each radionuclide [Table A3.3]. A uniform wind rose was assumed and the average weather category for the Gaussian plume model was assumed to be 60% (category D). These assumptions have been chosen from those existing at potential sites that would be likely to give rise to the highest doses to CRP 1.

A3.13 For radionuclides discharged to atmosphere which deposit on the ground (that is all radionuclides except tritium and noble gases), a deposition velocity of 0.001 m/s was used to calculate the deposition rate with the exception of iodine where a deposition velocity of 0.01 m/s was used [Ref A3.7]. A washout coefficient of 10^{-4} s^{-1} was used to calculate wet deposition.

A3.14 Concentrations in terrestrial foodstuffs and animal products at the nearest allotments and gardens around residences (100 m) and farmland (500 m) were predicted from the air concentrations. For all nuclides, except tritium and carbon-14, food concentrations were derived using deposition velocity and food activity concentration per unit deposition rate factors. For tritium and carbon-14 food concentrations were calculated using factors which relate food activity concentration to unit air activity concentration [Ref A3.7]. The food activity concentration factors are shown in Table A3.4.

Habits Data

A3.15 Doses to candidates for the representative person were calculated using the predicted environmental concentrations and generic habits data for:

- food intakes
- occupancy of the environment at the nearest habitation and the nearest farm
- occupancy at the habitation (100 m from the discharge point)
- time spent indoors and outdoors
- breathing rates.

A3.16 The assessment used information derived from the Environment Agency's Initial Radiological Assessment Methodology [Ref. A3.3] and NRPB-W41 [Ref. A3.4]. The data used for the assessment of effective doses to adult, child and infant candidates for representative person for gaseous releases are provided in Table A3.5.

A3.17 Generic breathing rates were used throughout the assessment, these are presented in Table A3.6 [Ref. A3.4]. It was assumed that candidates for representative person for gaseous releases (CRP1) spent 90% of their time at their homes, but that the time spent indoors is assumed to vary with age group. Adults are assumed to spend 50% of their time indoors while children and infants are assumed to spend 80% and 90% of their time indoors respectively [Ref. 3.4].

A3.18 Generic shielding factors were used to modify the external doses for time spent indoors. A shielding factor of 0.1 was used for shielding from material deposited in the ground [Ref A3.7]. A shielding factor of 0.2 was used for shielding of external radiation from material in the plume [Ref A3.7].

Dose to the candidates for representative person (CRP1) for gaseous releases

A3.19 The generic habits data which were chosen were considered to provide a conservative estimate of the doses to CRP1 arising from atmospheric discharges from the UK EPR nuclear power plant.

A3.20 Doses to the infant, child and adult candidates for representative person were calculated using assessment systems based on PC CREAM 98 and customised for the UK EPR nuclear power plant.

A3.21 For internal exposure, inhalation and ingestion dose coefficients [Table A3.7] set out in the Euratom Basic Safety Standards Directive [Ref A3.8] and the predicted concentrations of radionuclides in the environment and foods have been used. For external exposure, cloudshine and groundshine factors have been used and were derived from in the updated version of FGR-12 [Ref A3.9], which is available on the US EPA web site (Table A3.8).

A3.22 The doses associated with the maximum annual radioactive atmospheric discharges predicted by EDF and AREVA [Ref. A3.1] were calculated from the dose per unit release data for each radionuclide using generic habits data.

A3.23 The contribution to dose from predicted marine discharges (see Appendix 4), are shown in Table A3.9. The doses to the candidates for representative person from gaseous discharges to atmosphere were found to be less than 10 μSv/y.

A3.24 A breakdown of the highest effective doses to CRP1 arising from the UK EPR nuclear power plant (infant), at the predicted discharges broken down by radionuclide and pathway is provided in Table A3.10.

A3.25 The dose from atmospheric discharges from the UK EPR nuclear power plant accounts for around 50% of the dose to the representative person from discharges (atmospheric and liquid). Individuals within this group would also receive a contribution from direct radiation, as discussed in Appendix 8.

References

A3.1 EDF and AREVA, UK EPR Pre-Construction Environmental Report, Chapter 11: Radiological Health Impact, Document No. UKEPR-0003-110-Issue 01 (2008).

A3.2 Jones, J A, The Fifth Report of the Working Group on Atmospheric Dispersion: Models to Allow for the Effects of Coastal Sites, Plume Rise and Buildings on Dispersion of Radionuclides and Guidance on the Value of Deposition Velocity and Washout Coefficients, NRPB-R157, NRPB, Chilton, 1983.

A3.3 Environment Agency, Initial Radiological Assessment Methodology (Parts 1 and 2), Science Report SC030162/SR1 (2006)

A3.4 Smith, K R and Jones A L, Generalised Habit Data for Radiological Assessments, NRPB-W41, NRPB, Chilton (2003).

A3.5 NDAWG, Acquisition and Use of Habits Data for Prospective Assessments, NDAWG/2/2009, http://www.ndawg.org/NDAWGpapers.htm

A3.6 Mayall A, Cabianca T, Attwood C, Fayers CA, Smith JG, Penfold J, Steadman D, Martin G, Morris TP and Simmonds JR. PC CREAM-97 (PC CREAM-98 code update) NRPB, Chilton NRPB-SR-296 (EUR 17791) (1997).

A3.7 European Commission (1995). Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment. Radiation Protection 72. EUR 15760 EN.

A3.8 Council Directive 96/29 Euratom of 13 May 1996, Laying Down Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers Arising from Ionising Radiation. Official Journal of the European Communities, L159, Volume 39, 29 June 1996.

A3.9 EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081(Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

Table A3.1 Atmospheric Discharge Points from the UK EPR Nuclear Power Plant

Stack Name	Discharge Position	Effective Release Height (metres)
Main Plant Stack	Reactor Building	20

Table A3.2 Predicted Discharges used in the Assessment for Aerial Discharges to Atmosphere

Radionuclide	Atmospheric Discharges (TBq/y)
Ar-41	6.53E-01
C-14	9.00E-01
Co-58	8.67E-05
Co-60	1.02E-04
Cs-134	7.96E-05
Cs-137	7.14E-05
H-3	3.00E+00
I-131	1.82E-04
I-133	2.18E-04
Kr-85	3.13E+00
Xe-131m	6.75E-02
Xe-133	1.42E+01
Xe-135	4.46E+00

Table A3.3 Air Concentration Factors and Ground Deposition

Discharge Point	Nuclide	Air concentration Bq/m^3 per TBq/y		Resuspended Air conc at home Bq s/m^3 per Bq/m^2/s for 1y	Ground deposition Bq/m^2/s per TBq/y	
		at home	At farm		at home	at farm
Stack 1	Ar-41*	5.39E-02	3.81E-02		0.00E+00	0.00E+00
	C-14	5.39E-02	3.81E-02		0.00E+00	0.00E+00
	Co-58	5.39E-02	3.81E-02	1.33E+07	7.61E-05	5.07E-05
	Co-60	5.39E-02	3.81E-02	2.40E+07	7.61E-05	5.07E-05
	Cs-134	5.39E-02	3.81E-02	2.10E+07	7.61E-05	5.07E-05
	Cs-137	5.39E-02	3.81E-02	2.92E+07	7.61E-05	5.07E-05
	H-3	5.39E-02	3.81E-02		0.00E+00	0.00E+00
	I-131	5.39E-02	3.81E-02	6.40E+06	5.39E-04	4.12E-04
	I-133	5.39E-02	3.81E-02	1.02E+06	5.39E-04	4.12E-04
	Kr-85*	5.39E-02	3.81E-02		0.00E+00	0.00E+00
	Xe-131m*	5.39E-02	3.81E-02		0.00E+00	0.00E+00
	Xe-133*	5.39E-02	3.81E-02		0.00E+00	0.00E+00
	Xe-135*	5.39E-02	3.81E-02		0.00E+00	0.00E+00

* Noble gases where no deposition to ground occurs

Table A3.4 Terrestrial Food Concentration Factors

Radionuclide	Activity Concentrations in Food per Unit Deposition Rate (Bq/kg per Bq/m^2/s per year)							
	Green Veg	Root Veg	Fruit	Milk	Cow Meat	Cow Offal	Sheep Meat	Sheep Offal
C-14	2.67E+02	5.33E+02	5.33E+02	2.67E+02	8.00E+02	8.00E+02	8.00E+02	8.00E+02
Co-58	9.16E+04	2.56E+02	1.59E+04	5.12E+04	6.93E+03	6.93E+05	1.16E+04	1.16E+06
Co-60	1.15E+05	5.12E+03	4.42E+04	7.08E+04	2.92E+04	2.92E+06	4.34E+04	4.35E+06
Cs-134	1.31E+05	1.19E+05	7.24E+04	1.59E+05	7.93E+05	7.93E+05	1.54E+06	1.54E+06
Cs-137	1.45E+05	1.35E+05	7.52E+04	1.79E+05	9.14E+05	9.14E+05	1.91E+06	1.91E+06
H-3	1.13E+02	1.00E+02	1.00E+02	1.13E+02	8.75E+01	8.75E+01	8.75E+01	8.75E+01
I-131	4.14E+04	8.63E+03	3.10E+04	5.82E+04	2.47E+04	2.47E+04	3.17E+04	3.17E+04
I-133	6.19E+03	4.68E+01	5.36E+03	3.79E+03	1.11E+03	1.11E+03	6.79E+02	6.79E+02

[a] Values for tritium and carbon-14 are quoted in Bq/kg per Bq/m^3.

Table A3.5 Habits Data Profiles for CRP1*

Age Group	Profile Number	Profile Name	Consumption (kg/y or l/y)											Handling and Occupancy (h/y)			
			Green veg consumption	Potatoes & root veg	Domestic Fruit	Milk	Cattle Meat	Cow Offal	Sheep Meat	Sheep Offal	Sea Fish	Crustacea	Mollusca	Handling Fishing Gear	Over intertidal mud[a]	Internal occupancy	External occupancy
Adult	1	*All critical*	*80.0*	*130.0*	*75.0*	*240.0*	*45.0*	*10.0*	*25.0*	*10.0*					*300*	*4080*	*4380*
	2	*All average*	*35.0*	*60.0*	*20.0*	*95.0*	*15.0*	*2.8*	*8.0*	*2.8*	*15.0*	*1.8*	*1.8*	*300*	*300*	*4080*	*4380*
	3	**Top two approach**	**35.0**	**130.0**	**20.0**	**240.0**	**15.0**	**2.8**	**8.0**	**2.8**	9.5	0.3	0.3	300	300	4080	4380
10 y Child	1	*All critical*	*35.0*	*95.0*	*50.0*	*240.0*	*30.0*	*5.0*	*10.0*	*5.0*					*300*	*7008*	*1752*
	2	*All average*	*15.0*	*50.0*	*15.0*	*110.0*	*15.0*	*1.5*	*4.0*	*1.5*	*6.0*	*1.3*	*1.3*		*300*	*7008*	*1752*
	3	**Top two approach**	**15.0**	**95.0**	**15.0**	**240.0**	**15.0**	**1.5**	**4.0**	**1.5**	4.0	0.1	0.1		300	7008	1752
1y infant	1	*All critical*	*15.0*	*45.0*	*35.0*	*320.0*	*10.0*	*2.8*	*3.0*	*2.8*					*30*	*7008*	*1752*
	2	*All average*	*5.0*	*15.0*	*9.0*	*130.0*	*3.0*	*0.5*	*0.8*	*0.5*	*3.5*	*0.0*	*0.0*		*30*	*7008*	*1752*
	3	**Top two approach**	**5.0**	**15.0**	**9.0**	**320.0**	**3.0**	**0.5**	**0.8**	**0.5**	2.0	0.0	0.0		30	7008	1752

[a] – Time spent over intertidal areas was summed together to give a total occupancy over intertidal areas. It is number that is used in the assessment

* The values in italics are included in the assessment for calculation purposes only. These values are included in this table for completeness and ease of reference; they do not represent profiles for candidates for the representative person.

Table A3.6 Other Habit Data for Candidates for the Representative Person

Habit data	Adult	Child	Infant	Units
Breathing rate per y	8100	5600	1900	m3/y
Breathing rate per h	0.92466	0.639	0.217	m3/h
default fraction of time indoors	0.5	0.8	0.9	-
Default Occupancy	0.9	0.9	0.9	-
Inadvertent ingestion of seawater	0.5	0.5	0.2	l/y
Inadvertent ingestion of sediment	8.30E-03	0.018	0.044	kg/y
Default beach occupancy	300	300	30	h/y

Table A3.7 Internal Committed Dose Rate Factors for Exposure via Inhalation and Ingestion

Radionuclide	ICRP Lung Class	Inhalation Sv/Bq			Ingestion (Sv/Bq)		
		A	C	I	A	C	I
Ar-41	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	V	2.00E-09	2.80E-09	6.60E-09	5.80E-10	8.00E-10	1.60E-09
Co-58	M	1.60E-09	2.40E-09	6.50E-09	7.40E-10	1.70E-09	4.40E-09
Co-60	M	1.00E-08	1.50E-08	3.40E-08	3.40E-10	1.10E-08	2.70E-08
Cs-134	F	6.60E-09	5.30E-09	7.30E-09	1.90E-08	1.40E-08	1.60E-08
Cs-137	F	4.60E-09	3.70E-09	5.40E-09	1.30E-08	1.00E-08	1.20E-08
H-3	V	1.80E-11	2.30E-11	4.80E-11	1.80E-11	2.30E-11	4.80E-11
I-131	F	7.40E-09	1.90E-08	7.20E-08	2.20E-08	5.20E-08	1.80E-07
I-133	F	1.50E-09	3.80E-09	1.80E-08	4.30E-09	1.00E-08	4.40E-08
Kr-85	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-131m	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	G	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

A = Adult, C = Child, I = Infant. Note – Inhalation factors for noble gases are zero and are not presented

Table A3.8 External Effective Dose Rate Factors for Exposure to Cloudshine and Groundshine

Radionuclide	Cloudshine (Sv/h per Bq/m^3)	Groundshine (Sv/h per Bq/m^2/s)
Ar-41	2.34E-10	4.32E-12
C-14	9.40E-15	5.80E-17
Co-58	1.71E-10	3.42E-12
Co-60	4.54E-10	8.46E-12
Cs-134	2.73E-10	5.47E-12
Cs-137	9.93E-11	2.05E-12
H-3	1.19E-15	0.00E+00
I-131	6.55E-11	1.35E-12
I-133	1.06E-10	2.15E-12
Kr-85	4.28E-13	9.50E-15
Xe-131m	1.40E-12	7.42E-14
Xe-133	5.62E-12	1.66E-13
Xe-135	4.28E-11	8.71E-13

All values derived from updated version of Ref [A2.9]

Table A3.9 Doses to the candidates for the Representative Person (CRP1) from Gaseous Releases to Atmospheric at Predicted levels plus contribution from liquid discharges (µSv/y)

Habits Profile	Age	Dose (µSv/y)		
		Atmospheric Discharges	Marine Discharges	Total
CRP1 - local resident (high rate consumers of local terrestrial foods)	Adult	5.30	2.01	7.31
	Child	5.73	1.13	6.85
	Infant	8.46	1.10	9.56

Table A3.10 Dose Breakdown for the Candidate for the Representative Person (Infant) most exposed to Atmospheric Discharges at Predicted levels[1] (µSv/y)

Radionuclide	Terrestrial Pathways											
	Inhalation	Cloud Shine	Ground shine	Green vegetables (home/garden)	Root vegetables (home/garden)	Fruit (home/garden)	Milk (farm)	Cow Meat (farm)	Cow Liver (farm)	Sheep Meat (farm)	Sheep Liver	Total Terrestrial Pathways
Ar-41	0.00E+00	2.60E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.025976
C-14	6.08E-01	1.23E-07	0.00E+00	1.04E-01	1.86E+00	3.72E-01	4.68E+00	1.32E-01	2.19E-02	3.51E-02	2.19E-02	7.838295
Co-58	5.78E-05	2.53E-06	5.53E-11	1.33E-05	3.34E-07	4.15E-06	3.17E-04	4.02E-07	6.71E-06	1.80E-07	1.12E-05	0.000414
Co-60	3.56E-04	7.87E-06	1.61E-10	1.21E-04	4.83E-05	8.34E-05	3.17E-03	1.22E-05	2.04E-04	4.85E-06	3.04E-04	0.004306
Cs-134	5.96E-05	3.69E-06	8.13E-11	6.35E-05	5.19E-04	6.32E-05	3.29E-03	1.54E-04	2.56E-05	7.96E-05	4.98E-05	0.004305
Cs-137	3.95E-05	3.38E-10	1.37E-14	4.73E-05	3.96E-04	4.41E-05	2.49E-03	1.19E-04	1.99E-05	6.64E-05	4.15E-05	0.003264
H-3	1.47E-02	6.08E-07	0.00E+00	4.39E-03	3.49E-02	6.99E-03	1.98E-01	1.44E-03	2.40E-04	3.84E-04	2.40E-04	0.261491
I-131	1.34E-03	2.03E-06	3.26E-10	3.66E-03	6.86E-03	4.93E-03	2.52E-01	1.00E-03	1.67E-04	3.42E-04	2.14E-04	0.270021
I-133	4.02E-04	3.92E-06	6.19E-10	1.60E-04	1.09E-05	2.49E-04	4.80E-03	1.32E-05	2.19E-06	2.15E-06	1.34E-06	0.005641
Kr-85	0.00E+00	2.28E-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	0.000228
Xe-131m	0.00E+00	1.61E-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	1.61E-05
Xe-133	0.00E+00	1.36E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.013557
Xe-135	0.00E+00	3.25E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.032481
Grand Total	**6.25E-01**	**7.23E-02**	**1.24E-09**	**1.12E-01**	**1.90E+00**	**3.85E-01**	**5.15E+00**	**1.34E-01**	**2.26E-02**	**3.59E-02**	**2.28E-02**	**8.459996**

[1] No contribution from marine discharges.

Appendix 4 –Independent radiological assessment of liquid discharges

Introduction

A4.1 In accordance with information provided by EDF and AREVA, the UK EPR Generic Design is assumed to be located at a coastal site and to discharge liquid radioactive wastes into the coastal environment [Ref A4.1]. The methodology used to assess doses from the maximum liquid radioactive discharges from a coastally located UK EPR nuclear power plant is described in this Appendix.

A4.2 The assessment is based on maximum annual radioactive discharges to the marine environment, as presented by EDF and AREVA. The validity of these predictions has not been assessed.

Radioactive Liquid Discharges to the Marine Environment

A4.3 According to information presented by EDF and AREVA, the UK EPR nuclear power plant would discharge radioactive liquids offshore from a location close to the site into the marine environment [Ref. A4.1]. The maximum annual activity released from all sources are presented in the EDF and AREVA submission [Ref. A4.1]. The values on which this assessment is based are given detailed in Table A4.1.

Receptor Points and Candidates for Representative Person

A4.4 Assumptions about the pattern of coastal land use and commercial and leisure activities around the site were based on generic assumptions, derived from the Environment Agency Initial Radiological Assessment Methodology [Ref. A4.2] and NRPB-W41 [Ref. A4.3], to represent candidates for representative person for exposure to liquid discharges from the UK EPR nuclear power plant.

A4.5 In accordance with the generic site information provided by EDF and AREVA [Ref. A4.1], it has been assumed that there would be commercial fishing in the vicinity of the UK EPR nuclear power plant such that exposure pathways associated with fisheries and marine food consumption should be assessed.

A4.6 The following candidates for representative person (CRP2) have been chosen to reflect the fishing communities who could be potentially affected by liquid discharges from an UK EPR nuclear power plant located at the coast and discharging into the coastal environment:

- ***CRP2 Fisherman and family.*** For the purposes of this assessment, it has been assumed that the fishermen and their families (adults, children (10 years) and infants (1 year)) are exposed to liquid discharges from the site by spending time on the intertidal sediments in the area and consuming locally caught fish and shellfish (crustaceans and molluscs). Doses from atmospheric discharges from the UK EPR nuclear power plant were also assessed for individuals in this group via the consumption of some local produced terrestrial foodstuffs.

A4.7 Doses to the candidates for representative person most exposed to gaseous discharge to atmosphere (CRP1) were assessed as described in Appendix 3.

Exposure Pathways

A4.8 The exposure pathways considered were:

- internal exposure to radionuclides from ingestion of sea fish and marine shellfish (crustaceans and molluscs) caught from the local coastal waters;
- external doses from exposure to radionuclides incorporated into coastal sediment; and,
- Other exposure pathways such as external exposure from handling fishing gear and inhalation of sea spray, inadvertent ingestion of sediment and inadvertent ingestion of seawater.

Modelling of Environmental Concentrations

A4.9 The assessment of environmental concentrations per unit release rate in the local and regional coastal area has been performed using the PC DORIS Model, which is part of the PC CREAM software suite of radiological assessment models [Ref A4.4].

A4.10 Activity concentrations per unit release rate of radionuclides in filtered seawater (Bq/l per TBq/y), unfiltered seawater (Bq/l per TBq/y) and marine sediment (Bq/kg per TBq/y) have been predicted using PC DORIS assuming continuous discharges for a period of 50 years.

A4.11 PC DORIS calculates the activity concentration values in local coastal waters, ('Local Box'). For this assessment, the 'North Sea Central' Local Box has been chosen. The pre-defined characteristics for this box have been used [Ref A4.5], and are shown in Table A4.2. This marine compartment has been chosen on the basis that it has the lowest volumetric exchange rate for potential coastal UK nuclear sites and therefore is unlikely to provide an under-estimate of the doses to CRP 2. The sediment concentration factors used in PC DORIS for the calculation of the environmental concentrations are shown in Table A4.3. The environmental activity concentrations per unit release rate (per Bq/y) for the North Sea Central Local Box are shown in Table A4.4.

A4.12 Concentration factors for sea fish, marine crustacea and marine molluscs are shown in Table A4.5. The concentration factors and the filtered seawater activity concentration per unit release rate factors have been used to calculate the local sea fish, and shellfish activity concentration per unit release rate values [Table A4.5].

A4.13 The internal dose rates per unit concentration arising from internal exposure to radionuclides through ingestion of foodstuffs or inhalation are given in Table A4.7 [Ref A4.6].

A4.14 External effective dose rates per unit concentration arising from exposure to radionuclides from occupancy on marine sediment (Sv/h per Bq/kg) have been derived from Reference A4.7 for all radionuclides. These data are based on a semi-infinite plane of contaminated material. In this case, it is appropriate to apply a modifying factor of 0.5 [Ref A4.7] for exposure to radionuclides in marine sediment to take account of the fact that the beach is not a semi-infinite source. A sediment density of 1600 kg/m^3 was assumed in the derivation of the values as recommended in Reference A4.7. The external effective dose rate factors used in the assessment are provided in Table A4.8.

A4.15 The inadvertent ingestion of sediment and seawater during beach activities has been included in the assessment. Critical rates of ingestion have been used [Ref A4.3]. The doses have been calculated by determining the radionuclide intake from the appropriate environmental concentration and the level of intake. The radionuclide intake has been multiplied by the ingestion dose coefficient [Ref A4.6] to determine the doses.

A4.16 The inhalation of sea-spray has also been taken into account in the assessment. PC CREAM [Ref. 4.4] has been used to determine sea-spray concentrations. This output has been used to calculate inhalation doses based on the appropriate age group inhalation rates and occupancy over the inter-tidal sediments.

A4.17 External skin equivalent dose rates have also been calculated, using the external beta skin dose rate factors (Sv/h per Bq/cm^2) [Ref A4.8]. The exposure pathway is handling fishing gear, which had come into contact with marine sediment incorporating radionuclides. The majority of skin dose arises from radionuclides emitting beta radiation. Beta skin dose rates have been calculated using the simple Hunt model [Ref A4.8].

Habits Data

A4.18 Doses to the candidates for the representative person have been calculated using the predicted environmental and seafood concentrations and habits data, including generic information concerning seafood intakes and occupancy of the coastal environment in the UK.

A4.19 The high rate generic intake rates for marine fish, crustaceans and molluscs presented in NRPB-W41 [Ref. A4.3] have been used to represent the habits of CRP 2. Beach occupancy, inhalation rates and inadvertent ingestion rates have also been derived from this source. Adult candidates for the representative person have been assumed to spend their working life (2000 hours per year) on inter-tidal sediments and handling fishing nets. Beach occupancy rates for other age groups have been assumed to be based on leisure activities (300 and 30 hours per year for children and infants respectively). Only adults have been assumed to handle fishing gear.

A4.20 Habits data applied for CRP2 are presented in Table A4.9.

A4.21 It has been assumed that all occupancy and all seafood consumption is associated with the local marine environment (North Sea Central compartment).

Doses to the Candidates for the Representative person

A4.22 Effective doses to the infant, child and adult candidates for the representative person CRP2 have been calculated using ingestion and inhalation dose coefficients from the Euratom Basic Safety Standards Directive [Ref A4.6], generic habits data representative of fishing communities in the UK, predicted dose rate data and predicted concentrations of radionuclides in foods and the environment. Doses to CRP2 from liquid discharges, plus the contribution from predicted atmospheric discharges are shown in Table A4.10.

A4.23 A breakdown of the doses to candidates for the representative person arising from liquid discharges by radionuclide and pathway to the fisherman at the predicted levels is provided in Table A4.11. The majority of the dose is due to the intake of carbon-14 in fish.

References

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A4.3 Smith, K R and Jones A L, Generalised Habit Data for Radiological Assessments, NRPB-W41, NRPB, Chilton (2003).

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A4.5 Simmonds. J.R., Lawson, G. and Mayall, A., Methodology For Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment. Radiation Protection 72, Report EUR 15760, 1995.

A4.6 Council Directive 96/29 Euratom of 13 May 1996, Laying Down Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers Arising from Ionising Radiation. Official Journal of the European Communities, L159, Volume 39, 29 June 1996.

A4.7 EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081 (Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

A4.8 Hunt G, Simple models for prediction of external radiation exposure from aquatic pathways, 1984, Radiation Protection Dosimetry Vol. 8 No. 4 p 215-224

Table A4.1 Predicted UK EPR Nuclear Power Plant Discharges Assumed in the Assessment for Liquid Discharges to Sea

Radionuclide	Predicted Marine Discharges (TBq/y)
Ag-110m	5.70E-04
C-14	9.50E-02
Co-58	2.07E-03
Co-60	3.00E-03
Cr-51	6.00E-05
Cs-134	5.60E-04
Cs-137	9.45E-04
H-3	7.50E+01
I-131	5.00E-05
Mn-54	2.70E-04
Ni-63	9.60E-04
Sb-124	4.90E-04
Sb-125	8.15E-04
Te-123m	2.60E-04

Table A4.2 North Sea Central Local Box Parameters

Parameter	Value	Source of data/Comments
Release rate (TBq/y)	1.00E+00	User defined.
Volume (m^3)	2.00E+08	Default value from RP-72 [Table A4.5, Ref A4.5]
Depth (m)	10	
Volumetric Exchange Rate (with North Sea central and North Sea South East regional compartment) (m^3/y)	4.0E+9	
Suspended Sediment Load (t/m^3)	2.00E-04	
Sedimentation Rate (t/m^3/y)	1.00-E05	
Sediment density (t/m^3)	2.60	Default value from RP-72 [Table A4.7 Ref A4.5]
Bioturbation Rate (m^2/y)	3.60-E05	
Diffusion Rate (m^2/y)	3.15-E02	

Table A4.3 Marine Sediment Concentration Factors

Radionuclide	Marine Sediment Concentration Factor[a] (Bq/t per Bq/m^3)
Ag-110m	1.00E+03
C-14	2.00E+03
Co-58	2.00E+05
Co-60	2.00E+05
Cr-51	5.00E+04
Cs-134	3.00E+03
Cs-137	3.00E+03
H-3	1.00E+00
I-131	2.00E+01
Mn-54	2.00E+05
Ni-63	1.00E+05
Sb-124	1.00E+03
Sb-125	1.00E+03
Te-123m	1.00E+03

[a] Default values from PC DORIS input file.

Table A4.4 Environmental Concentrations per Unit Release Rate to the North Sea Central Local Box

Radionuclide	North Sea South West Local Box			
	Unfiltered Sea water (Bq/l per TBq/y)	Filtered Seawater (Bq/l per TBq/y)	Seaspray (Bq/m3 per TBq/y)	Sea Bed Sediment (Bq/kg per TBq/y)
Ag-110m	2.38E-01	1.98E-01	2.10E-14	2.47E-01
C-14	2.50E-01	1.79E-01	6.00E-17	1.36E+01
Co-58	2.12E-01	5.16E-03	3.00E-13	3.69E-01
Co-60	2.48E-01	6.05E-03	2.00E-13	1.02E+01
Cr-51	1.71E-01	1.56E-02	2.70E-14	1.09E-01
Cs-134	2.46E-01	1.54E-01	6.40E-15	1.65E+00
Cs-137	2.50E-01	1.56E-01	2.00E-14	1.19E+01
H-3	2.49E-01	2.49E-01		1.61E-01
I-131	9.71E-02	9.67E-02	5.00E-15	6.21E-04
Mn-54	2.40E-01	5.85E-03	2.60E-14	1.81E+00
Ni-63	2.50E-01	1.19E-02	4.60E-13	4.13E+01
Sb-124	2.07E-01	1.72E-01		5.26E-02
Sb-125	2.47E-01	2.06E-01		9.64E-01
Te-123m	2.26E-01	1.88E-01		1.14E-01

Table A4.5 Fish and Shellfish Concentration Factors

Radionuclide	Concentration Factors (Bq/kg per Bq/l)[a]		
	Sea fish	Crustacea	Mollusca
Ag-110m	5.00E+02	5.00E+03	1.00E+04
C-14	2.00E+04	2.00E+04	2.00E+04
Co-58	1.00E+03	5.00E+03	5.00E+03
Co-60	1.00E+03	5.00E+03	5.00E+03
Cr-51	2.00E+02	5.00E+02	8.00E+02
Cs-134	1.00E+02	3.00E+01	3.00E+01
Cs-137	1.00E+02	3.00E+01	3.00E+01
H-3	1.00E+00	1.00E+00	1.00E+00
I-131	1.00E+01	1.00E+01	1.00E+01
Mn-54	4.00E+02	5.00E+02	5.00E+03
Ni-63	1.00E+03	1.00E+03	2.00E+03
Sb-124	4.00E+02	4.00E+02	2.00E+02
Sb-125	4.00E+02	4.00E+02	2.00E+02
Te-123m	1.00E+03	1.00E+03	1.00E+03

[a] Default values taken from PC CREAM and are relative to filtered seawater.

Table A4.6 Fish and Shellfish Concentrations per Unit Release to the North Sea Central Local Box

Radionuclide	Fish and Shellfish Concentrations per Unit Release (Bq/kg per TBq/y)[a]		
	Sea fish	Crustacea	Mollusca
Ag-110m	9.90E+01	9.90E+02	1.98E+03
C-14	3.58E+03	3.58E+03	3.58E+03
Co-58	5.16E+00	2.58E+01	2.58E+01
Co-60	6.05E+00	3.03E+01	3.03E+01
Cr-51	3.12E+00	7.80E+00	1.25E+01
Cs-134	1.54E+01	4.62E+00	4.62E+00
Cs-137	1.56E+01	4.68E+00	4.68E+00
H-3	2.49E-01	2.49E-01	2.49E-01
I-131	9.67E-01	9.67E-01	9.67E-01
Mn-54	2.34E+00	2.93E+00	2.93E+01
Ni-63	1.19E+01	1.19E+01	2.38E+01
Sb-124	6.88E+01	6.88E+01	3.44E+01
Sb-125	8.24E+01	8.24E+01	4.12E+01
Te-123m	1.88E+02	1.88E+02	1.88E+02

[a] Calculated using data in Table A4.4 and Table A4.5.

Table A4.7 Internal Committed Dose Rate Factors for Expose via Inhalation and Ingestion

Radionuclide	ICRP Lung Class	Inhalation Sv/Bq			Ingestion (Sv/Bq)		
		A	C	I	A	C	I
Ag-110m	M	7.60E-09	1.20E-08	2.80E-08	2.80E-09	5.20E-09	1.40E-08
C-14	V	2.00E-09	2.80E-09	6.60E-09	5.80E-10	8.00E-10	1.60E-09
Co-58	M	1.60E-09	2.40E-09	6.50E-09	7.40E-10	1.70E-09	4.40E-09
Co-60	M	1.00E-08	1.50E-08	3.40E-08	3.40E-10	1.10E-08	2.70E-08
Cr-51	S	3.70E-11	6.60E-11	2.10E-10	3.80E-11	7.80E-11	2.30E-10
Cs-134	F	6.60E-09	5.30E-09	7.30E-09	1.90E-08	1.40E-08	1.60E-08
Cs-137	F	4.60E-09	3.70E-09	5.40E-09	1.30E-08	1.00E-08	1.20E-08
H-3	V	1.80E-11	2.30E-11	4.80E-11	1.80E-11	2.30E-11	4.80E-11
I-131	F	7.40E-09	1.90E-08	7.20E-08	2.20E-08	5.20E-08	1.80E-07
Mn-54	M	1.50E-09	2.40E-09	6.20E-09	7.10E-10	1.30E-09	3.10E-09
Ni-63	M	4.80E-10	7.00E-10	1.90E-09	1.50E-10	2.80E-10	8.40E-10
Sb-124	M	6.40E-09	9.60E-09	2.40E-08	2.50E-09	5.20E-09	1.60E-08
Sb-125	M	4.80E-09	6.80E-09	1.60E-08	1.10E-09	2.10E-09	6.10E-09
Te-123m	M	4.00E-09	5.70E-09	1.30E-08	1.40E-09	2.80E-09	8.80E-09

A = Adult, C = Child, I = Infant

Table A4.8 External Effective Dose Rate Factors for Occupancy Over Marine Sediment

Radionuclide	External Effective Dose Rate Factor for Exposure over Sediment[b,c]		Gamma fishing gear	Beta skin dose from handling gear
	[a]Sv/s per Bq/m^3	uSv/h per TBq/y	uSv/h per TBq/y	uSv/h per TBq/y
Ag-110m	9.19E-17	6.54E-05	1.72E-06	0.00E+00
C-14	7.20E-23	2.82E-09	0.00E+00	0.00E+00
Co-58	3.19E-17	3.39E-05	9.13E-07	0.00E+00
Co-60	8.68E-17	2.55E-03	6.46E-05	0.00E+00
Cr-51	9.34E-19	2.93E-07	8.73E-09	0.00E+00
Cs-134	5.07E-17	2.41E-04	6.48E-06	2.32E-05
Cs-137	4.02E-21	1.38E-07	1.70E-05	2.56E-04
H-3	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-131	1.16E-17	2.07E-08	6.01E-10	1.03E-08
Mn-54	2.76E-17	1.44E-04	3.83E-06	0.00E+00
Ni-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-124	6.26E-17	9.48E-06	2.43E-07	1.76E-06
Sb-125	1.31E-17	3.64E-05	1.05E-06	8.33E-06
Te-123m	3.36E-18	1.10E-06	4.28E-08	0.00E+00

[a] Derived from data in FGR-12 [Ref A3.7]
[b] Assuming a sediment density of 1600 kg/m^3,
[C] After applying a modifying factor of 0.5 to take account for time spent on the shoreline or top of beach

Table A4.9 Habit Data Profiles for the Candidates for the Representative Person for Liquid Discharges to the Marine Environment

	Terrestrial Food Consumption Rates (kg/y or l/y)								Marine Food Consumption Rates (kg/y)			Handling and Occupancy (h/y)				
Age Group	Green veg total	Root veg total	Fruit total	Milk	Cow meat*	Cow liver*	Sheep meat	Sheep Liver	Fish (sea)	Crustaceans	Molluscs	Handling fishing gear	Handling sediment	Intertidal occupancy over mud	External occupancy	Internal occupancy (used)
Adult	35.0	60.0	20.0	95.0	15.0	2.8	8.0	2.8	100.0	20.0	20.0	2000	2000	2000	876	2380.0
Child	15.0	50.0	15.0	110.0	15.0	1.5	4.0	1.5	20.0	5.0	5.0			300	876	7008.0
Infant	5.0	15.0	9.0	130.0	3.0	0.5	0.8	0.5	5.0	0.0	0.0			30	876	7008.0

Table A4.10 Doses to the Candidates for the Representative Person (CRP2, from Fisherman Family) for Liquid Discharges at Predicted levels and Contribution From Atmospheric Discharges (µSv/y)

Habits Profile	Age	Dose (µSv/y)		
		Atmospheric Discharges	Marine Discharges	Total
CRP2 - local fisherman (high marine exposure)	Adult	3.24	27.87	31.11
	Child	3.75	8.26	12.02
	Infant	4.14	2.74	6.88

Table A4.11 Dose by Radionuclide and Pathway for Adult Candidates for the Representative Person based on Predicted Liquid Discharges to the Marine Environment from the UK EPR Nuclear Power Plant and Generic Habits Data (μSv/y)

Radionuclide	Marine Pathways Dose (μSv/y)					
	Sum of Ingestion of Fish	Sum of Ingestion of Crustaceans	Sum of Ingestion of Molluscs	Sum of External sediments	Sum of Other marine pathways	Total Marine Pathways
C-14	1.97E+01	3.95E+00	3.95E+00	5.36E-07	1.31E-05	**2.76E+01**
Co-58	7.90E-04	7.90E-04	7.90E-04	1.40E-04	3.95E-06	**2.52E-03**
Co-60	6.17E-04	6.17E-04	6.17E-04	1.53E-02	3.88E-04	**1.75E-02**
Cr-51	7.11E-07	3.56E-07	5.69E-07	3.52E-08	1.24E-09	**1.67E-06**
Cs-134	1.64E-02	9.83E-04	9.83E-04	2.70E-04	3.47E-05	**1.87E-02**
Cs-137	1.92E-02	1.15E-03	1.15E-03	2.60E-07	5.19E-04	**2.20E-02**
H-3	3.36E-02	6.72E-03	6.72E-03	0.00E+00	1.70E-04	**4.72E-02**
I-131	1.06E-04	2.13E-05	2.13E-05	2.07E-09	5.45E-08	**1.49E-04**
Mn-54	4.49E-05	1.12E-05	1.12E-04	7.77E-05	2.10E-06	**2.48E-04**
Ni-63	1.71E-04	3.43E-05	6.85E-05	0.00E+00	6.74E-08	**2.74E-04**
Sb-124	8.43E-03	1.69E-03	8.43E-04	9.29E-06	2.09E-06	**1.10E-02**
Sb-125	7.39E-03	1.48E-03	7.39E-04	5.93E-05	1.54E-05	**9.68E-03**
Te-123m	6.84E-03	1.37E-03	1.37E-03	5.74E-07	6.37E-08	**9.58E-03**
Total	1.98E+01	3.99E+00	4.02E+00	1.59E-02	1.15E-03	**2.79E+01**

Appendix 5 – Independent radiological assessment of collective doses

A5.1 Collective dose provides an assessment of the radiation exposure in a population. It is the time integral of doses across a population. It is dependent on how far the discharged radionuclides spread with time; the concentrations in particular in foods; the radioactive half life; the size of the populations exposed and time integration period. It has been agreed that the collective doses to the populations of the UK, Europe and the World, truncated at 500 years, should be estimated for authorisation purposes [Ref. A5.1]. An estimate of collective dose has also been identified as a requirement in the Environment Agency's Process and Information Document for Generic Assessment of Candidate Nuclear Power Plants [Ref. A5.2]

Calculation of Collective Doses

A5.2 Collective doses have been calculated for the UK, European and World populations, truncated at 500 years, in accordance with guidance identified above and from Defra [Ref A5.3] for discharges to atmosphere and from discharges to the marine environment. The assessment was made using PC CREAM [Ref. A5.4].

A5.3 The annual maximum discharges to atmosphere and to the marine environment shown in Table 1 and Table 3 were used in the calculations. Collective doses are dependent on the release point. The independent assessment was made at 5 UK coastal nuclear sites (Dungeness, Hartlepool, Heysham, Hinkley Point and Sizewell). A range of collective doses arising from atmospheric and liquid discharges for representative annual discharges and annual limit discharges were calculated. The locations that gives the highest collective doses were identified and presented in this report. This is the same approach as was adopted by the EDF.

A5.4 Atmospheric discharges from reactors located at Hinkley Point and Sizewell would give rise to the highest collective doses to UK and EU populations respectively. The collective dose to the UK population from an UK EPR at Hinkley Point is only marginally higher than that at Sizewell discharges, whilst the Sizewell EU dose is higher than that due to Hinkley point by a greater margin. The data presented above are therefore based on the assumption that the UK EPR is located at Sizewell (the most conservative case).

A5.5 Marine discharges from reactors located at Heysham and Sizewell would give rise to the highest collective doses to UK and EU populations respectively. The collective doses from each of these sites are similar. The assessed collective doses for atmospheric discharges at Sizewell are higher so for consistency it is assumed that UK EPR is located at Sizewell for liquid discharges.

A5.6 The highest collective doses arising from atmospheric and liquid discharges are presented in Tables A5.1 (to atmosphere) and A5.2 (to the marine environment), respectively.

Assessed Collective Doses

A5.7 A summary of collective doses are given in Table A5.3.

A5.8 The collective doses from the maximum annual atmospheric discharges from an UK EPR nuclear power plant have been estimated to be: to the UK 0.09 manSv/y, to Europe 1.1 manSv/y, and to the world 15.8 manSv/y. The majority of the atmospheric collective dose have been predicted to arise from carbon-14.

A5.9 The collective doses from expected discharges to sea from a coastally located UK EPR nuclear power plant have been estimated to be: to UK 0.02 manSv/y, to Europe 0.1 manSv/y, to the world 1 manSv/y. The majority of the marine collective dose have been predicted to arise from carbon -14.

A5.10 The total collective dose from liquid discharges and atmospheric discharges is 0.11 manSv/y to the UK, 1,22 manSv/y to Europe and 16.9 manSv/y to the world. The majority of the collective dose is predicted to arise from carbon -14. These estimates of collective dose are the same as those predicted by EDF

A5.11 Average per caput doses (i.e. average individual doses derived from collective dose) were calculated for UK, European and World populations. The collective doses and the population data for UK, Europe and the World are shown in Table A5.4. The average per caput doses are presented in Table A5.5 (truncated at 500 years). At predicted levels, the average per caput dose to the UK, EU and World populations from the UK EPR nuclear power plant were each approaching 2 nSv. Most of this is predicted to arise from atmospheric discharges.

A5.12 The UK regulatory and advisory agencies have agreed that the risks associated with annual average per caput doses in the nanosieverts range may considered to be miniscule and should be ignored in the authorisation decision making processes [Ref A5.1]. The results of this study show that the per-caput doses from the UK EPR are of the order of a few nanosieverts and therefore within the range that might be considered trivial.

References

A5.1 Joint Environment Agencies, Principles for the Assessment of Prospective Public Doses (Interim Guidance), (December 2002).

A5.2 Environment Agency. The Environment Agency's Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs version 1 (http://publications.environment-agency.gov.uk/pdf/GEHO0107BLTN-e-e.pdf) (2007

A5.3 Defra, The Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000. Defra (May 2000).

A5.4 Mayall A, Cabianca T, Attwood C, Fayers CA, Smith JG, Penfold J, Steadman D, Martin G, Morris TP and Simmonds JR. PC CREAM-97 (PC CREAM-98 code update) NRPB Chilton NRPB-SR-296 (EUR 17791) (1997).

Table A5.1 Collective Dose factors for Atmospheric Discharges

Source	Nuclide	Collective dose (ManSv)				
		UK	GC (UK)	EU	GC (EU)	WLD
UK EPR (Sizewell)	H-3	1.40E-05	5.40E-06	4.40E-05	6.87E-05	9.81E-04
	C-14	4.00E-03	8.71E-02	6.40E-03	1.11E+00	1.58E+01
	AR-41	7.40E-08		6.60E-06		
	CO-58	1.20E-08		1.90E-07		
	CO-60	2.70E-07		8.20E-06		
	Kr-85	2.10E-09	4.36E-06	1.40E-07	5.54E-05	7.92E-04
	I-131	3.80E-09		2.30E-07		
	I-133	8.50E-09		5.20E-07		
	XE-131M	7.60E-11		5.50E-09		
	XE-133	5.90E-08		4.60E-06		
	XE-135	1.10E-07		9.30E-06		
	CS-134	2.90E-06		1.00E-05		
	CS-137	2.40E-06		9.60E-06		
	Total	4.00E-03	8.71E-02	6.50E-03	1.11E+00	1.58E+01

GC - Global Circulation. All values derived from PC CREAM [Ref. 14.4]

Table A5.2 Collective Dose factors for Liquid Discharges

Source	Nuclide	Collective dose (ManSv)					
		UK	GC (UK)	EU	GC (EU)	WLD	GC (WLD)
UK EPR (Sizewell)	H-3	1.40E-05	1.80E-05	5.50E-05	1.10E-04	6.20E-05	3.20E-03
	I-131	1.80E-08		2.30E-08		2.30E-08	
	C-14	1.40E-02	5.70E-03	6.10E-02	3.60E-02	8.10E-02	1.00E+00
	Co-58	3.40E-06		9.80E-06		9.80E-06	
	Co-60	5.70E-05		2.10E-04		2.20E-04	
	Ni-63	7.70E-07		3.40E-06		3.80E-06	
	Ag-110m	5.40E-05		9.60E-05		9.60E-05	
	Sb-124	1.20E-06		3.70E-06		3.70E-06	
	Sb-125	2.50E-06		1.10E-05		1.20E-05	
	Te-123m	1.70E-06		5.20E-06		5.20E-06	
	Cs-134	5.50E-06		2.70E-05		2.90E-05	
	Cs-137	9.20E-06		4.50E-05		5.40E-05	
	Cr-51	1.20E-09		2.30E-09		2.30E-09	
	Mn-54	6.00E-07		1.80E-06		1.80E-06	
	Total	1.40E-02	5.70E-03	6.20E-02	3.60E-02	8.10E-02	1.00E+00

GC - Global Circulation. All values derived from PC CREAM [Ref. 14.4]

Table A5.3 Collective Dose Truncated at 500 year for Predicted Discharges from a UK EPR Nuclear Power Plant.

Discharge location	Release	Collective Dose 500 years (ManSv)		
		UK	Europe	World
Sizewell	Atmospheric (1st pass)	4.00E-03	6.50E-03	-
	Atmospheric (GC)	8.71E-02	1.11E+00	1.58E+01
	Atmospheric (Total)	**9.11E-02**	**1.12E+00**	**1.58E+01**
Sizewell	Marine (1st Pass)	1.40E-02	6.20E-02	8.10E-02
	Marine (GC)	5.72E-03	3.61E-02	1.00E+00
	Marine (Total)	**1.97E-02**	**9.81E-02**	**1.08E+00**
Sizewell	**Total**	**1.1E-01**	**1.22E+00**	**1.69E+02**

Table A5.4 Population Data

Region	Population
UK	5.50E+07
Europe	7.00E+08
World	1.00E+10

Table A5.5 Average per Caput Doses at Predicted Discharge Levels Truncated to 500 years

Region	Aerial Release	Marine Discharges
	Sv/y	Sv/y
UK	1.66E-09	3.59E-10
Europe	1.60E-09	1.40E-10
World	1.58E-09	1.08E-10

Appendix 6 – Independent radiological assessment of doses from potential short term releases

Introduction

A6.1 The information provided by EDF and AREVA includes an assessment of the potential short-term gaseous discharges that may arise, e.g. during routine maintenance operations of the plant. The objective was to determine the potential for higher doses if short duration peak activity concentrations in air and foodstuffs coincide with particular agricultural or other seasonal variations. The timescale of releases to the marine environment are relatively less important; due to the effect of the limitation in pumping capacity of radioactive liquid discharge tanks and the distance at which releases occur from the shore. The methodology used to assess doses from short-term planned discharges to atmosphere is described in this Appendix.

A6.2 The radiological assessments undertaken by EDF and AREVA and in this independent assessment are based on the methods outlined in Reference A6.1 and use the ADMS 4.1 atmospheric dispersion model [Ref. A6.2].

A6.3 This assessment is based on the predicted maximal monthly discharge values, as presented by EDF and AREVA. The validity of the discharge predictions themselves has not been assessed.

Short-term Discharges to Atmosphere

A6.4 The predicted short-term discharge rates and the total activities discharged over a 24 hour release period are presented in Table A6.1. In accordance with information provided by EDF and AREVA, these releases have been assumed to occur from a 63 m high stack located on a building with dimensions 60 × 60 × 60 m. The building has been assumed to be downwind of the stack in order to provide a conservative estimate of doses.

A6.5 The ADMS 4.1 dispersion model has been used to estimate activity concentrations in the air and deposited on the ground at potential receptor locations of 100 m and 500 m. These distances have been chosen to maintain consistency with those used in the assessment of continuous discharges, as outlined in Appendix 3. Dry and wet deposition has been modelled simultaneously, using the default deposition velocities specified within the ADMS 4.1 model set out in Table A6.2. Meteorological data have been defined on the basis of recommendations set out in Reference A6.1, and are summarised in Table A6.3.

Receptor Points and Habit Data

A6.6 The most exposed members of the public from short-term discharges have been assumed to be located at the habitation at 100 m from the point of release, as assumed for the continuous release assessment, which has been assumed to be the location of the candidates for the representative person from continuous atmospheric discharges, as outlined in Appendix 2.

A6.7 Activity concentrations have been determined at ground level 100 m downwind of the release point. The activity concentrations in air, related to the defined release rates, and the deposition rate and cumulative deposition have been determined using ADMS 4.1, and are presented in Table A6.4.

A6.8 It has been assumed that the most exposed members of the public remain at this location throughout the duration of passage of the short-term release plume (24 hours) and that 50% of that time was spent outdoors.

A6.9 Doses from food pathways have been based on generic factors provided in NRPB-W54 [Ref. A6.1]. These are based on the assumption that food is sourced at 1 km from the point of release and the two most important terrestrial foods are consumed at high rates (97.5 percentile) while others are assumed to be consumed at average rates (50 percentile).

Exposure Pathways

A6.10 The exposure pathways considered were:

- Internal exposure from inhalation of radionuclides from the plume. The secondary inhalation of radionuclides which have been deposited on the ground and resuspended was not included, since the release did not include radionuclides for which this pathway is likely to provide a significant contribution to dose [Ref. A6.1].;
- External dose from exposure to radionuclides in the short-term release plume ('cloudshine') and beta and gamma radiation from radionuclides deposited on the ground ('groundshine');
- Internal dose from radionuclides from ingestion of local fruit and vegetable produce, cow and sheep meat and cow milk.

Doses from Short-term Releases

A6.11 Inhalation rates for adults, children and infants have been derived from those in NRPB-W41 [Ref. A6.3]. Activity concentrations in air at 100 m have been used and assumed to be equivalent indoors and outdoors. Dose coefficients for inhalation have been taken from the Euratom Basic Safety Standards [Ref. A6.4] and external dose factors for 'cloudshine' were taken from FGR-12 [Ref. A6.5]. These values are presented in Table A6.5.

A6.12 The doses arising from deposited activity have been estimated on the basis of data presented in Reference 6.1. The external doses arising from deposition have been based on the integrated effective doses after an integrated deposit of 1 Bq m^{-2} over 1 year and the total deposit at 100 m.

A6.13 Doses arising from terrestrial food pathways have been estimated in two ways. The first way has been to use derived factors for the adult effective dose (Sv) summed over food consumption pathways for a total release of 4.32 10^4 MBq (30 minute release duration) on 1 July, presented in Reference 6.1. These factors are presented in Table A6.6. An alternative approach, based on the use of the equilibrium transfer parameters, used in the approach outlined in Appendix 2, and applied to a 24 hour release, has been applied assuming that these foods were derived from 100 and 500 m from the point of release. Both approaches are likely to overestimate the ingestion doses from short-term releases due to complexities in the timing of agricultural practices, processing delays and radioactive decay, which have not been taken into account in this assessment.

A6.14 The estimated dose arising from a single short-term release, from the exposure pathways above, has been estimated to be in the order of a few microSv (2 - 5.7 μSv), primarily due to C-14 ingested from terrestrial foods (root vegetables and milk), as indicated in Table 5.7.

A6.15 Reference A6.1 recommends that a first order approximation of the impact of multiple releases may be made by multiplying the dose estimated for a single release by a factor of 10.

References

A6.1 Smith, J G, Bedwell, P, Walsh C and Haywood, S M, A Methodology for Assessing Doses from Short-term Planned Discharges to Atmosphere, NRPB-W54, NRPB, Chilton (Issue 5, 2006).

A6.2 ADMS 4, Industrial Air Pollution Model, http://www.cerc.co.uk/software/adms4.htm

A6.3 Smith, K R and Jones A L, Generalised Habit Data for Radiological Assessments, NRPB-W41, NRPB, Chilton (2003).

A6.4 Council Directive 96/29 Euratom of 13 May 1996, Laying Down Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers Arising from Ionising Radiation. Official Journal of the European Communities, L159, Volume 39, 29 June 1996.

A6.5 EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081 (Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

Table A6.1 Predicted Short-Term Discharges to Atmosphere

Radionuclide	Total release in 24 hours TBq	Emission Rate over 24 hours (TBq/s)
Ar-41	1.45E-01	1.68E-06
C-14	1.00E-01	1.16E-06
Co-58	4.34E-05	5.02E-10
Co-60	5.12E-05	5.93E-10
Cs-134	3.98E-05	4.61E-10
Cs-137	3.57E-05	4.13E-10
H-3	3.00E-01	3.47E-06
I-131	1.82E-04	2.11E-09
I-133	2.18E-04	2.52E-09
Kr-85	6.95E-01	8.04E-06
Xe-131m	1.50E-02	1.74E-07
Xe-133	3.16E+00	3.66E-05
Xe-135	9.90E-01	1.15E-05

Table A6.2 Deposition and Washout Coefficients

Radionuclide	Deposition Velocity (m/s)	Washout Coefficient
Ar-41	0	0
C-14	0	0
Co-58	0.001	2.30E-05
Co-60	0.001	2.30E-05
Cs-134	0.001	2.30E-05
Cs-137	0.001	2.30E-05
H-3	0	0
I-131	0.01	2.30E-05
I-133	0.01	2.30E-05
Kr-85	0	0
Xe-131m	0	0
Xe-133	0	0
Xe-135	0	0

Table A6.3 Meteorological Assumptions

Condition	Value
Rainfall	0.1mm/hour
Wind speed	3m/s
Boundary layer height	800m
reciprocal of the Monin-Obukhov length	0
standard deviation of the mean wind direction	27.1 degrees

Table A6.4 Activity Concentrations for Short-term Release Rates

Nuclide	100 m		
	Air Concentration (Bq/m3)	Total deposition (Bq/m2/s)	Total deposition for a 24 hour release (Bq/m2)
Ar-41	1.11E+01	0.00E+00	0.00E+00
C-14	7.65E+00	0.00E+00	0.00E+00
Co-58	3.30E-03	2.77E-05	2.39E+00
Co-60	3.90E-03	3.27E-05	2.82E+00
Cs-134	3.03E-03	2.54E-05	2.20E+00
Cs-137	2.72E-03	2.28E-05	1.97E+00
H-3	2.30E+01	0.00E+00	0.00E+00
I-131	1.33E-02	2.36E-04	2.04E+01
I-133	1.60E-02	2.82E-04	2.44E+01
Kr-85	5.32E+01	0.00E+00	0.00E+00
Xe-131m	1.15E+00	0.00E+00	0.00E+00
Xe-133	2.42E+02	0.00E+00	0.00E+00
Xe-135	7.58E+01	0.00E+00	0.00E+00

Table A6.5 Inhalation Dose Coefficients

Age group	Radionuclide	ICRP Lung class	Inhalation Sv/Bq	Ingestion Sv/Bq
Adult	C-14	V	2E-09	5.8E-10
	Co-58	M	1.6E-09	7.4E-10
	Co-60	M	1E-08	3.4E-10
	Cs-134	F	6.6E-09	1.9E-08
	Cs-137	F	4.6E-09	1.3E-08
	H-3	V	1.8E-11	1.8E-11
	I-131	F	7.4E-09	2.2E-08
	I-133	F	1.5E-09	4.3E-09
Child	C-14	V	2.8E-09	8E-10
	Co-58	M	2.4E-09	1.7E-09
	Co-60	M	1.5E-08	1.1E-08
	Cs-134	F	5.3E-09	1.4E-08
	Cs-137	F	3.7E-09	1E-08
	H-3	V	2.3E-11	2.3E-11
	I-131	F	1.9E-08	5.2E-08
	I-133	F	3.8E-09	1E-08
Infant	C-14	V	6.6E-09	1.6E-09
	Co-58	M	6.5E-09	4.4E-09
	Co-60	M	3.4E-08	2.7E-08
	Cs-134	F	7.3E-09	1.6E-08
	Cs-137	F	5.4E-09	1.2E-08
	H-3	V	4.8E-11	4.8E-11
	I-131	F	7.2E-08	1.8E-07
	I-133	F	1.8E-08	4.4E-08

Table A6.6 Factors for External Dose Rate and Ingestion Dose

Radio-nuclide	Cloud Shine (Sv/s per Bq/m^3)	Integrated effective dose (1 year) after instantaneous deposit of 1 Bq/m^2	Effective dose for a total release of 4.32 10^4 MBq
Ar-41	6.5E-14		
C-14	2.24E-19		2.08E-06
Co-58	4.76E-14		
Co-60	1.26E-13	4.38E-08	2.64E-06
Cs-134	7.57E-14	2.55E-08	*4.08E-05*
Cs-137	2.73 E-14	1.08E-08	4.08E-05
H-3	3.31E-19		1.18E-08
I-131	1.82E-14	2.48E-10	2.39E-05
I-133	2.94E-14		
Kr-85	1.19E-16		
Xe-131m	3.89E-16		
Xe-133	1.56E-15		
Xe-135	1.19E-14		

Table A6.7 Estimated Doses from a Single Short-term Release to Representative Member of the Public at 100 m from release (µSv)

Radio-nuclide	Inhalation			External Dose		Food (Adult)	Total (Adult)
	Adult	Child	Infant	Cloud	Ground		
Ar-41	0.00E+00	0.00E+00	0.00E+00	3.74E-02	0.00E+00	0.00E+00	3.74E-02
C-14	3.40E-01	3.29E-01	2.63E-01	8.89E-08	0.00E+00	4.81E+00	5.15E+00
Co-58	1.17E-04	1.22E-04	1.12E-04	8.15E-06	0.00E+00	0.00E+00	1.25E-04
Co-60	8.65E-04	8.97E-04	6.90E-04	2.55E-05	6.80E-02	3.13E-03	7.21E-02
Cs-134	4.44E-04	2.46E-04	1.15E-04	1.19E-05	3.08E-02	3.76E-02	6.88E-02
Cs-137	2.77E-04	1.54E-04	7.64E-05	3.85 E-06	1.17E-02	3.37E-02	4.57E-02
H-3	9.17E-03	8.10E-03	5.74E-03	3.94E-07	0.00E+00	8.19E-02	9.11E-02
I-131	2.19E-03	3.88E-03	4.99E-03	1.26E-05	2.78E-03	1.01E-01	1.06E-01
I-133	5.31E-04	9.30E-04	1.49E-03	2.43E-05	0.00E+00	0.00E+00	5.55E-04
Kr-85	0.00E+00	0.00E+00	0.00E+00	3.28E-04	0.00E+00	0.00E+00	3.28E-04
Xe-131m	0.00E+00	0.00E+00	0.00E+00	2.32E-05	0.00E+00	0.00E+00	2.32E-05
Xe-133	0.00E+00	0.00E+00	0.00E+00	1.96E-02	0.00E+00	0.00E+00	1.96E-02
Xe-135	0.00E+00	0.00E+00	0.00E+00	4.67E-02	0.00E+00	0.00E+00	4.67E-02
Total	**3.53E-01**	**3.43E-01**	**2.76E-01**	**1.04E-01**	**1.13E-01**	**5.20E+00**	**5.64E+00**

*The derived factors for the effective dose from Co-60, Cs-137 and I-131 were applied to releases of Co-58, Cs-134 and I-133 respectively to provide a conservative estimate of ingestion dose. The corresponding results are given in italics above.

Table A6.8 Equilibrium Terrestrial Food Transfer Factors

Radio-nuclide	Food Transfer Factors Bq/kg per Bq/m^2 s^{-1}							
	Green Veg	Root Veg	Fruit	Milk	Cow Meat	Cow liver	Sheep Meat	Sheep Liver
C-14	2.67E+02	5.33E+02	5.33E+02	2.67E+02	8.00E+02	8.00E+02	8.00E+02	8.00E+02
Co-58	9.16E+04	2.56E+02	1.59E+04	5.12E+04	6.93E+03	6.93E+05	1.16E+04	1.16E+06
Co-60	1.15E+05	5.12E+03	4.42E+04	7.08E+04	2.92E+04	2.92E+06	4.34E+04	4.35E+06
Cs-134	1.31E+05	1.19E+05	7.24E+04	1.59E+05	7.93E+05	7.93E+05	1.54E+06	1.54E+06
Cs-137	1.45E+05	1.35E+05	7.52E+04	1.79E+05	9.14E+05	9.14E+05	1.91E+06	1.91E+06
H-3	1.13E+02	1.00E+02	1.00E+02	1.13E+02	8.75E+01	8.75E+01	8.75E+01	8.75E+01
I-131	4.14E+04	8.63E+03	3.10E+04	5.82E+04	2.47E+04	2.47E+04	3.17E+04	3.17E+04
I-133	6.19E+03	4.68E+01	5.36E+03	3.79E+03	1.11E+03	1.11E+03	6.79E+02	6.79E+02

Table A6.9 Short-term Doses from Terrestrial Foods based on Equilibrium Transfer Factors (modified for short-term discharge duration)

Radio-nuclide	Short-term Ingestion Dose (μSv)								Total
	Green Veg	Root Veg	Fruit	Milk	Cow Meat	Cow liver	Sheep Meat	Sheep Liver	
Adult	1.50E-07	9.08E-07	1.44E-07	5.18E-07	8.53E-08	1.57E-08	4.92E-08	1.70E-08	1.89E-06
Child	9.64E-08	9.10E-07	1.55E-07	7.77E-07	1.16E-07	1.26E-08	3.25E-08	1.37E-08	2.11E-06
Infant	7.44E-08	8.75E-07	2.00E-07	2.41E-06	4.69E-08	8.67E-09	1.30E-08	9.43E-09	3.63E-06

*As indicated above, the contribution of other exposure pathways is of the order of 0.5 μSv

Appendix 7 – Effects of alternative assumptions on the independent assessment

Introduction

A7.1 The predicted doses to the representative person associated with annual maximum radioactive discharges from a UK EPR nuclear power plant and generic site conditions are within the range of 1 to 30 µSv/y. A limited consideration of some key factors that may affect the results has therefore been made, taking into account three main areas:-

- ***Foetal and breastfed infant dose.*** The candidates for the representative person for a prospective site is likely to include adult women of child bearing age who may be pregnant from time to time. Dose coefficients for foetuses have been published by the ICRP [Ref A7.1, A7.2] and the HPA have provided factors linking the doses to adults to those to the foetus and breast fed infant [Ref A7.2]. These factors have been used to assess dose to the foetus and infant in the first months of life.

- ***Uncertainty in internal doses from radionuclides taken into the body exists.*** Recent reviews of doses and risks from radionuclides have suggested that uncertainty associated with internal doses from radionuclides may be greater than those for external exposure [e.g. Ref A7.4]. In response to this, the Environment Agency provides separate estimates of effective doses from intakes of radionuclides, from estimates of effective doses from external exposure, so that uncertainty in internal exposure can be considered in more detail if required.

- ***Variation in wind direction around the generic site.*** The assessment of dispersion of radionuclides discharged to air over the course of a year assumes a uniform wind rose. For a generic site no specific meteorological data exists, nonetheless the effect of a non-uniform wind rose, where the candidates for the representative person is assumed to be located in a predominant downwind location, on the predicted doses has been assessed.

- ***Location of candidates for the representative person affected by atmospheric discharges.*** The assessment of dispersion of radionuclides discharged to air assumes that the candidates for the representative person affected by atmospheric discharges live 100 m from the release point and eat food produced at 500 m from the release point. Other assessments that will be made assume that candidates for the representative person live and eat food produced at the location where air concentrations are highest. The affect of adopting these latter assumptions on predicted doses can be assessed.

Dose to Foetus and Breastfed Infant

A7.2 Doses to the foetus and breastfed infant may be assessed on the basis of the dose to an adult mother and foetal and breastfed infant dose coefficients [Ref. A7.1, A7.2]. HPA guidance [Ref. A7.3] indicates that explicit assessment of doses to the foetus is often not necessary. Four radionuclides (^{32}P, ^{33}P, ^{45}Ca and ^{89}Sr) are identified for which such assessments are necessary, where these radionuclides form a significant part of any release of radioactivity to the environment. None of these radionuclides are included in the predicted releases from the UK EPR. However, for the purposes of providing a scoping assessment of foetal doses from intakes by the foetus and during breast-feeding infants, the doses to adults arising from inhalation and ingestion from atmospheric and marine discharges were multiplied by the time-weighted ratio of the dose coefficients for foetus (9 months) and breastfed infant during breastfeeding (3 months) to those of the adult. The relevant dose coefficients and multiplication factors are given in Table A7.1.

A7.1 The contribution to doses from key radionuclides to adults and foetus and breast fed infants from key who are either CRP1 (atmospheric discharges) or CRP2 (liquid discharges) are presented Table A7.2 and Table A7.3 respectively.

A7.3 The highest foetal/infant dose was estimated to be around 30 µSv/y to CRP2 - most exposed to liquid discharges from the UK EPR nuclear power plant. This dose was 4 µSv/y higher than that to the mother, primarily due to the transfer of the adult intake of C-14 in fish. It should be noted, however, that the combination of adult habits is based on a working fisherman. This combination of habits is likely to lead to an overestimate of the exposure of a pregnant or breast feeding woman.

Internal/External Exposure

A7.4 The internal and external component of effective doses to the representative person most exposed to aerial and liquid discharges from the UK EPR nuclear power plant are given in Tables A7.4 and A7.5.

The Effect of Local Meteorological Conditions

A7.5 The assessment made for atmospheric discharges uses a uniform windrose in which the wind blows into each of the 12 30 degree sectors 8.3% of the time. The frequency of wind blowing into each sector determines the air concentration in that sector and hence the dose received by a member of the public located in that sector. In a uniform windrose, the air concentration and doses are the same regardless of the sector in which the member of the public is located.

A7.6 To assess the effect of a non-uniform windrose on dose, it has been assumed that CRP1 are at a location which is predominantly downwind of the release point and that the wind blows in that direction twice as often as it would in a uniform windrose. This factor is based on an analysis of the amount of time the wind blows towards a given 30 degree sector for a coastal location in the North West of England. Data showed that the wind blows in the prevailing wind direction between 1.63 and 1.85 times as often as would be expected in a uniform windrose. For this assessment, this factor has been rounded to 2.

A7.7 The range of doses from atmospheric discharges to a candidate for the reference person (CRP1) who is situated in a predominant downwind direction will be around twice that for a candidate for the reference person assuming a uniform windrose. Thus, such doses would be around 10 µSv/y to adult and 17 µSv/y to infant, compared with the uniform windrose dose of 5.3 µSv/y to adult and 8.5 µSv/y to infant.

The effect of adopting different locations for candidate reference person

A7.8 The dose assessment will also be influenced by the choice of the distance at which the candidate for the representative person (or receptor) is assumed to live and derive their foods, from the release point.

A7.9 In the independent assessment, standard assumptions regarding the habitation and domestic fruit and vegetable production (100 m) and agricultural produce (500 m) were made. In order to determine the likely magnitude of the difference such assumptions could make to the doses assessed, the ratios of the time integrated air concentrations at the assumed locations to the maximum values were determined, using the appropriate plots of air concentrations for a continuing release for 60% Category D conditions, from NRPB-R91 [Ref. A7. 5]. The integrated air concentration at 100 m was found to be around 70% of that at 200 m (the location of the maximum air concentration) and that at 500 m was found to be 50% of this value, as demonstrated in Table A7.5. By making alternative assumptions about the location of the candidates for the representative person exposed to gaseous discharges, it may therefore be possible to predict doses that are higher by up to a factor of 2 than the independent assessment.

References

A7.1 International Commission on Radiological Protection, Doses to the Embryo and Fetus from Intakes of Radionuclides by the Mother, ICRP Publication No. 88, Corrected Version 2001, Ann. ICRP 31 (1-3) (2001).

A7.2 International Commission on Radiological Protection, Doses to Infants from Ingestion of Radionuclides in Mother's Milk, ICRP Publication No. 95, Ann. ICRP 34 (3-4) (2004).

A7.3 Guidance on the Application of Dose Coefficients for the Embryo, Fetus and Breastfed Intant in Dose Assessments for Members of the Public, Health Protection Agency, RCE-5 (2008).

A7.4 Committee on Examining Radiation Risks of Internal Emitters, Report (2004).

A7.10 Table A7.1 Adult, Foetal and Breast Feeding Infant Dose Coefficients and Derived Modification Factors for Adult Doses (Sv/Bq)

Radio-nuclide	Inhalation			Ingestion			Inhalation factor	Ingestion factor
	Foetus	Infant	Adult	Foetus	Infant	Adult		
H-3	6.30E-11	3.00E-11	4.10E-11	3.10E-11	2.00E-11	1.80E-11	1.34E+00	1.57E+00
C-14	8.00E-10	2.60E-10	5.80E-10	8.00E-10	2.60E-10	5.80E-10	1.15E+00	1.15E+00
Sr-89	2.10E-09	4.30E-10	6.10E-09	1.20E-08	2.00E-09	2.60E-09	2.76E-01	3.65E+00
Sr-90	8.80E-09	3.90E-09	3.80E-08	4.30E-08	1.50E-08	3.10E-08	1.99E-01	1.16E+00
I-131	8.10E-09	1.90E-08	7.40E-09	2.30E-08	5.50E-08	2.20E-08	1.46E+00	1.41E+00

Table A7.2 Foetal Dose from discharges from the UK EPR Nuclear Power Plant (pregnant women CRP1, most exposed to Gaseous Discharges)

Radio-nuclide	Adult Dose (µSv/y)		Foetal/ infant doses (µSv/y)*	
	Inhalation	Ingestion	Inhalation	Ingestion
H-3	2.28E-02	1.16E-01	3.04E-02	1.82E-01
C-14	7.59E-01	4.24E+00	8.70E-01	4.86E+00
Sr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-131	5.69E-04	3.12E-02	8.32E-04	4.40E-02
Total	**7.82E-01**	**4.39E+00**	**9.02E-01**	**5.09E+00**

*For the period of 12 months in which the foetal dose coefficient applies to 9 months and the dose coefficient for infants during lactation is applied for 3 months

Table A7.3 Foetal Dose from Discharges from the UK EPR Nuclear Power Plant (pregnant women CRP2, most exposed to Liquid Discharges)

Radio-nuclide	Adult Dose (µSv/y)		Foetal/ infant doses (µSv/y)*	
	Inhalation	Ingestion	Inhalation	Ingestion
H-3	0.00E+00	4.71E-02	0.00E+00	7.39E-02
C-14	0.00E+00	2.76E+01	0.00E+00	3.17E+01
Sr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-131	0.00E+00	1.49E-04	0.00E+00	2.10E-04
Total	**0.00E+00**	**2.77E+01**	**0.00E+00**	**3.17E+01**

*For the period of 12 months in which the foetal dose coefficient applies to 9 months and the dose coefficient for infants during lactation is applied for 3 months

Table A7.4 Separation of Internal and External Doses to CRP1 most exposed to Gaseous Discharges from the UK EPR Nuclear Power Plant

Radionuclide	Effective Dose to CRP1 UK EPR Reactor μSv/y		
	Total dose	External dose	Internal dose
Ar-41	2.60E-02	2.60E-02	0.00E+00
C-14	7.84E+00	1.23E-07	7.84E+00
Co-58	4.14E-04	2.53E-06	4.11E-04
Co-60	4.31E-03	7.87E-06	4.30E-03
Cs-134	4.31E-03	3.69E-06	4.30E-03
Cs-137	3.26E-03	3.38E-10	3.26E-03
H-3	2.61E-01	6.08E-07	2.61E-01
I-131	2.70E-01	2.03E-06	2.70E-01
I-133	5.64E-03	3.92E-06	5.64E-03
Kr-85	2.28E-04	2.28E-04	0.00E+00
Xe-131m	1.61E-05	1.61E-05	0.00E+00
Xe-133	1.36E-02	1.36E-02	0.00E+00
Xe-135	3.25E-02	3.25E-02	0.00E+00
Total	8.46E+00	7.23E-02	8.39E+00
		0.85%	**99.15%**

Table A7.5 Separation of Internal and External Doses to CRP2 most exposed to Liquid Discharges from the UK EPR Nuclear Power Plant

Radionuclide	Effective Dose to CRP2 UK EPR Nuclear Power Plant μSv/y		
	Total dose	External dose	Internal dose
Ag-110m	1.11E-01	7.45E-05	1.11E-01
C-14	2.76E+01	5.36E-07	2.76E+01
Co-58	2.52E-03	1.40E-04	2.38E-03
Co-60	1.75E-02	1.53E-02	2.24E-03
Cr-51	1.67E-06	3.52E-08	1.64E-06
Cs-134	1.87E-02	2.70E-04	1.84E-02
Cs-137	2.20E-02	2.60E-07	2.20E-02
H-3	4.72E-02	0.00E+00	4.72E-02
I-131	1.49E-04	2.07E-09	1.49E-04
Mn-54	2.48E-04	7.77E-05	1.70E-04
Ni-63	2.74E-04	0.00E+00	2.74E-04
Sb-124	1.10E-02	9.29E-06	1.10E-02
Sb-125	9.68E-03	5.93E-05	9.62E-03
Te-123m	9.58E-03	5.74E-07	9.58E-03
Total	2.79E+01	1.59E-02	2.78E+01
		0.06%	**99.94%**

Table A7.6 Time Integrated Air Concentration for 20 m release height for 60% D Stability Category

Distance from release point	Time Integrated Air Concentration (Bq s m^{-3})	Ratio of Time Integrated Air Concentration to the Maximum Value
100 m	2.00E-06	0.74
500 m	1.30E-06	0.48
Distance of maximum air concentration (200 m)	2.70E-06	-

Appendix 8 – Independent assessment of doses from direct radiation

Introduction

A8.1 Ensuring that the exposure of the public from direct radiation from nuclear sites in the UK is As Low As Reasonably Practicable (ALARA) is the responsibility of the HSE who require site operators to measure direct radiation at the site perimeter and estimate exposure to a reference person on an annual basis.

A8.2 As no UK EPR nuclear power plants have yet been built and operated, it is necessary to estimate the direct radiation dose that may arise. For the purposes of the independent assessment, measured direct radiation data from Sizewell B have been used. This is currently the only operational PWR nuclear power station in the UK.

A8.3 Direct radiation exposure is included within this assessment for comparison against the relevant dose constraints

A8.4 The assessment of doses from atmospheric and liquid discharges from the UK EPR is outlined in Appendices 3 and 4, respectively. These data are collated for application of dose constraints in Appendix 9.

Direct Exposure Estimates

A8.5 The effective dose to the candidates for the representative person from direct radiation measured around Sizewell B in 2007, and presented in the relevant RIFE report, was 4 μSv over the course of the year [Ref. A8.1], Table 8.1. The direct radiation measurements in previous years were higher, due to the contribution from the adjacent Magnox station (Sizewell A). The value in 2007 is considered to more appropriate for the purposes of this assessment than an average value due to the fact that Sizewell A ceased generation in 2006, and therefore the 2007 value is less likely to include a contribution from an adjacent radiation source.

A8.6 This direct radiation estimate is assumed to apply to CRP1 only. This dose has been applied without allowance for shielding during time spent indoors. It has been assumed that local fisherman and their families (CRP2) do not collect seafood from near to the site and do not live close enough to receive a dose from direct radiation. Application of direct radiation assumptions is summarised in Table 8.2.

References

A8.1 Food Standards Agency and Joint Environment Agencies. Radioactivity in Food and the Environment, 2007(RIFE-13) (2008).

Table A8.1 Sizewell B Dose Rate from Direct Radiation

Installation	Annual Dose to Candidates for the Reference Person from Direct Radiation (µSv/y)
Sizewell B	4

Table A8.2 Application of Direct Exposure to CRP1 and CRP2

Installation	Candidate for representative person	Total Annual Dose from Direct Radiation (µSv/y)
UK EPR Nuclear Power Plant	CRP1 (gaseous discharges)	4
	CRP2 (liquid discharges)	0

Appendix 9 –Independent assessment of site dose and total dose at the predicted discharge levels

Introduction

A9.1 The Environment Agency has responsibility to assess the maximum doses to individuals which may result from a defined source for use at the planning stage in radiation protection [Ref A9.1]. The current applicable criteria to existing sites are:

- 0.3 millisieverts per year (mSv/y) (300 µSv/y) from any source (source dose constraint);
- 0.5 millisieverts per year (mSv/y) (500 µSv/y) from the discharges from any single site (site dose constraint).

A9.2 The Environment Agency has also been directed to ensure that the sum of doses resulting from exposure to ionising radiation (total dose) does not exceed 1 mSv/y (1,000 µSv/y) [Ref A9.1].

A9.3 In its consultation document on advice on the application of the 2007 ICRP Recommendations to the UK [Ref. A9.2], the HPA has recommended that a maximum source constraint for members of the public of 150 µSv/y for new nuclear power stations should be used.

Source Dose

A9.4 The dose for comparison with the source dose constraint includes the contributions from discharges from a given source and any additional contribution from direct radiation. The assessment of doses from predicted future discharges from the UK EPR nuclear power plant is outlined in Appendices 2 and 3 for discharges to atmospheric and liquid discharges, respectively. The dose from direct radiation was estimated, as outlined in Appendix 8. The effective dose to the representative person from the UK EPR is predicted to be around 31 µSv/y to an adult fisherman. The highest effective dose to the candidates for the representative person from gaseous discharges is 13.5 µSv/y, including a contribution from direct radiation. These doses are summarised in Table A9.1 and are around 10% or less of the existing source constraint.

A9.5 It is proposed that the annual effective dose to the representative person summed over all relevant exposure pathways should be for comparison with the proposed dose constraint from new nuclear power stations [Ref.9.2]. It is therefore assumed that this would include the potential contribution from direct radiation from the power plant. The summed doses assessed from atmospheric and liquid discharges and from direct radiation are therefore also compared with the proposed maximum dose constraint for new nuclear power stations [Ref.9.2]. The doses, presented in Table A9.1, are also well below this level.

Site Dose

A9.6 To assess the dose from an UK EPR nuclear power plant located at a given site, for comparison with the 500 µSv/y site dose constraint, it would be necessary to include doses from future discharges from any other sources on the site and other sites with contingent boundaries. For the purposes of this assessment, it is assumed that the UK EPR is the only source located at the generic site. In this case, the source dose and site dose are equivalent. The representative person dose of 31 µSv/y is also significantly lower than the site constraint of 500 µSv/y.

A9.7 If the UK EPR were to be co-located with another current or past source of radioactive discharges, the site dose would need to be reassessed taking into account discharges from any other sites.

Total dose

A9.8 An assessment of total dose for comparison with the dose limit would take account of:

- Historical discharges from any other reactors or practices with which the UK EPR nuclear power plant is co-located;
- Historical discharges from other sites that lead to elevated levels of radioactivity in the area;
- Future discharges from the UK EPR and co-located reactors or other practices;
- Direct radiation from the UK EPR and co-located reactors or other practices; and,
- Future discharges from other sites that lead to elevated levels of radioactivity in the area.

A9.9 For a generic assessment, it is not possible to make a realistic or meaningful estimate of the total dose, given that information on the location of the UK EPR nuclear power plant, co-located reactors or other sources cannot be defined. In the absence of such information, it has been assumed that the UK EPR is in an isolated location some distance from any existing or previous sources of radioactive discharges. In this case, the total dose would be 31 µSv/y which is significantly less than the dose limit of 1000 µSv/y.

A9.10 If the UK EPR were to be located in the vicinity of another source of radioactive discharges, the total dose would need to be reassessed taking into account discharges and direct radiation from any other sites.

References

A9.1 Joint Agencies, Principles for the Assessment of Prospective Public Doses (Interim Guidance) December 2002.

A9.2 Health Protection Agency, HPA Advice on the Application of the ICRP's 2007 Recommendations to the UK, Consultation Document, HPA, Chilton, (2008).

Table A9.1 Summary of Doses from the UK EPR Nuclear Power Plant for Predicted Discharges (μSv/y) for Comparison against the Source Constraint and Proposed Maximum Dose Constraint for New Nuclear Power Stations

Candidates for Representative person[a]	Age group	UK EPR Nuclear Power Plant Dose (µSv/y)			
		Atmospheric Discharges	Marine Discharges	Direct Radiation	Total Source Dose
Family at nearest dwelling (CRP1)	Adult	5.30	2.01	4	11.31
	Child	5.73	1.13	4	10.85
	Infant	8.46	1.10	4	13.56
Fisherman and family (CRP2)	Adult	3.24	27.87	0	31.11
	Child	3.75	8.26	0	12.02
	Infant	4.14	2.74	0	6.88

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