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Initial radiological assessment methodology – part 1 user report

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Executive summary

The Radioactive Substances Act 1993 (RSA 93) provides the framework for controlling the generation and disposal of solid, liquid and gaseous radioactive waste so as to protect the public and the environment. In particular, RSA 93 requires prior authorisation for the disposal or discharge of radioactive waste to the environment. The UK Environment Agencies are required to ensure that doses to critical groups of the public do not exceed specified dose constraints, as part of the process of authorising such disposals or discharges.

The Environment Agency, Scottish Environment Protection Agency and the Department of Environment in Northern Ireland in collaboration with the Food Standards Agency and National Radiological Protection Board (now Health Protection Agency) have developed and published principles and guidance for the prospective assessment of public doses. A staged approach to the assessment of critical group doses for authorisation purposes is recommended, the first stage consisting of a simple and cautious assessment of the critical group dose (initial radiological assessment).

This document describes an initial radiological assessment methodology which may be used by the Environment Agencies and applicants for RSA 93 authorisations. The methodology allows assessment of the release of 100 radionuclides via the following routes:

- air;
- estuary/coastal water;
- river/stream;
- public sewer.

Doses can be calculated for seven different groups of the public and to four age groups (including the fetus), who may receive doses as a result of discharges to these release routes.

The methodology is based on dose per unit release (DPUR) data, which are combined with authorisation limits to calculate doses to members of the public. This document contains all the DPUR data required to carry out initial assessment calculations, and guidance on how to apply them, together with some example assessments.

The key assumptions which have been used to calculate DPUR data for this initial radiological assessment methodology are described in the accompanying report ‘Methods and Input Data for an Initial Radiological Assessment Methodology’. In that report, the methods used are described in full detail and all input data and intermediate output data used to derive the DPUR data are listed.

Contents

1 Introduction

The Radioactive Substances Act 1993 (RSA 93) provides the framework for controlling the generation and disposal of solid, liquid and gaseous radioactive waste so as to protect the public and the environment. In particular, RSA 93 requires prior authorisation for the disposal or discharge of radioactive waste to the environment. Responsibility for granting an authorisation rests with the Environment Agency in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland and the Department of Environment in Northern Ireland.

The Euratom Basic Safety Standards (BSS) Directive 1996 [1] requires member states, as part of the planning process for licensing practices subject to the Directive (i.e. practices involving a risk from ionising radiation), to ensure that specified dose limits are not exceeded.

Directions on the Environment Agency and Scottish Environment Protection Agency (SEPA) [2,3] require these Environment Agencies to ensure that doses to reference groups of the public do not exceed specified dose constraints, in discharging their functions in relation to the disposal of radioactive waste under RSA 93. There is equivalent legislation for Northern Ireland [4].

The Environment Agency, Scottish Environment Protection Agency and the Department of Environment in Northern Ireland in collaboration with the Food Standards Agency and National Radiological Protection Board (now Health Protection Agency – HPA) have developed and published principles and guidance for the prospective assessment of public doses [5]. A staged approach to the assessment of critical group doses for authorisation purposes is recommended, as shown in Figure 1. The first stage consists of a simple and cautious assessment of the critical group dose rate (initial radiological assessment). If the resulting effective dose rate is less than 20 µSv/y then no further assessment would be warranted for the purpose of authorising the discharge of radioactive waste to the environment. Further investigation using more realistic data should be undertaken when effective dose rates exceed 20 µSv/y, in particular if a regulatory decision is dependent on the outcome of the assessment.

This document describes an initial radiological assessment methodology which may be used by the Environment Agencies and applicants for RSA 93 authorisations. The initial methodology enables decisions to be taken on when a more detailed assessment is required as shown in Figure 1 (i.e. including detailed source and site assessment; short-term release assessment, collective dose assessment and variability and uncertainty assessments).

The key assumptions which have been used to calculate dose per unit release (DPUR) data for this initial radiological assessment methodology are described in the accompanying report 'Methods and Input Data for an Initial Radiological Assessment Methodology' [6]. In that report the methods used are described in full detail and all input data and intermediate output data used to derive the DPUR data are listed.

2 Purpose and scope of initial radiological assessment methodology

The purpose of the initial radiological assessment methodology is to:

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

The purpose of this report is to:

- present all the data necessary to undertake initial assessments;
- provide guidance on how to carry out initial assessments;
- provide guidance for refining the initial assessment to make it more realistic;
- illustrate the initial assessment method with some example calculations.

The methodology can be applied to all premises which are authorised by the Environment Agency under RSA 93 to discharge radioactive waste to the environment:

- to air;
- to estuary/coastal water;
- to river;
- to public sewer (and then on to river and estuary).

The methodology does not apply to the disposal of radioactive waste to land or discharges to lakes.

3 Overview of initial radiological assessment methodology

The methodology is based on the simple use of dose per unit release (DPUR) values for different radionuclides, release routes (e.g. to air, water, sewer) and exposure pathways (e.g. external dose from deposited radionuclides). DPUR factors have been derived for the four discharge scenarios (discharges to air, estuary/coastal water, river and sewer), 100 radionuclides and seven exposure groups, including a total of 41 exposure pathways. Four age groups have been considered, including the fetus. The term offspring has been used to collectively denote the embryo, fetus and newborn child [7]. The doses assessed by this methodology are the doses for the worst age group of offspring, infant, child or adult. Table 1 lists the radionuclides included for each discharge scenario.

The DPUR values are then multiplied by the actual or proposed authorised limits to calculate the initial dose. Some scaling can be applied to take account of site-specific dispersion conditions arising during releases to air (different release heights), releases to river (river flow), releases to estuary (water exchange rate) and releases to sewer (raw sewage input rate).

The assessment calculations have followed a conventional critical group approach as described in EC guidance [8] and the approach is similar to the calculations used to define Generalised Derived Constraints (GDC) [9, 10]. It should be noted that the endpoint for GDCs is different, being the annual release that would give rise to a dose of 300 μSv/y.

The assumptions which have been used to calculate DPUR factors for the initial radiological assessment methodology are generally cautious and are described in the accompanying report 'Methods and Input Data for an Initial Radiological Assessment Methodology' [6]. In that report, the methods used are described in full detail and all input data and intermediate output data used to derive the DPUR values are listed.

The methodology does require that significant direct external radiation doses from a site using radioactive substances are included. However, DPUR factors are not appropriate for this exposure pathway. Rather, direct radiation doses would be determined by measurement.

3.1 Releases to air

The exposure group for releases to air and relevant exposure pathways is:

<u>Local resident family</u>

- Inhalation of radionuclides in the effluent plume
- External irradiation from radionuclides in the effluent plume and deposited to the ground

- Consumption of terrestrial food incorporating radionuclides deposited to the ground

The detailed calculations to derive the DPUR factors for a local resident are provided in reference [6]. Key assumptions in the calculations are that the release is at ground level, the local resident is assumed to be located at a distance of 100 m from the release point and food is produced at a distance of 500 m from the release point.

The summary DPUR factors for local residents are shown in Table 2.

A scaling factor may be applied, if the release point is higher than ground level (see Figure 2). There are separate scaling factors for the inhalation and external dose pathways and the food pathway. This is because the location of exposure of the local habitant is assumed to be nearer the release point than the location where they source their food. See Section 4 for guidance on applying the methodology.

3.2 Releases to estuary or coastal water

The exposure group for releases to an estuary or coastal water and relevant exposure pathways is:

Fisherman family
- External irradiation from radionuclides deposited in shore sediments
- Consumption of seafood incorporating radionuclides

The detailed calculations to derive the DPUR factors for a fisherman are provided in reference [6]. A key assumption in the calculation of the DPUR factors is that all shellfish and 50% of the fish are caught from a 'local compartment', which might be the estuary or a theoretical box along the coast. The other 50% of the fish are assumed to be caught in the adjacent regional compartment. The minimum exchange rate for most large estuaries and coastal areas, particularly on the west coast of Britain (where tidal height changes are greater), is likely to be 100 m^3/s. However, for small estuaries, particularly on the east cost of Britain, a default exchange rate of 30 m^3/s may be more appropriate. For example, the Seaton channel part of the Tees Estuary, with a surface area of 375,000 m^2, an average tidal height change of 3.45 m and a tidal cycle of 43,200 s, has an exchange rate of 30 m^3/s.

The summary DPUR factors for the fisherman family are shown in Table 3 for a default exchange rate of 100 m^3/s. The DPUR factors should be multiplied by a factor of 3.3 if a default exchange rate of 30 m^3/s is appropriate (e.g. for a small estuary).

The assessment can be refined by applying a different water exchange rate. Typical exchange rates for different estuaries and coastal water are shown in Table 4. See Section 4 for guidance on applying the methodology.

3.3 Releases to river

The exposure groups for releases to river and relevant exposure pathways are:

Angler family
- External irradiation from radionuclides deposited in bank sediments
- Consumption of freshwater fish incorporating radionuclides
- Consumption of drinking water containing radionuclides

Irrigated food consumer family
- Consumption of terrestrial food irrigated with river water and incorporating radionuclides

The detailed calculations to derive the DPUR factors for the exposure groups affected by releases to river are provided in reference [6]. Key assumptions in the calculation of the DPUR factors are that the river has a flow rate of 1 m^3/s and that fish are caught and drinking water abstracted close to the release point into the river.

The summary DPUR factors for the angler and irrigated food consumer families are shown in Tables 5 and 6, respectively.

The DPUR factors may be scaled by dividing by the known river flow rate (m^3/s), subject to a recommended maximum river flow rate of 100 m^3/s. See Section 4 for guidance on applying the methodology.

3.4 Releases to sewer

The exposure groups for releases to public sewer and relevant exposure pathways are:

Sewage treatment workers (adults only)
- External irradiation from radionuclides in raw sewage and sludge
- Inadvertent inhalation and ingestion of raw sewage and sludge containing radionuclides

Farming family living on land conditioned with sewage sludge
- Consumption of food produced on land conditioned with sludge and incorporating radionuclides
- External irradiation from radionuclides in sludge conditioned soil
- Inadvertent inhalation and ingestion of sludge conditioned soil

Children playing in brook which receives treated effluent from sewage works (children only)
- External irradiation from radionuclides deposited in bank sediments
- Inadvertent consumption of water and sediment containing radionuclides

Angler family (river receives treated effluent from sewage works)
- External irradiation from radionuclides deposited in bank sediments
- Consumption of freshwater fish incorporating radionuclides

- Consumption of water containing radionuclides

Irrigated food consumer family (river receives treated effluent from sewage works)
- Consumption of terrestrial food irrigated with river water and incorporating radionuclides

Fisherman family (estuary/coastal water receives treated effluent from sewage works, typically via a river)
- External irradiation from radionuclides deposited in sediments
- Consumption of fish incorporating radionuclides

The detailed calculations to derive the DPUR factors for the exposure groups affected by releases to sewer are provided in reference [6]. Key assumptions are that the flow of raw sewage into the sewage treatment works (STW) is only 60 m^3/d and that sludge is used to condition pasture which is used for milk and meat production and soil which is used for vegetable production. The default water flow rate in a brook receiving treated effluent from a sewage treatment works is assumed to be 0.1 m^3/s. Assumptions for the angler family, irrigated food consumer and fisherman family are as described in the previous sections.

The summary DPUR factors for sewage treatment workers, members of the farming family living on sludge conditioned land and children playing in a brook are shown in Tables 7, 8 and 9, respectively.

Dose assessments for the sewage treatment workers and the farming family living on land conditioned with sewage sludge may be refined by scaling by the known input rate of raw sewage into the sewage treatment works compared to the default of 60 m^3/d. The DPUR factors for a child playing in a brook may be scaled for different water flow rates, compared to the default flow rate of 0.1 m^3/s. See Section 4 for guidance on applying the methodology.

The DPUR factors for the angler family, irrigated food consumer and fisherman family are those provided in Tables 3, 5 and 6. However, the DPUR factors for these groups need to be scaled by a factor to take account of losses to sludge and radioactive decay through the sewage treatment works (Table 10). Revised assessments may be undertaken to take account of different river flow rates and local compartment exchange rates as noted in the previous sections. See Section 4 for guidance on applying the methodology.

4 Guidance on using the initial radiological assessment methodology

Users of this initial radiological assessment methodology should apply it in the following three main stages:

- ***Stage 1*** – Initial radiological assessment using default data. If assessed dose is > 20 µSv/y, then proceed to Stage 2.

- ***Stage 2*** – Initial radiological assessment using refined data. If assessed dose is > 20 µSv/y, then proceed to Stage 3.

- ***Stage 3*** – Determine need for separate site-specific assessment.

4.1 Stage 1 – Initial radiological assessment using default data

The first stage of the assessment methodology is to use the unmodified DPUR data with the default assumptions. The steps are as follows:

- ***Establish the source term*** – Specific information on the releases to air, estuary/coastal water, river and sewer expressed on an annual basis (i.e. Bq/y) are required. This may be in the form of current annual limits, the proposed limits or recent annual discharge returns. In some cases radionuclide-specific information may not be available, and the discharges may be expressed as other radionuclides, other beta/gamma, etc. In these cases, the mostappropriate representative radionuclide should be selected. Default radionuclides that can be used for other alpha and other beta/gamma categories are given in Table 11.

- ***Calculate doses for releases to air, estuary/coastal water, river and sewer*** – Multiply the total DPUR factors in Tables 2, 3, 5, 6, 7, 8 and 9 by the source term (Bq/y) using the Stage 1 pro formas in Appendix A to guide the calculations. Factors in Table 10 should be used to take account of losses through a sewage treatment works when assessing the doses to angler and irrigated food consumer families as a result of releases to sewer, as shown in the Stage 1 pro formas in Appendix A. Multiply the fisherman family DPUR factors by 3.3 if the release is to a small estuary, particularly on the east coast of Britain.

- ***Check for direct radiation doses*** – If direct radiation exposure of the public from sources on the site is known to occur (e.g. dose rate at site boundary above background) an assessment of direct radiation dose should be made.

- ***Calculate total dose*** – Where discharges occur by more than one route (e.g. to air and to sewer) and/or direct radiation exposure occurs from one site/premises, an initial assessment of total dose from all the discharges/exposures should be made by summing the initial assessment doses calculated for each discharge route and direct radiation. See Stage 1 pro forma in Appendix A.

If the total dose is less than or equal to 20 μSv/y, then no further assessment is necessary. Otherwise, proceed to Stage 2.

4.2 Stage 2 – Initial radiological assessment using refined data

The main refinement that can be made is to take account of local dispersion in the air or water:

- ***Air*** – The initial assessment using default data assumes a ground-level release. Stacks may discharge to the atmosphere well above ground level. A graph of dispersion scaling factors is provided in Figure 2 for releases to air to take account of different release heights. One scaling factor can be applied to the inhalation and external radiation exposure pathways while another scaling factor is applied to the food consumption exposure pathways. There are separate scaling factors for these pathways, because the location of exposure of the local habitant is assumed to be nearer the release point than the location where they source their food. See Stage 2 pro forma in Appendix A to guide calculations.

- ***Estuary/coastal water*** – A default water exchange of 100 m^3/s is assumed. Other site-specific data can be entered (see Table 4 for example exchange rates). Higher exchange rates will reduce the assessed dose. See Stage 2 pro forma in Appendix A to guide calculations.

- ***River*** – A low default flow rate of 1 m^3/s is assumed. Other site-specific flow rate data can be entered, subject to a recommended maximum river flow rate of 100 m^3/s. Higher volumetric flow will reduce the assessed dose. See Stage 2 pro forma in Appendix A to guide calculations.

- ***Sewer*** – A very low default flow rate of 60 m^3/d is assumed. Other site-specific data can be entered. Higher volumetric flow will reduce the assessed dose. Site-specific dispersion data can also be entered for onward releases to a brook, river and estuary/coastal water. See Stage 2 pro forma in Appendix A to guide calculations.

A further refinement is to review how realistic any use of the generic other alpha and other beta/gamma categories has been. The radionuclides listed in Table 11 result in the highest doses in each category. It might be appropriate to substitute them with different radionuclides if the typical mix of radionuclides that are normally discharged is known.

If the total doses have been assessed from the sum of initial assessment results from more than one discharge route/mode and/or direct radiation exposure from one site, consideration should be given as to whether to refine the assessment by determining whether it is realistic to assume that a group exposed to one mode of discharge may also be exposed to another discharge mode and/or direct radiation and whether, therefore, the initial dose assessment results should be considered separately.

In the initial assessment system, exposure to atmospheric discharges at the nearest dwelling and food production point is assumed to be at a few hundred metres from the discharge point. If direct radiation exposure occurs, the highest direct radiation exposure is also likely to occur close to the site (within a few hundred metres). Therefore, where atmospheric discharges occur and direct radiation is important, the exposed group may be common and the estimated doses can be added.

In the initial assessment system, the location where aqueous discharges reach the environment has not been specified. However, unless liquid discharges reach the environment close to the site (within a few hundred metres) then overlap between groups exposed to atmospheric discharges (and/or direct radiation) and liquid discharges is less likely. In these cases, where a Stage 2 assessment is carried out it may be appropriate to consider two separate groups: one for liquid discharges and one for discharges to atmosphere and direct radiation.

If the total dose from the Stage 2 assessment is less than or equal to 20 µSv/y, then no further assessment is necessary. Otherwise, the Environment Agency guidance states that there is a need to proceed to Stage 3 [5].

4.3 Stage 3 – Determine need for a site-specific radiological assessment

Having assessed the dose as greater than 20 µSv/y, one refinement which can be undertaken is to calculate the doses for each age group, using the age-specific DPUR factors in Reference [6]. The DPUR factors presented in the user guide are the highest DPUR factors for each radionuclide, regardless of age group, and thus may over-estimate the dose to a specific age group.

A site-specific radiological assessment should be undertaken if the total dose remains greater than 20 µSv/y and the advice of a competent radiological assessor should normally be sought. It may be possible to show that the initial radiological assessment methodology has provided a realistic estimate of the dose. Alternatively, more detailed DPUR data are provided in the supporting report [6] to this user guide, which may be used to provide a more realistic site-specific assessment. There will still be a need to ensure that short-term release doses, collective doses and uncertainty and variability are adequately addressed (see Figure 1 and Reference [5]).

The following steps should be undertaken:

- ***Review release and disposal routes*** – Identify location of release points (e.g. to air and to river) and location of habitation, water abstraction points and access points along river. Identify disposal route for sewage sludge (e.g. disposal to land, incineration, land reclamation).

- ***Review dispersion in the environment*** – Site-specific air dispersion modelling may be undertaken, in particular to take account of realistic annual weather conditions, and the effect of buildings and the local terrain.

- ***Review exposure pathways*** – Identify the realistic exposure pathways for the radionuclides, in particular the types of food being produced (e.g. milk, meat products, ‘wild’ meat, fruit and vegetables, fish farming, watercress, etc.).

- ***Review likely exposure groups and their habits*** – Identify those people who might be exposed via the above exposure pathways and obtain any available data on their habits (e.g. food consumption rates, occupancy times). If necessary, commission surveys of their habits.

Once more detailed site-specific information is obtained, the example refinements provided in Table 12 will help determine whether the initial radiological assessment methodology may be used to make the assessment more site specific and realistic.

The initial radiological assessment methodology is based around exposure pathways and groups which are likely to be the worst affected for a particular discharge route. If one of these exposure pathways or groups is found not to be present, then it is important to decide whether doses not yet considered (i.e. from other exposure pathways and to other exposure groups) need to be assessed.

The initial radiological assessment methodology assumes that all food types are eaten at critical consumption rates (e.g. higher than average consumption rates). It is usual practice to assume that only two food types are eaten at critical rates and other food types are eaten at average rates [5]. A site-specific assessment would take this into account and the initial radiological assessment methodology cannot be easily refined to address this cautious assumption. However, in reality one or two food types will usually dominate the dose and reducing other food types to average consumption rates will not make much difference to the total dose.

The Health Protection Agency provides guidance for small users to undertake separate detailed assessments [11].

Situations where a separate site-specific assessment will be required are as follows:

- ***Sludge disposal routes*** – Sludge disposed of by a route other than conditioning of soil on farmland or incineration of sludge (e.g. disposal to landfill or land reclamation).

- ***Different food types produced and consumed*** – Food types other than those included in the calculation of DPUR factors are found to be produced in the vicinity of the discharge (e.g. watercress).

- ***Other exposure groups*** – Dose assessments for other groups of the public (e.g. swimmers) are required.

Factors which may influence the amount of effort expended on undertaking a site-specific assessment are as follows:

- How close the assessed dose is to 300 μSv/y.
- Whether the discharges giving rise to the dose have already been constrained by best practicable means (BPM) and doses are as low as reasonably achievable (ALARA), social and economic factors taken into account.
- Whether there is a need to present a realistic assessment to stakeholders rather than a generic and probably cautious assessment. This is likely to be the case for nuclear sites.
- Whether there are discharges from other premises/sites to the receiving environment (e.g. sewer) and the total dose from all the discharges > 300 μSv/y (particularly so if the total dose > 1,000 μSv/y).

5 Worked examples of initial assessment methodology

Several worked examples of the application of the initial radiological assessment methodology are provided in Appendix B.

For the first example a hospital in the Thames Valley, which has an incinerator permitted to discharge 420 MBq/month (5.04 GBq/y) of carbon-14 to air and an authorisation permitting the discharge of 120 GBq/month (1.44 TBq/y) of iodine-131 to sewer, was considered. The first stage of the initial assessment, using default DPUR data, showed a dose of 0.34 μSv/y from the release to air and 22,000 μSv/y to adult sewage workers from the release to sewer. As a result, a refined assessment was carried out for the release to sewer. For the Stage 2 assessment site-specific flow rates for the sewage treatment works and the water bodies receiving liquid effluent from the sewage treatment works were applied. After the Stage 2 assessment the highest dose was for children playing in the brook at 82 μSv/y. The second highest dose was 62 μSv/y to the angler family and the third highest 43 μSv/y to the sewage treatment workers. As these doses are all still greater than 20 μSv/y, it is necessary to consider a separate detailed site-specific assessment (Stage 3).

For the second example a research department in a large university, which is seeking an authorisation to discharge radionuclides to air, was considered. The following discharge limits are to be included: 2 MBq/month (24 MBq/y) of tritium, 4.2 MBq/month (50.4 MBq/y) of carbon-14, 4.2 MBq/month (50.4 MBq/y) of sulphur-35, 1.5 MBq/month (18 MBq/y) of iodine-125 and 260 MBq/month (3.12 GBq/y) of iodine-131. The first stage of the initial assessment resulted in a total dose for the local resident family from releases to air of 14 μSv/y, which is below 20 μSv/y. As a result, no further assessments should be warranted.

For the third example a nuclear power station, which is licensed, under authorisation, to discharge radionuclides to air and to sea, was assessed. The following rolling 12-month limits for discharges to air are included in the authorisation: 6 TBq of tritium, 5 TBq of carbon-14, 160 GBq of sulphur-35, 60 TBq of argon-41, 5 GBq of iodine-131 and 1 GBq of ‘beta particulates’, here represented by cobalt-60. The following rolling 12-month limits for discharges to sea are included: 1.2 PBq of tritium, 3 TBq of sulphur-35, 30 GBq of cobalt-60 and 300 GBq of ‘other’, here represented by caesium-137. The first stage of the initial assessment, using default DPUR data, resulted in a dose of 590 μSv/y for releases to air and 130 μSv/y for releases to sea. Adding the contribution from direct radiation, of 19 μSv/y, this resulted in a total dose of 739 μSv/y. As this is greater than 20 μSv/y, a refined Stage 2 assessment was undertaken, for both the releases to atmosphere and the coastal environment. A site-specific effective stack height was applied to the atmospheric discharges and a site-specific water exchange rate for the local compartment was applied to the coastal assessment. This resulted in a maximum dose to the exposure groups of 100 μSv/y. As this is still greater than 20 μSv/y, it is necessary to consider a separate detailed site-specific assessment (Stage 3).

6 Summary and conclusions

Prospective radiological assessments are required to assess the dose to members of the public arising from authorised discharges of radioactive waste to the environment. The Environment Agency, the Scottish Environment Protection Agency and the Department of Environment, Northern Ireland, in collaboration with the Food Standards Agency and National Radiological Protection Board (now Health Protection Agency) have developed and published principles and guidance for the prospective assessment of public doses. This guidance recommends that the first step in undertaking a prospective assessment would be to carry out an initial radiological assessment using simple generic assumptions. If the resultant dose exceeded 20 μSv/y, then a more detailed assessment, using site-specific assumptions, should be undertaken.

An initial radiological assessment methodology has been developed based on the use of DPUR data which have been derived using generic assumptions. The methodology provides for the inclusion of some site-specific information to make the assessment more realistic, this being local factors affecting dispersion in air or water. The key assumptions underlying the methodology, together with all input and intermediate data, are presented in the accompanying report ‘Methods and Input Data for an Initial Radiological Assessment Methodology’ [6].

Guidance has been provided on using the initial radiological assessment methodology and will allow those assessing doses from authorised releases of radioactive substances to the environment to identify when a separate site-specific detailed assessment is required.

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List of abbreviations

Bq	Becquerel
DPUR	dose per unit release
GDC	Generalised Derived Constraints
HPA	Health Protection Agency
NRPB	National Radiological Protection Board
RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
STW	sewage treatment works
Sv	Sievert

Tables

Table 1 Radionuclides considered in the initial assessment methodology

Radionuclide	Half-life	Release to air	Release to estuary/coastal water	Release to river	Release to public sewer
H-3	12.35 y	✓	✓	✓	✓
H-3 organic	12.35 y	✓	✓	✓	✓
C-11	20.38 m	✓	not considered	not considered	✓
C-14	5,730 y	✓	✓	✓	✓
N-13	9.965 m	✓	gas	gas	gas
O-15	122.24 s	✓	gas	gas	gas
F-18	109.77 m	✓	not considered	not considered	✓
Na-22	2.602 y	✓	✓	✓	✓
Na-24	15 h	✓	✓	✓	✓
P-32	14.29 d	✓	✓	✓	✓
P-33	25.4 d	✓	✓	✓	✓
S-35	87.44 d	✓	✓	✓	✓
Cl-36	301,000 y	✓	✓	✓	✓
Ar-41	1.827 h	✓	gas	gas	gas
Ca-45	163 d	✓	✓	✓	✓
Ca-47	4.53 d	✓	✓	✓	✓
V-48	16.238 d	✓	✓	✓	✓
Cr-51	27.704 d	✓	✓	✓	✓
Mn-52	5.591 d	✓	✓	✓	✓
Mn-54	312.5 d	✓	✓	✓	✓
Mn-56	2.5785 h	✓	not considered	not considered	✓
Fe-55	2.7 y	✓	✓	✓	✓
Fe-59	44.529 d	✓	✓	✓	✓
Co-56	78.76 d	✓	✓	✓	✓
Co-57	270.9 d	✓	✓	✓	✓
Co-58	70.8 d	✓	✓	✓	✓
Co-60	5.271 y	✓	✓	✓	✓
Ni-63	96 y	✓	✓	✓	✓
Zn-65	243.9 d	✓	✓	✓	✓
Ga-67	78.26 h	✓	✓	✓	✓
Se-75	119.8 d	✓	✓	✓	✓
Br-82	35.3 h	✓	✓	✓	✓
Kr-79	35 h	✓	gas	gas	gas
Kr-81m	13 s	✓	gas	gas	gas
Kr-85	10.72 y	✓	gas	gas	gas
Kr-85m	4.48 h	✓	gas	gas	gas
Rb-82	1.3 m	✓	not considered	not considered	✓
Rb-83	86.2 d	✓	✓	✓	✓
Sr-89	50.5 d	✓	✓	✓	✓
Sr-90	29.12 y	✓	✓	✓	✓
Y-90	64 h	✓	✓	✓	✓
Zr-95	63.98 d	✓	✓	✓	✓
Nb-95	35.2 d	✓	✓	✓	✓
Mo-99	66 h	✓	✓	✓	✓
Tc-99	213,000 y	✓	✓	✓	✓
Tc-99m	6.02 h	✓	✓	✓	✓
Ru-103	39.28 d	✓	✓	✓	✓
Ru-106	368.2 d	✓	✓	✓	✓
Ag-110m	249.9 d	✓	✓	✓	✓
In-111	2.83 d	✓	✓	✓	✓

Table 1 continued

Radionuclide	Half-life	Release to air	Release to estuary/coastal water	Release to river	Release to public sewer
In-113m	1.658 h	✓	not considered	not considered	✓
Sb-125	2.77 y	✓	✓	✓	✓
I-123	13.2 h	✓	✓	✓	✓
I-125	60.14 d	✓	✓	✓	✓
I-129	1.57E+07 y	✓	✓	✓	✓
I-131	8.04 d	✓	✓	✓	✓
I-132	2.3 h	✓	not considered	not considered	✓
I-133	20.8 h	✓	✓	✓	✓
I-134	52.6 m	✓	not considered	not considered	✓
I-135	6.61 h	✓	✓	✓	✓
Xe-133	5.245 d	✓	gas	gas	gas
Cs-134	2.062 y	✓	✓	✓	✓
Cs-136	13.1 d	✓	✓	✓	✓
Cs-137	30 y	✓	✓	✓	✓
Ba-140	12.74 d	✓	✓	✓	✓
La-140	40.272 h	✓	✓	✓	✓
Ce-141	32.501 d	✓	✓	✓	✓
Ce-144	284.3 d	✓	✓	✓	✓
Pm-147	2.6234 y	✓	✓	✓	✓
Sm-153	46.7 h	✓	✓	✓	✓
Eu-152	13.33 y	✓	✓	✓	✓
Eu-154	8.8 y	✓	✓	✓	✓
Eu-155	4.96 y	✓	✓	✓	✓
Er-169	9.3 d	✓	✓	✓	✓
Lu-177	6.71 d	✓	✓	✓	✓
Au-198	2.696 d	✓	✓	✓	✓
Tl-201	3.044 d	✓	✓	✓	✓
Pb-210	22.3 y	✓	✓	✓	✓
Po-210	138.38 d	✓	✓	✓	✓
Rn-222	3.8235 d	✓	gas	gas	gas
Ra-223	11.434 d	✓	✓	✓	✓
Ra-226	1,600 y	✓	✓	✓	✓
Th-230	77,000 y	✓	✓	✓	✓
Th-232	1.405E+10 y	✓	✓	✓	✓
Th-234	24.1 d	✓	✓	✓	✓
U-234	244,500 y	✓	✓	✓	✓
U-235	7.038E+08 y	✓	✓	✓	✓
U-238	4.468E+09 y	✓	✓	✓	✓
Np-237	2.14E+06 y	✓	✓	✓	✓
Pu-238	87.74 y	✓	✓	✓	✓
Pu-239	24,065 y	✓	✓	✓	✓
Pu-240	6,537 y	✓	✓	✓	✓
Pu-241	14.4 y	✓	✓	✓	✓
Pu-242	376,300 y	✓	✓	✓	✓
Am-241	432.2 y	✓	✓	✓	✓
Am-242	16.02 h	✓	✓	✓	✓
Am-243	7,380 y	✓	✓	✓	✓
Cm-242	162.8 d	✓	✓	✓	✓
Cm-243	28.5 y	✓	✓	✓	✓
Cm-244	18.11 y	✓	✓	✓	✓

Table 2 Dose per unit release factors for local resident family – atmospheric release scenario

Radionuclide	DPUR for worst age group local resident family (µSv/y per Bq/y of discharge to atmosphere)*				
	Terrestrial food consumption DPUR	External irradiation DPUR	Inhalation DPUR	Total DPUR	Age group
H-3	2.7E-13	0.0E+00	6.9E-13	9.6E-13	Offspring
H-3 organic	5.7E-13	0.0E+00	1.4E-12	1.9E-12	Offspring
C-11	0.0E+00	2.4E-12	4.0E-13	2.8E-12	Adult
C-14	3.3E-11	6.4E-17	3.5E-11	6.8E-11	Infant
N-13	0.0E+00	2.4E-12	0.0E+00	2.4E-12	Adult
O-15	0.0E+00	2.1E-12	0.0E+00	2.1E-12	Adult
F-18	0.0E+00	2.7E-12	1.3E-12	4.0E-12	Adult
Na-22	9.9E-11	6.0E-09	2.9E-11	6.1E-09	Adult
Na-24	6.6E-14	2.0E-11	6.1E-12	2.6E-11	Adult
P-32	8.8E-10	2.8E-14	1.4E-10	1.0E-09	Offspring
P-33	2.6E-12	4.6E-16	3.3E-11	3.5E-11	Child
S-35	6.0E-11	7.6E-17	2.4E-11	8.4E-11	Infant
Cl-36	1.8E-09	7.9E-13	1.4E-10	2.0E-09	Infant
Ar-41	0.0E+00	3.2E-12	0.0E+00	3.2E-12	Adult
Ca-45	3.7E-12	4.8E-16	6.1E-11	6.5E-11	Child
Ca-47	8.8E-13	2.1E-11	4.3E-11	6.5E-11	Adult
V-48	1.6E-12	1.9E-10	5.4E-11	2.5E-10	Adult
Cr-51	1.3E-13	3.5E-12	8.3E-13	4.5E-12	Adult
Mn-52	5.9E-12	8.4E-11	3.1E-11	1.2E-10	Adult
Mn-54	2.8E-11	9.1E-10	3.4E-11	9.7E-10	Adult
Mn-56	0.0E+00	5.0E-12	2.7E-12	7.7E-12	Adult
Fe-55	5.1E-11	2.7E-15	7.5E-12	5.8E-11	Infant
Fe-59	1.6E-11	2.0E-10	8.3E-11	3.0E-10	Adult
Co-56	1.6E-11	1.0E-09	1.1E-10	1.1E-09	Adult
Co-57	2.1E-12	1.0E-10	1.2E-11	1.2E-10	Adult
Co-58	4.4E-12	2.7E-10	3.6E-11	3.1E-10	Adult
Co-60	5.3E-11	1.1E-08	2.2E-10	1.2E-08	Adult
Ni-63	1.8E-12	0.0E+00	1.0E-11	1.2E-11	Infant
Zn-65	1.0E-09	1.7E-10	3.5E-11	1.2E-09	Infant
Ga-67	5.7E-14	2.3E-12	5.4E-12	7.7E-12	Adult
Se-75	1.1E-09	6.0E-11	3.2E-11	1.2E-09	Infant
Br-82	6.7E-11	8.3E-12	1.6E-11	9.1E-11	Infant
Kr-79	0.0E+00	5.9E-13	0.0E+00	5.9E-13	Adult
Kr-81m	0.0E+00	8.3E-14	0.0E+00	8.3E-14	Adult
Kr-85	0.0E+00	1.3E-14	0.0E+00	1.3E-14	Adult
Kr-85m	0.0E+00	3.6E-13	0.0E+00	3.6E-13	Adult
Rb-82	0.0E+00	2.2E-12	3.6E-14	2.2E-12	Adult
Rb-83	3.4E-11	1.7E-10	1.5E-11	2.2E-10	Adult
Sr-89	2.2E-11	1.6E-14	1.3E-10	1.5E-10	Infant
Sr-90	6.4E-10	3.2E-15	8.0E-10	1.4E-09	Child
Y-90	1.2E-12	1.9E-14	4.7E-11	4.8E-11	Infant
Zr-95	1.2E-12	3.7E-10	1.1E-10	4.8E-10	Adult
Nb-95	6.3E-13	1.1E-10	3.4E-11	1.4E-10	Adult
Mo-99	1.5E-12	7.3E-13	2.4E-11	2.6E-11	Infant
Tc-99	7.4E-09	7.1E-16	7.0E-11	7.4E-09	Infant
Tc-99m	7.7E-15	3.9E-13	4.3E-13	8.3E-13	Adult

Table 2 continued

Radionuclide	DPUR for worst age group local resident family (µSv/y per Bq/y of discharge to atmosphere)*				
	Terrestrial food consumption DPUR	External irradiation DPUR	Inhalation DPUR	Total DPUR	Age group
Ru-103	7.7E-13	7.5E-11	5.4E-11	1.3E-10	Adult
Ru-106	1.1E-11	2.6E-10	6.3E-10	9.0E-10	Adult
Ag-110m	3.1E-10	2.4E-09	1.7E-10	2.9E-09	Adult
In-111	8.7E-14	5.2E-12	5.2E-12	1.0E-11	Adult
In-113m	0.0E+00	6.6E-13	4.5E-13	1.1E-12	Adult
Sb-125	1.9E-11	1.2E-09	1.1E-10	1.4E-09	Adult
I-123	1.4E-12	1.2E-12	4.2E-12	6.8E-12	Infant
I-125	2.9E-09	7.2E-12	1.2E-10	3.1E-09	Infant
I-129	2.8E-08	1.2E-10	4.6E-10	2.9E-08	Infant
I-131	4.1E-09	3.8E-11	3.9E-10	4.5E-09	Infant
I-132	0.0E+00	1.3E-11	2.1E-12	1.5E-11	Adult
I-133	7.2E-11	7.6E-12	9.7E-11	1.8E-10	Infant
I-134	0.0E+00	9.8E-12	1.0E-12	1.1E-11	Adult
I-135	1.9E-12	7.8E-12	2.0E-11	3.0E-11	Infant
Xe-133	0.0E+00	7.0E-14	0.0E+00	7.0E-14	Adult
Cs-134	4.7E-10	3.6E-09	1.5E-10	4.2E-09	Adult
Cs-136	1.9E-11	1.2E-10	2.7E-11	1.6E-10	Adult
Cs-137	3.8E-10	6.5E-09	1.0E-10	7.0E-09	Adult
Ba-140	2.8E-12	1.2E-10	1.1E-10	2.4E-10	Adult
La-140	3.3E-13	2.1E-11	2.5E-11	4.6E-11	Adult
Ce-141	8.0E-13	8.9E-12	7.2E-11	8.2E-11	Adult
Ce-144	2.4E-11	1.6E-11	8.6E-10	9.0E-10	Infant
Pm-147	5.2E-13	9.8E-15	1.1E-10	1.1E-10	Adult
Sm-153	1.3E-13	2.4E-13	1.6E-11	1.6E-11	Child
Eu-152	4.0E-12	9.0E-09	9.4E-10	9.9E-09	Adult
Eu-154	5.2E-12	7.8E-09	1.2E-09	9.0E-09	Adult
Eu-155	7.3E-13	1.9E-10	1.5E-10	3.4E-10	Adult
Er-169	2.3E-13	9.4E-16	2.3E-11	2.4E-11	Child
Lu-177	2.5E-13	9.5E-13	2.7E-11	2.8E-11	Adult
Au-198	7.1E-13	2.0E-12	2.4E-11	2.6E-11	Infant
Tl-201	5.8E-13	3.9E-13	1.8E-12	2.7E-12	Infant
Pb-210	5.7E-09	3.2E-12	2.3E-08	2.9E-08	Child
Po-210	1.6E-08	2.2E-15	7.2E-08	8.8E-08	Child
Rn-222	0.0E+00	4.5E-16	2.4E-10	2.4E-10	Infant
Ra-223	9.5E-11	1.3E-11	1.7E-07	1.7E-07	Adult
Ra-226	1.9E-09	2.7E-08	7.9E-08	1.1E-07	Adult
Th-230	3.5E-10	2.0E-10	3.1E-07	3.1E-07	Adult
Th-232	3.9E-10	6.9E-08	5.6E-07	6.3E-07	Adult
Th-234	2.9E-12	1.8E-12	1.7E-10	1.8E-10	Adult
U-234	1.4E-10	1.2E-12	7.9E-08	7.9E-08	Adult
U-235	1.3E-10	2.0E-09	7.0E-08	7.2E-08	Adult
U-238	1.3E-10	3.2E-10	6.5E-08	6.6E-08	Adult
Np-237	4.4E-10	2.9E-09	5.2E-07	5.2E-07	Adult
Pu-238	6.0E-10	4.4E-13	1.0E-06	1.0E-06	Adult
Pu-239	6.6E-10	7.0E-13	1.1E-06	1.1E-06	Adult
Pu-240	6.6E-10	5.6E-13	1.1E-06	1.1E-06	Adult
Pu-241	1.2E-11	1.6E-12	2.0E-08	2.0E-08	Adult
Pu-242	6.3E-10	8.7E-12	1.1E-06	1.1E-06	Adult

Table 2 continued

Radionuclide	DPUR for worst age group local resident family (µSv/y per Bq/y of discharge to atmosphere)*				
	Terrestrial food consumption DPUR	External irradiation DPUR	Inhalation DPUR	Total DPUR	Age group
Am-241	5.7E-10	1.3E-10	9.4E-07	9.4E-07	Adult
Am-242	1.9E-14	6.4E-14	3.8E-10	3.8E-10	Adult
Am-243	5.7E-10	2.4E-09	9.2E-07	9.2E-07	Adult
Cm-242	1.8E-11	6.7E-14	1.2E-07	1.2E-07	Adult
Cm-243	3.8E-10	1.1E-09	7.0E-07	7.0E-07	Adult
Cm-244	3.0E-10	1.9E-12	6.1E-07	6.1E-07	Adult

*For a release at ground level

Table 3 Dose per unit release factors for fisherman family – coastal release scenario

Radionuclide	DPUR for worst age group fisherman family (µSv/y per Bq/y of discharge to estuary/coastal water)*+			
	External irradiation DPUR	Seafood consumption DPUR	Total DPUR	Age group
H-3	0.0E+00	8.9E-16	8.9E-16	Offspring
H-3 organic	0.0E+00	3.7E-11	3.7E-11	Offspring
C-14	1.6E-16	4.6E-10	4.6E-10	Offspring
Na-22	1.4E-13	5.9E-14	2.0E-13	Adult
Na-24	2.7E-16	5.7E-16	8.3E-16	Adult
P-32	1.3E-17	6.8E-09	6.8E-09	Offspring
P-33	6.8E-20	1.6E-09	1.6E-09	Offspring
S-35	8.4E-20	7.9E-15	7.9E-15	Offspring
Cl-36	3.1E-17	1.6E-15	1.6E-15	Adult
Ca-45	1.9E-17	6.7E-13	6.7E-13	Offspring
Ca-47	2.3E-14	2.3E-13	2.5E-13	Offspring
V-48	3.6E-11	6.2E-13	3.7E-11	Adult
Cr-51	3.7E-13	2.3E-13	6.0E-13	Adult
Mn-52	1.2E-11	7.9E-12	2.0E-11	Adult
Mn-54	2.2E-10	5.0E-12	2.3E-10	Adult
Fe-55	0.0E+00	3.0E-13	3.0E-13	Adult
Fe-59	4.7E-11	1.5E-12	4.9E-11	Adult
Co-56	2.3E-10	5.0E-11	2.8E-10	Adult
Co-57	1.9E-11	4.4E-12	2.3E-11	Adult
Co-58	5.4E-11	1.5E-11	6.9E-11	Adult
Co-60	2.7E-09	7.5E-11	2.8E-09	Adult
Ni-63	0.0E+00	3.6E-12	3.6E-12	Adult
Zn-65	8.0E-11	3.3E-09	3.4E-09	Adult
Ga-67	5.9E-16	1.1E-12	1.1E-12	Adult
Se-75	2.6E-12	6.4E-10	6.4E-10	Adult
Br-82	9.2E-16	1.5E-14	1.5E-14	Adult
Rb-83	2.3E-13	3.2E-12	3.4E-12	Adult
Sr-89	4.0E-17	1.5E-12	1.5E-12	Offspring
Sr-90	1.0E-15	6.1E-12	6.1E-12	Offspring
Y-90	8.4E-15	6.5E-13	6.6E-13	Adult
Zr-95	8.6E-11	6.5E-13	8.7E-11	Adult
Nb-95	2.2E-11	2.0E-13	2.2E-11	Adult
Mo-99	3.9E-15	2.1E-13	2.2E-13	Adult
Tc-99	1.0E-16	7.0E-12	7.0E-12	Adult
Tc-99m	1.8E-18	7.2E-15	7.2E-15	Adult
Ru-103	7.6E-12	1.2E-12	8.8E-12	Adult
Ru-106	3.5E-11	1.3E-11	4.8E-11	Adult
Ag-110m	1.2E-10	3.9E-09	4.0E-09	Adult
In-111	1.8E-13	6.0E-12	6.1E-12	Adult
Sb-125	1.5E-11	1.5E-11	2.9E-11	Adult
I-123	7.7E-18	3.0E-15	3.0E-15	Adult
I-125	2.1E-16	3.0E-12	3.0E-12	Adult
I-129	5.4E-15	2.5E-11	2.5E-11	Adult
I-131	2.5E-15	2.5E-12	2.5E-12	Adult
I-133	8.8E-17	9.4E-14	9.4E-14	Adult
I-135	2.6E-17	6.9E-15	7.0E-15	Adult

Table 3 continued

Radionuclide	DPUR for worst age group fisherman family (µSv/y per Bq/y of discharge to estuary/coastal water)*+			
	External irradiation DPUR	Seafood consumption DPUR	Total DPUR	Age group
Cs-134	8.4E-11	4.0E-11	1.2E-10	Adult
Cs-136	1.6E-12	3.9E-12	5.5E-12	Adult
Cs-137	1.2E-10	2.8E-11	1.5E-10	Adult
Ba-140	4.6E-12	3.5E-13	5.0E-12	Adult
La-140	1.3E-12	1.8E-13	1.5E-12	Adult
Ce-141	1.6E-12	1.6E-13	1.7E-12	Adult
Ce-144	1.4E-11	1.3E-12	1.5E-11	Adult
Pm-147	6.0E-15	3.8E-13	3.9E-13	Adult
Sm-153	1.9E-14	2.7E-13	2.9E-13	Adult
Eu-152	2.2E-09	2.2E-12	2.2E-09	Adult
Eu-154	2.0E-09	3.1E-12	2.0E-09	Adult
Eu-155	3.7E-11	4.8E-13	3.7E-11	Adult
Er-169	1.5E-16	7.0E-14	7.0E-14	Adult
Lu-177	1.2E-13	9.1E-14	2.1E-13	Adult
Au-198	4.6E-13	8.4E-14	5.4E-13	Adult
Tl-201	1.5E-14	2.5E-12	2.5E-12	Adult
Pb-210	2.5E-12	1.9E-07	1.9E-07	Adult
Po-210	9.1E-17	5.4E-10	5.4E-10	Adult
Ra-223	5.4E-13	1.6E-10	1.6E-10	Adult
Ra-226	2.6E-10	8.6E-10	1.1E-09	Offspring
Th-230	3.0E-11	7.5E-11	1.1E-10	Adult
Th-232	5.1E-09	1.6E-09	6.7E-09	Adult
Th-234	4.2E-11	8.6E-13	4.3E-11	Adult
U-234	4.9E-15	1.3E-11	1.3E-11	Adult
U-235	9.6E-12	1.3E-11	2.2E-11	Adult
U-238	1.8E-12	1.2E-11	1.4E-11	Adult
Np-237	1.4E-11	3.5E-10	3.6E-10	Adult
Pu-238	5.0E-14	1.6E-09	1.6E-09	Adult
Pu-239	1.2E-13	1.7E-09	1.7E-09	Adult
Pu-240	5.3E-14	1.7E-09	1.7E-09	Adult
Pu-241	2.4E-13	3.2E-11	3.2E-11	Adult
Pu-242	4.7E-14	1.6E-09	1.6E-09	Adult
Am-241	2.5E-11	4.6E-11	7.1E-11	Adult
Am-242	9.6E-16	1.0E-14	1.1E-14	Adult
Am-243	5.3E-10	4.6E-11	5.8E-10	Adult
Cm-242	3.9E-15	2.9E-12	2.9E-12	Adult
Cm-243	2.6E-10	3.4E-11	3.0E-10	Adult
Cm-244	4.0E-14	2.7E-11	2.7E-11	Adult

*For a water exchange rate of 100 m^3/s
+The factors in this table should be multiplied by factors in Table 10 when assessing doses as a result of releases to sewer, to take account of losses during transit through the sewage treatment works

Table 4 Typical exchange rates for estuary/coastal water

Estuary or coastal water	Volumetric exchange (m^3/s)
Hartlepool Bay	130
Inner Tidal Thames	380
Suffolk coast	350
Weymouth Bay	1,300
Upper Severn Estuary	130
Bristol Channel	3,200
North Wales coast	1,300
Ribble Estuary	130
Morecambe Bay	250
Cumbrian coast	2,500

Table 5 Dose per unit release factors for angler family – river release scenario

Radionuclide	DPUR for worst age group angler family (µSv/y per Bq/y of discharge to river)*+				
	Fish consumption DPUR	External irradiation DPUR	Drinking water consumption DPUR	Total DPUR	Age group
H-3	1.7E-14	0.0E+00	5.8E-13	6.0E-13	Offspring
H-3 organic	8.8E-10	0.0E+00	1.2E-12	8.8E-10	Offspring
C-14	1.0E-08	3.9E-15	1.4E-11	1.0E-08	Offspring
Na-22	9.5E-12	4.5E-13	1.2E-10	1.3E-10	Infant
Na-24	1.5E-12	1.5E-13	1.9E-11	2.1E-11	Infant
P-32	1.4E-07	3.8E-12	4.3E-10	1.5E-07	Offspring
P-33	2.9E-08	9.4E-15	8.7E-11	2.9E-08	Offspring
S-35	2.3E-11	6.2E-15	3.4E-12	2.6E-11	Offspring
Cl-36	1.0E-11	0.0E+00	5.2E-11	6.2E-11	Infant
Ca-45	2.0E-10	1.9E-14	1.5E-10	3.4E-10	Offspring
Ca-47	1.8E-10	4.6E-10	1.3E-10	7.7E-10	Offspring
V-48	3.8E-08	3.4E-10	3.8E-11	3.8E-08	Adult
Cr-51	4.8E-13	3.2E-10	3.6E-13	3.2E-10	Adult
Mn-52	3.3E-11	1.1E-08	9.8E-12	1.1E-08	Adult
Mn-54	1.3E-11	1.4E-08	3.9E-12	1.4E-08	Adult
Fe-55	1.2E-11	0.0E+00	8.1E-12	2.0E-11	Child
Fe-59	7.6E-11	9.4E-09	2.3E-11	9.5E-09	Adult
Co-56	2.4E-10	4.4E-08	2.4E-11	4.4E-08	Adult
Co-57	2.0E-11	8.9E-10	2.0E-12	9.1E-10	Adult
Co-58	7.0E-11	1.1E-08	7.0E-12	1.1E-08	Adult
Co-60	3.2E-10	3.0E-08	3.2E-11	3.0E-08	Adult
Ni-63	4.8E-12	0.0E+00	1.4E-12	6.2E-12	Adult
Zn-65	1.2E-08	6.5E-10	7.1E-11	1.2E-08	Adult
Ga-67	4.8E-11	6.5E-12	3.6E-12	5.8E-11	Adult
Se-75	3.1E-10	3.4E-10	4.7E-11	7.0E-10	Adult
Br-82	1.4E-10	0.0E+00	1.0E-11	1.5E-10	Adult
Rb-83	1.6E-09	3.6E-09	2.4E-11	5.2E-09	Adult
Sr-89	4.1E-10	5.4E-12	2.1E-10	6.3E-10	Offspring
Sr-90	1.5E-09	1.4E-11	7.3E-10	2.2E-09	Offspring
Y-90	1.3E-11	4.6E-13	1.4E-10	1.5E-10	Infant
Zr-95	4.5E-11	2.5E-08	4.5E-12	2.5E-08	Adult
Nb-95	1.1E-10	8.6E-11	1.1E-11	2.1E-10	Adult
Mo-99	3.6E-12	5.4E-11	1.1E-11	6.8E-11	Adult
Tc-99	2.3E-12	1.3E-16	3.9E-11	4.1E-11	Infant
Tc-99m	2.1E-13	5.2E-12	4.1E-13	5.8E-12	Adult
Ru-103	3.4E-12	2.6E-09	1.0E-11	2.6E-09	Adult
Ru-106	3.3E-11	1.3E-09	9.9E-11	1.4E-09	Adult
Ag-110m	4.0E-12	6.3E-10	5.3E-11	6.8E-10	Adult
In-111	3.1E-10	1.4E-09	9.2E-13	1.7E-09	Adult
Sb-125	6.8E-13	2.2E-10	2.0E-11	2.4E-10	Adult
I-123	5.2E-12	9.6E-12	3.9E-12	1.9E-11	Adult
I-125	3.7E-10	6.9E-13	2.8E-10	6.6E-10	Adult
I-129	2.7E-09	5.5E-13	2.1E-09	4.8E-09	Adult
I-131	2.2E-10	7.5E-13	1.5E-09	1.7E-09	Infant
I-133	5.5E-11	1.2E-12	3.6E-10	4.1E-10	Infant
I-135	2.3E-11	1.0E-10	1.7E-11	1.4E-10	Adult

Table 5 continued

Radionuclide	DPUR for worst age group angler family (µSv/y per Bq/y of discharge to river)*+				
	Fish consumption DPUR	External irradiation DPUR	Drinking water consumption DPUR	Total DPUR	Age group
Cs-134	2.2E-08	3.2E-09	3.3E-10	2.5E-08	Adult
Cs-136	3.5E-09	8.6E-10	5.2E-11	4.4E-09	Adult
Cs-137	1.5E-08	1.1E-09	2.2E-10	1.6E-08	Adult
Ba-140	5.3E-12	2.1E-09	4.0E-11	2.2E-09	Adult
La-140	2.0E-12	6.0E-09	1.5E-11	6.0E-09	Adult
Ce-141	5.4E-12	6.8E-10	5.4E-12	6.9E-10	Adult
Ce-144	4.0E-11	7.7E-10	4.0E-11	8.5E-10	Adult
Pm-147	1.4E-12	1.0E-15	1.3E-11	1.4E-11	Infant
Sm-153	5.6E-12	1.2E-10	5.6E-12	1.3E-10	Adult
Eu-152	8.9E-12	1.6E-08	1.1E-11	1.6E-08	Adult
Eu-154	1.3E-11	1.7E-08	1.5E-11	1.7E-08	Adult
Eu-155	2.0E-12	3.8E-10	2.4E-12	3.8E-10	Adult
Er-169	8.9E-13	3.5E-15	9.2E-12	1.0E-11	Infant
Lu-177	4.0E-12	8.7E-11	4.0E-12	9.5E-11	Adult
Au-198	7.6E-12	1.1E-09	7.6E-12	1.1E-09	Adult
Tl-201	3.0E-10	1.7E-10	9.0E-13	4.7E-10	Adult
Pb-210	9.8E-08	7.3E-12	9.8E-09	1.1E-07	Adult
Po-210	1.0E-08	1.5E-15	5.4E-08	6.5E-08	Infant
Ra-223	1.7E-09	5.3E-12	8.8E-09	1.1E-08	Infant
Ra-226	9.5E-09	1.0E-09	5.7E-09	1.6E-08	Offspring
Th-230	8.9E-09	1.4E-12	2.7E-09	1.2E-08	Adult
Th-232	9.7E-09	2.0E-08	2.9E-09	3.3E-08	Adult
Th-234	1.4E-10	1.8E-10	4.3E-11	3.7E-10	Adult
U-234	1.5E-09	3.4E-15	9.3E-10	2.5E-09	Adult
U-235	1.5E-09	6.7E-12	8.9E-10	2.4E-09	Adult
U-238	1.4E-09	1.4E-12	8.5E-10	2.3E-09	Adult
Np-237	2.1E-09	2.0E-12	2.1E-09	4.2E-09	Adult
Pu-238	1.2E-09	3.8E-13	7.3E-10	1.9E-09	Adult
Pu-239	1.3E-09	8.6E-13	7.9E-10	2.1E-09	Adult
Pu-240	1.3E-09	3.7E-13	7.9E-10	2.1E-09	Adult
Pu-241	2.5E-11	1.7E-14	1.5E-11	4.1E-11	Adult
Pu-242	1.3E-09	3.2E-13	7.6E-10	2.0E-09	Adult
Am-241	6.0E-09	1.4E-10	1.8E-10	6.4E-09	Adult
Am-242	9.1E-12	5.2E-11	2.7E-13	6.2E-11	Adult
Am-243	6.0E-09	3.0E-09	1.8E-10	9.2E-09	Adult
Cm-242	2.9E-12	1.4E-14	3.0E-11	3.3E-11	Infant
Cm-243	1.1E-10	2.0E-09	1.4E-10	2.2E-09	Adult
Cm-244	9.1E-11	3.3E-13	1.1E-10	2.0E-10	Adult

*For a river flow rate of 1 m^3/s
+The factors in this table should be multiplied by factors in Table 10 when assessing doses as a result of releases to sewer, to take account of losses during transit through the sewage treatment works

Table 6 Dose per unit release factors for irrigated food consumer family – river release scenario

Radionuclide	DPUR for worst age group irrigated food consumer family (µSv/y per Bq/y of discharge to river)*+		
	Terrestrial food consumption DPUR	Total DPUR	Age group
H-3	4.4E-14	4.4E-14	Offspring
H-3 organic	2.1E-14	2.1E-14	Offspring
C-14	4.8E-11	4.8E-11	Offspring
Na-22	1.6E-11	1.6E-11	Infant
Na-24	4.8E-14	4.8E-14	Infant
P-32	1.8E-10	1.8E-10	Offspring
P-33	8.0E-12	8.0E-12	Offspring
S-35	7.5E-13	7.5E-13	Infant
Cl-36	3.1E-10	3.1E-10	Infant
Ca-45	1.0E-11	1.0E-11	Offspring
Ca-47	2.0E-12	2.0E-12	Offspring
V-48	1.4E-12	1.4E-12	Infant
Cr-51	2.9E-14	2.9E-14	Infant
Mn-52	6.0E-13	6.0E-13	Infant
Mn-54	8.8E-13	8.8E-13	Infant
Fe-55	5.5E-13	5.5E-13	Infant
Fe-59	2.3E-12	2.3E-12	Infant
Co-56	3.0E-12	3.0E-12	Infant
Co-57	3.6E-13	3.6E-13	Infant
Co-58	8.6E-13	8.6E-13	Infant
Co-60	9.5E-12	9.5E-12	Infant
Ni-63	1.2E-12	1.2E-12	Infant
Zn-65	8.1E-12	8.1E-12	Infant
Ga-67	5.4E-14	5.4E-14	Infant
Se-75	1.3E-11	1.3E-11	Infant
Br-82	1.2E-13	1.2E-13	Infant
Rb-83	6.6E-12	6.6E-12	Infant
Sr-89	1.0E-11	1.0E-11	Offspring
Sr-90	3.0E-10	3.0E-10	Offspring
Y-90	7.6E-13	7.6E-13	Infant
Zr-95	1.1E-12	1.1E-12	Infant
Nb-95	5.3E-13	5.3E-13	Infant
Mo-99	1.4E-13	1.4E-13	Infant
Tc-99	7.4E-10	7.4E-10	Infant
Tc-99m	1.3E-15	1.3E-15	Infant
Ru-103	6.5E-13	6.5E-13	Infant
Ru-106	9.3E-12	9.3E-12	Infant
Ag-110m	4.3E-12	4.3E-12	Infant
In-111	6.8E-14	6.8E-14	Infant
Sb-125	1.6E-12	1.6E-12	Infant
I-123	3.5E-14	3.5E-14	Infant
I-125	4.3E-11	4.3E-11	Child
I-129	7.2E-10	7.2E-10	Child
I-131	3.8E-11	3.8E-11	Infant
I-133	1.2E-12	1.2E-12	Infant
I-135	8.3E-14	8.3E-14	Infant

Table 6 continued

Radionuclide	DPUR for worst age group irrigated food consumer family (µSv/y per Bq/y of discharge to river)*+		
	Terrestrial food consumption DPUR	Total DPUR	Age group
Cs-134	6.0E-11	6.0E-11	Adult
Cs-136	3.0E-12	3.0E-12	Adult
Cs-137	4.6E-11	4.6E-11	Adult
Ba-140	2.0E-12	2.0E-12	Infant
La-140	3.3E-13	3.3E-13	Infant
Ce-141	6.9E-13	6.9E-13	Infant
Ce-144	7.1E-12	7.1E-12	Infant
Pm-147	3.8E-13	3.8E-13	Infant
Sm-153	1.3E-13	1.3E-13	Infant
Eu-152	2.3E-12	2.3E-12	Infant
Eu-154	3.2E-12	3.2E-12	Infant
Eu-155	4.9E-13	4.9E-13	Infant
Er-169	2.2E-13	2.2E-13	Infant
Lu-177	2.5E-13	2.5E-13	Infant
Au-198	2.3E-13	2.3E-13	Infant
Tl-201	5.0E-14	5.0E-14	Infant
Pb-210	3.2E-09	3.2E-09	Infant
Po-210	7.5E-09	7.5E-09	Infant
Ra-223	1.2E-10	1.2E-10	Infant
Ra-226	1.9E-09	1.9E-09	Child
Th-230	2.3E-10	2.3E-10	Adult
Th-232	2.5E-10	2.5E-10	Adult
Th-234	3.1E-12	3.1E-12	Infant
U-234	6.1E-11	6.1E-11	Adult
U-235	5.9E-11	5.9E-11	Adult
U-238	5.6E-11	5.6E-11	Adult
Np-237	1.7E-10	1.7E-10	Adult
Pu-238	2.1E-10	2.1E-10	Adult
Pu-239	2.3E-10	2.3E-10	Adult
Pu-240	2.3E-10	2.3E-10	Adult
Pu-241	4.4E-12	4.4E-12	Adult
Pu-242	2.2E-10	2.2E-10	Adult
Am-241	1.9E-10	1.9E-10	Adult
Am-242	2.0E-14	2.0E-14	Infant
Am-243	1.9E-10	1.9E-10	Adult
Cm-242	1.3E-11	1.3E-11	Infant
Cm-243	1.4E-10	1.4E-10	Adult
Cm-244	1.1E-10	1.1E-10	Adult

*For a river flow rate of 1 m^3/s
+The factors in this table should be multiplied by factors in Table 10 when assessing doses as a result of releases to sewer, to take account of losses during transit through the sewage treatment works

Table 7 Dose per unit release factors for sewage treatment workers – sewage release scenario

Radionuclide	DPUR for worst age group sewage treatment workers (µSv/y per Bq/y of discharge to sewer)*			
	External irradiation DPUR	Inadvertent ingestion and inhalation DPUR	Total DPUR	Age group
H-3	0.0E+00	3.8E-14	3.8E-14	Adult
H-3 organic	0.0E+00	8.8E-14	8.8E-14	Adult
C-11	4.3E-10	3.0E-16	4.3E-10	Adult
C-14	1.4E-13	1.3E-12	1.4E-12	Adult
F-18	2.2E-09	3.2E-15	2.2E-09	Adult
Na-22	1.2E-07	4.7E-12	1.2E-07	Adult
Na-24	4.8E-08	1.2E-13	4.8E-08	Adult
P-32	6.7E-10	1.3E-11	6.9E-10	Adult
P-33	2.1E-12	1.9E-12	4.0E-12	Adult
S-35	1.0E-13	2.2E-13	3.3E-13	Adult
Cl-36	2.3E-11	1.6E-12	2.4E-11	Adult
Ca-45	2.9E-12	6.9E-12	9.8E-12	Adult
Ca-47	1.1E-07	4.1E-12	1.1E-07	Adult
V-48	6.8E-07	1.3E-11	6.8E-07	Adult
Cr-51	7.7E-09	3.0E-13	7.7E-09	Adult
Mn-52	2.5E-07	3.6E-12	2.5E-07	Adult
Mn-54	1.8E-07	4.4E-12	1.8E-07	Adult
Mn-56	7.5E-09	2.9E-14	7.5E-09	Adult
Fe-55	0.0E+00	3.6E-12	3.6E-12	Adult
Fe-59	3.9E-07	1.6E-11	3.9E-07	Adult
Co-56	1.2E-06	2.2E-11	1.2E-06	Adult
Co-57	2.6E-08	2.0E-12	2.6E-08	Adult
Co-58	2.9E-07	6.5E-12	2.9E-07	Adult
Co-60	8.9E-07	3.4E-11	8.9E-07	Adult
Ni-63	0.0E+00	9.7E-13	9.7E-13	Adult
Zn-65	1.3E-07	2.3E-11	1.3E-07	Adult
Ga-67	8.7E-09	4.1E-13	8.7E-09	Adult
Se-75	6.3E-08	1.5E-11	6.3E-08	Adult
Br-82	3.7E-08	2.1E-13	3.7E-08	Adult
Rb-82	4.3E-11	5.5E-20	4.3E-11	Adult
Rb-83	1.4E-07	1.6E-11	1.4E-07	Adult
Sr-89	1.2E-10	3.5E-12	1.2E-10	Adult
Sr-90	3.7E-10	4.3E-11	4.1E-10	Adult
Y-90	1.2E-10	1.3E-12	1.2E-10	Adult
Zr-95	2.4E-07	9.8E-12	2.4E-07	Adult
Nb-95	1.3E-07	2.9E-12	1.3E-07	Adult
Mo-99	3.8E-09	3.0E-13	3.8E-09	Adult
Tc-99	9.9E-13	1.1E-12	2.1E-12	Adult
Tc-99m	5.5E-10	4.0E-15	5.5E-10	Adult
Ru-103	2.0E-08	9.8E-13	2.0E-08	Adult
Ru-106	1.1E-08	1.1E-11	1.1E-08	Adult
Ag-110m	1.0E-06	3.0E-11	1.0E-06	Adult
In-111	2.1E-08	5.4E-13	2.1E-08	Adult
In-113m	7.5E-10	2.6E-15	7.5E-10	Adult
Sb-125	1.3E-07	1.1E-11	1.3E-07	Adult
I-123	1.2E-09	6.4E-14	1.2E-09	Adult
I-125	1.7E-10	3.5E-11	2.0E-10	Adult

Table 7 continued

Radionuclide	DPUR for worst age group sewage treatment workers (µSv/y per Bq/y of discharge to sewer)*			
	External irradiation DPUR	Inadvertent ingestion and inhalation DPUR	Total DPUR	Age group
I-129	1.5E-10	2.9E-10	4.4E-10	Adult
I-131	1.5E-08	2.7E-11	1.5E-08	Adult
I-132	7.0E-09	2.5E-14	7.0E-09	Adult
I-133	7.8E-09	1.6E-12	7.8E-09	Adult
I-134	3.2E-09	3.7E-15	3.2E-09	Adult
I-135	1.2E-08	1.9E-13	1.2E-08	Adult
Cs-134	2.0E-07	7.1E-11	2.0E-07	Adult
Cs-136	1.7E-07	6.5E-12	1.7E-07	Adult
Cs-137	7.4E-08	4.9E-11	7.4E-08	Adult
Ba-140	8.7E-08	2.5E-12	8.7E-08	Adult
La-140	3.5E-08	8.1E-13	3.5E-08	Adult
Ce-141	8.3E-09	3.7E-12	8.3E-09	Adult
Ce-144	1.2E-08	3.5E-11	1.2E-08	Adult
Pm-147	1.6E-12	2.3E-12	3.8E-12	Adult
Sm-153	7.7E-10	6.7E-13	7.7E-10	Adult
Eu-152	2.5E-07	1.4E-11	2.5E-07	Adult
Eu-154	2.7E-07	2.0E-11	2.7E-07	Adult
Eu-155	6.0E-09	2.9E-12	6.0E-09	Adult
Er-169	2.1E-12	1.1E-12	3.1E-12	Adult
Lu-177	2.0E-09	1.2E-12	2.0E-09	Adult
Au-198	1.5E-08	1.1E-12	1.5E-08	Adult
Tl-201	1.9E-09	1.2E-13	1.9E-09	Adult
Pb-210	4.9E-10	7.6E-09	8.0E-09	Adult
Po-210	3.0E-12	1.3E-08	1.3E-08	Adult
Ra-223	2.0E-07	8.6E-10	2.0E-07	Adult
Ra-226	3.9E-07	2.2E-09	4.0E-07	Adult
Th-230	7.0E-11	5.8E-09	5.8E-09	Adult
Th-232	3.0E-11	8.8E-09	8.8E-09	Adult
Th-234	6.5E-09	2.7E-11	6.5E-09	Adult
U-234	3.1E-12	2.0E-10	2.0E-10	Adult
U-235	6.3E-09	1.8E-10	6.5E-09	Adult
U-238	1.3E-09	1.7E-10	1.5E-09	Adult
Np-237	2.6E-09	4.0E-09	6.6E-09	Adult
Pu-238	4.3E-12	8.0E-09	8.0E-09	Adult
Pu-239	9.8E-12	8.7E-09	8.7E-09	Adult
Pu-240	4.2E-12	8.7E-09	8.7E-09	Adult
Pu-241	2.0E-13	1.6E-10	1.6E-10	Adult
Pu-242	3.7E-12	8.4E-09	8.4E-09	Adult
Am-241	2.4E-09	1.3E-08	1.5E-08	Adult
Am-242	1.7E-10	4.3E-13	1.7E-10	Adult
Am-243	5.3E-08	1.3E-08	6.6E-08	Adult
Cm-242	7.9E-12	1.4E-09	1.4E-09	Adult
Cm-243	3.5E-08	9.4E-09	4.4E-08	Adult
Cm-244	5.8E-12	8.1E-09	8.1E-09	Adult

*For a raw sewage flow rate into the sewage treatment works of 60 m^3/d

Table 8 Dose per unit release factors for farming family – sewage release scenario

Radionuclide	DPUR for worst age group farming family (µSv/y per Bq/y of discharge to sewer)*				
	Terrestrial food consumption DPUR	External irradiation DPUR	Inadvertent ingestion and inhalation DPUR	Total DPUR	Age group
H-3	5.1E-11	0.0E+00	6.5E-18	5.1E-11	Infant
H-3 organic	6.9E-12	0.0E+00	1.6E-17	6.9E-12	Infant
C-14	8.5E-08	2.7E-13	9.4E-15	8.5E-08	Offspring
Na-22	2.5E-08	1.1E-06	4.2E-13	1.1E-06	Adult
P-32	1.0E-07	1.0E-10	1.5E-13	1.0E-07	Offspring
P-33	1.1E-07	8.1E-13	3.6E-14	1.1E-07	Offspring
S-35	1.3E-08	4.7E-14	1.1E-14	1.3E-08	Infant
Cl-36	1.4E-06	1.5E-10	1.2E-12	1.4E-06	Infant
Ca-45	2.6E-08	9.1E-12	6.8E-13	2.6E-08	Offspring
Ca-47	4.1E-13	6.6E-10	3.4E-16	6.6E-10	Offspring
V-48	6.0E-13	1.3E-07	5.7E-14	1.3E-07	Adult
Cr-51	1.4E-12	3.4E-09	2.5E-15	3.4E-09	Adult
Mn-52	3.2E-12	3.3E-09	7.4E-16	3.3E-09	Adult
Mn-54	3.0E-08	9.4E-07	8.5E-13	9.7E-07	Adult
Fe-55	2.4E-08	0.0E+00	1.0E-12	2.4E-08	Infant
Fe-59	1.0E-09	3.1E-07	4.7E-13	3.1E-07	Adult
Co-56	3.7E-09	1.8E-06	1.1E-12	1.8E-06	Adult
Co-57	9.2E-10	1.2E-07	4.4E-13	1.3E-07	Adult
Co-58	4.2E-10	3.9E-07	3.2E-13	3.9E-07	Adult
Co-60	7.6E-08	1.4E-05	2.6E-11	1.4E-05	Adult
Ni-63	7.7E-10	0.0E+00	5.7E-13	7.8E-10	Infant
Zn-65	2.8E-06	1.9E-07	1.4E-12	2.9E-06	Infant
Se-75	2.1E-06	5.0E-08	5.6E-13	2.1E-06	Infant
Rb-83	2.1E-08	2.4E-07	2.4E-13	2.6E-07	Adult
Sr-89	1.2E-09	2.8E-11	6.5E-14	1.2E-09	Infant
Sr-90	3.9E-07	1.2E-09	4.4E-12	3.9E-07	Infant
Zr-95	9.5E-12	5.9E-07	9.3E-13	5.9E-07	Adult
Nb-95	5.5E-13	7.5E-08	7.4E-14	7.5E-08	Adult
Tc-99	5.1E-06	6.7E-12	7.2E-13	5.1E-06	Infant
Ru-103	3.3E-13	1.0E-08	2.7E-14	1.0E-08	Adult
Ru-106	3.5E-10	5.5E-08	3.5E-12	5.5E-08	Adult
Ag-110m	8.5E-07	4.6E-06	6.3E-12	5.5E-06	Adult
Sb-125	4.6E-08	1.6E-06	9.3E-12	1.6E-06	Adult
I-125	9.7E-09	5.8E-11	4.4E-13	9.8E-09	Infant
I-129	1.1E-06	1.7E-09	4.5E-11	1.1E-06	Child
I-131	5.9E-10	1.8E-10	2.5E-14	7.7E-10	Infant
Cs-134	1.7E-07	1.9E-06	5.8E-12	2.1E-06	Adult
Cs-136	1.4E-10	2.0E-08	7.3E-15	2.0E-08	Adult
Cs-137	2.5E-07	1.6E-06	9.0E-12	1.8E-06	Adult
Ba-140	2.4E-12	7.4E-09	7.3E-15	7.4E-09	Adult
Ce-141	9.1E-12	4.3E-09	1.4E-13	4.4E-09	Adult
Ce-144	2.6E-09	5.8E-08	1.8E-11	6.1E-08	Adult
Pm-147	3.0E-10	6.2E-12	1.4E-12	3.0E-10	Infant

Table 8 continued

Radionuclide	DPUR for worst age group farming family (µSv/y per Bq/y of discharge to sewer)*				
	Terrestrial food consumption DPUR	External irradiation DPUR	Inadvertent ingestion and inhalation DPUR	Total DPUR	Age group
Eu-152	2.2E-09	4.8E-06	8.4E-11	4.8E-06	Adult
Eu-154	2.6E-09	4.9E-06	9.7E-11	4.9E-06	Adult
Eu-155	3.0E-10	9.0E-08	1.1E-11	9.1E-08	Adult
Er-169	2.9E-13	4.3E-14	1.9E-15	3.3E-13	Infant
Lu-177	1.6E-14	4.9E-11	1.2E-15	4.9E-11	Adult
Pb-210	9.6E-06	3.7E-09	3.2E-09	9.6E-06	Infant
Po-210	4.0E-06	2.8E-12	9.4E-10	4.0E-06	Infant
Ra-223	2.7E-10	1.9E-08	3.7E-11	2.0E-08	Adult
Ra-226	1.0E-06	9.4E-06	1.3E-10	1.0E-05	Offspring
Th-230	1.7E-07	1.7E-09	6.1E-08	2.3E-07	Adult
Th-232	1.8E-07	2.5E-05	1.1E-07	2.5E-05	Adult
Th-234	2.0E-12	2.3E-09	3.7E-13	2.3E-09	Adult
U-234	2.1E-08	2.1E-11	2.7E-10	2.1E-08	Infant
U-235	1.1E-08	1.2E-07	1.5E-09	1.4E-07	Adult
U-238	1.0E-08	2.5E-08	1.4E-09	3.7E-08	Adult
Np-237	3.7E-07	9.0E-07	5.6E-08	1.3E-06	Adult
Pu-238	2.5E-07	1.0E-10	1.1E-07	3.6E-07	Adult
Pu-239	2.9E-07	2.3E-10	1.2E-07	4.1E-07	Adult
Pu-240	2.9E-07	1.0E-10	1.2E-07	4.1E-07	Adult
Pu-241	4.3E-09	3.9E-12	1.8E-09	6.1E-09	Adult
Pu-242	2.8E-07	8.8E-11	1.2E-07	4.0E-07	Adult
Am-241	4.6E-07	5.9E-08	1.8E-07	7.1E-07	Adult
Am-243	4.8E-07	1.3E-06	1.8E-07	2.0E-06	Adult
Cm-242	1.5E-09	2.5E-11	2.7E-09	4.3E-09	Adult
Cm-243	3.4E-07	7.8E-07	1.2E-07	1.2E-06	Adult
Cm-244	2.2E-07	1.2E-10	1.0E-07	3.2E-07	Adult

*For a raw sewage flow rate into the sewage treatment works of 60 m^3/d

Table 9 Dose per unit release factors for children playing in brook – sewage release scenario

Radionuclide	DPUR for worst age group children playing in brook (µSv/y per Bq/y of discharge to sewer)*			
	External irradiation DPUR	Inadvertent ingestion DPUR	Total DPUR	Age group
H-3	0.0E+00	3.1E-14	3.1E-14	Child
H-3 organic	0.0E+00	7.6E-14	7.6E-14	Child
C-14	1.7E-14	3.0E-12	3.0E-12	Child
Na-22	6.8E-11	7.9E-12	7.6E-11	Child
Na-24	1.1E-11	5.5E-13	1.2E-11	Child
P-32	3.7E-12	3.2E-12	6.8E-12	Child
P-33	9.2E-15	3.2E-13	3.3E-13	Child
S-35	2.8E-14	1.4E-12	1.4E-12	Child
Cl-36	0.0E+00	2.7E-12	2.7E-12	Child
Ca-45	1.9E-14	1.6E-12	1.6E-12	Child
Ca-47	4.2E-10	2.4E-12	4.2E-10	Child
V-48	1.6E-10	6.6E-13	1.7E-10	Child
Cr-51	1.6E-10	1.3E-13	1.6E-10	Child
Mn-52	2.5E-08	3.8E-11	2.5E-08	Child
Mn-54	3.4E-08	1.6E-11	3.4E-08	Child
Fe-55	0.0E+00	1.3E-12	1.3E-12	Child
Fe-59	4.7E-09	5.6E-12	4.7E-09	Child
Co-56	4.3E-08	2.0E-11	4.3E-08	Child
Co-57	8.9E-10	2.0E-12	8.9E-10	Child
Co-58	1.1E-08	5.9E-12	1.1E-08	Child
Co-60	3.0E-08	3.8E-11	3.0E-08	Child
Ni-63	0.0E+00	2.4E-12	2.4E-12	Child
Zn-65	1.6E-09	9.8E-12	1.6E-09	Child
Ga-67	2.8E-12	6.6E-14	2.9E-12	Child
Se-75	8.5E-10	9.2E-12	8.5E-10	Child
Br-82	0.0E+00	1.0E-12	1.0E-12	Child
Rb-83	3.5E-09	7.7E-12	3.6E-09	Child
Sr-89	2.4E-11	2.3E-11	4.7E-11	Child
Sr-90	6.5E-11	2.4E-10	3.1E-10	Child
Y-90	5.8E-11	3.1E-11	8.9E-11	Child
Zr-95	1.3E-08	4.8E-12	1.3E-08	Child
Nb-95	2.1E-10	9.4E-13	2.1E-10	Child
Mo-99	2.1E-10	2.6E-12	2.1E-10	Child
Tc-99	1.9E-14	2.2E-12	2.2E-12	Child
Tc-99m	4.2E-12	1.3E-14	4.2E-12	Child
Ru-103	1.2E-08	1.3E-11	1.2E-08	Child
Ru-106	5.7E-09	1.3E-10	5.8E-09	Child
Ag-110m	3.1E-10	9.8E-13	3.1E-10	Child
In-111	6.0E-10	1.4E-12	6.0E-10	Child
Sb-125	2.2E-10	9.9E-13	2.2E-10	Child
I-123	1.7E-11	3.6E-13	1.8E-11	Child
I-125	2.7E-12	5.0E-11	5.3E-11	Child
I-129	2.2E-12	3.1E-10	3.1E-10	Child
I-131	9.4E-11	8.1E-11	1.7E-10	Child
I-133	9.6E-11	9.9E-12	1.1E-10	Child
I-135	8.3E-11	7.5E-13	8.3E-11	Child

Table 9 continued

Radionuclide	DPUR for worst age group children playing in brook (µSv/y per Bq/y of discharge to sewer)*			
	External irradiation DPUR	Inadvertent ingestion DPUR	Total DPUR	Age group
Cs-134	1.1E-08	4.4E-11	1.1E-08	Child
Cs-136	2.9E-09	1.3E-11	2.9E-09	Child
Cs-137	4.0E-09	3.1E-11	4.0E-09	Child
Ba-140	9.3E-09	4.0E-11	9.3E-09	Child
La-140	2.1E-08	6.0E-11	2.1E-08	Child
Ce-141	1.7E-09	1.5E-11	1.7E-09	Child
Ce-144	1.9E-09	1.1E-10	2.0E-09	Child
Pm-147	8.4E-14	2.2E-12	2.3E-12	Child
Sm-153	2.4E-10	1.3E-11	2.6E-10	Child
Eu-152	3.9E-08	2.7E-11	3.9E-08	Child
Eu-154	4.2E-08	4.2E-11	4.2E-08	Child
Eu-155	9.4E-10	7.0E-12	9.5E-10	Child
Er-169	2.8E-13	8.0E-12	8.3E-12	Child
Lu-177	2.0E-10	1.2E-11	2.2E-10	Child
Au-198	2.3E-09	1.9E-11	2.3E-09	Child
Tl-201	3.6E-10	1.4E-12	3.6E-10	Child
Pb-210	3.7E-12	1.8E-09	1.8E-09	Child
Po-210	2.4E-14	2.5E-09	2.5E-09	Child
Ra-223	4.3E-10	5.1E-10	9.3E-10	Child
Ra-226	2.5E-09	9.4E-10	3.5E-09	Child
Th-230	6.9E-13	2.9E-10	2.9E-10	Child
Th-232	9.9E-09	3.5E-10	1.0E-08	Child
Th-234	9.0E-11	8.8E-12	9.9E-11	Child
U-234	1.5E-14	1.1E-10	1.1E-10	Child
U-235	3.0E-11	1.1E-10	1.4E-10	Child
U-238	6.2E-12	1.0E-10	1.1E-10	Child
Np-237	4.9E-12	8.8E-11	9.3E-11	Child
Pu-238	9.5E-13	3.3E-09	3.3E-09	Child
Pu-239	2.1E-12	3.8E-09	3.8E-09	Child
Pu-240	9.1E-13	3.8E-09	3.8E-09	Child
Pu-241	4.3E-14	7.1E-11	7.1E-11	Child
Pu-242	8.0E-13	3.6E-09	3.6E-09	Child
Am-241	6.9E-11	7.0E-10	7.7E-10	Child
Am-242	1.4E-11	1.1E-12	1.5E-11	Child
Am-243	1.5E-09	7.0E-10	2.2E-09	Child
Cm-242	2.4E-13	7.6E-11	7.6E-11	Child
Cm-243	9.9E-10	5.1E-10	1.5E-09	Child
Cm-244	1.7E-13	4.4E-10	4.4E-10	Child

*For a brook flow rate of 0.1 m^3/s

Table 10 Discharge rate of radionuclides from the sewage treatment works per unit release into the sewage treatment works

Radionuclide	Discharge rate (Bq/y discharge from sewage works per Bq/y of discharge into sewage works)*
H-3	8.5E-01
H-3 organic	8.5E-01
C-14	8.5E-01
Na-22	9.0E-01
Na-24	4.5E-01
P-32	1.9E-01
P-33	2.0E-01
S-35	8.9E-01
Cl-36	9.0E-01
Ca-45	2.0E-01
Ca-47	1.8E-01
V-48	9.7E-02
Cr-51	9.8E-02
Mn-52	4.6E-01
Mn-54	5.0E-01
Fe-55	1.0E-01
Fe-59	9.9E-02
Co-56	2.0E-01
Co-57	2.0E-01
Co-58	2.0E-01
Co-60	2.0E-01
Ni-63	5.0E-01
Zn-65	5.0E-01
Ga-67	8.7E-02
Se-75	5.0E-01
Br-82	6.7E-01
Rb-83	2.0E-01
Sr-89	8.9E-01
Sr-90	9.0E-01
Y-90	7.6E-01
Zr-95	9.9E-02
Nb-95	4.9E-01
Mo-99	7.7E-01
Tc-99	9.0E-01
Tc-99m	1.6E-01
Ru-103	8.9E-01
Ru-106	9.0E-01
Ag-110m	9.9E-02
In-111	8.5E-02
Sb-125	2.0E-01
I-123	3.6E-01
I-125	7.9E-01
I-129	8.0E-01
I-131	7.6E-01
I-133	4.8E-01
I-135	1.7E-01

Table 10 continued

Radionuclide	Discharge rate (Bq/y discharge from sewage works per Bq/y of discharge into sewage works)*
Cs-134	7.0E-01
Cs-136	6.7E-01
Cs-137	7.0E-01
Ba-140	8.7E-01
La-140	6.9E-01
Ce-141	4.9E-01
Ce-144	5.0E-01
Pm-147	5.0E-01
Sm-153	4.0E-01
Eu-152	5.0E-01
Eu-154	5.0E-01
Eu-155	5.0E-01
Er-169	4.8E-01
Lu-177	4.7E-01
Au-198	4.2E-01
Tl-201	4.3E-01
Pb-210	1.0E-01
Po-210	9.9E-02
Ra-223	4.8E-01
Ra-226	5.0E-01
Th-230	1.0E-01
Th-232	1.0E-01
Th-234	9.8E-02
U-234	9.0E-01
U-235	9.0E-01
U-238	9.0E-01
Np-237	5.0E-01
Pu-238	5.0E-01
Pu-239	5.0E-01
Pu-240	5.0E-01
Pu-241	5.0E-01
Pu-242	5.0E-01
Am-241	1.0E-01
Am-242	5.2E-02
Am-243	1.0E-01
Cm-242	9.9E-02
Cm-243	1.0E-01
Cm-244	1.0E-01

*The factors in this table should be used to take account of losses during transit through a sewage treatment works when assessing the doses to angler and irrigated food consumer families as a result of releases to sewer

Table 11 Recommended default radionuclides for other alpha and other beta/gamma categories

Category	Default radionuclide for each discharge scenario*			
	Atmosphere	Estuary / coastal water	River	Sewage
Other alpha	Pu-239	Th-232	Po-210	Th-232
Other beta/gamma (half-life < 1 day)	Am-242	I-133	I-133	Na-24
Other beta/gamma (half-life < 10 days)	I-131	Mn-52	Mn-52	Mn-52
Other beta/gamma (half-life > 10 days)	Pb-210	Pb-210	P-32	Co-60

*The radionuclides shown here lead to the highest dose for each category and discharge scenario

Table 12 Examples of how initial assessment methodology data can be used for site-specific assessment

Parameter	Examples of site-specific information	Assessed using initial radiological assessment data
Releases to air		
Dispersion modelling data	Site-specific dispersion modelling data are available for persons living near the site who are exposed via inhalation of the plume and external radiation, and also for the point of local food production.	Site-specific scaling factors may be calculated to replace those derived from Figure 2. Annual average air concentrations per unit release are required. The scaling factors are calculated by dividing the annual average air concentration per unit release (s/m^3) by 7 10^{-5} s/m^3 for the exposed person scaling factor and by 4 10^{-6} s/m^3 for the food production scaling factors. These scaling factors may be used in the Stage 2 pro formas in Appendix A.
Location of food production	The site is in a built-up area. Fruit and vegetables could be grown at a distance of 500 m from the release point at an allotment, but the nearest farm at which milk and meat products could be produced is at a distance of 2 km from the release point. Site-specific dispersion modelling data (average air concentration per unit release) are available for these two food production locations.	Obtain DPUR factors from detailed report [6] for individual food groups (e.g. green vegetables, root vegetables, milk, etc.). Calculate new DPUR factors for allotment-produced food and farm-produced food for each age group. The DPUR factors can then be multiplied by a scaling factor. The scaling factors are calculated by dividing the annual average air concentration per unit release at the different food production locations (s/m^3) by 4 10^{-6} s/m^3.
Releases to estuary/coastal water		
Habits – fish consumption rate	Habit survey data are available on the consumption of fish and shellfish in the estuary into which the discharges flow.	The individual DPUR factors for fish, molluscs and crustacea are provided in the detailed report [6]. These DPUR factors can then be multiplied by the known consumption rates divided by the consumption rates used in the assessment, which are detailed in Reference [6].
Habits – occupancy on inter-tidal sediment	Habit survey data are available on the time spent on inter-tidal sediment around the estuary into which the discharges flow.	The DPUR factors for external dose can be multiplied by the known occupancy rate divided by the occupancy rate used in the assessment, which is detailed in Reference [6].

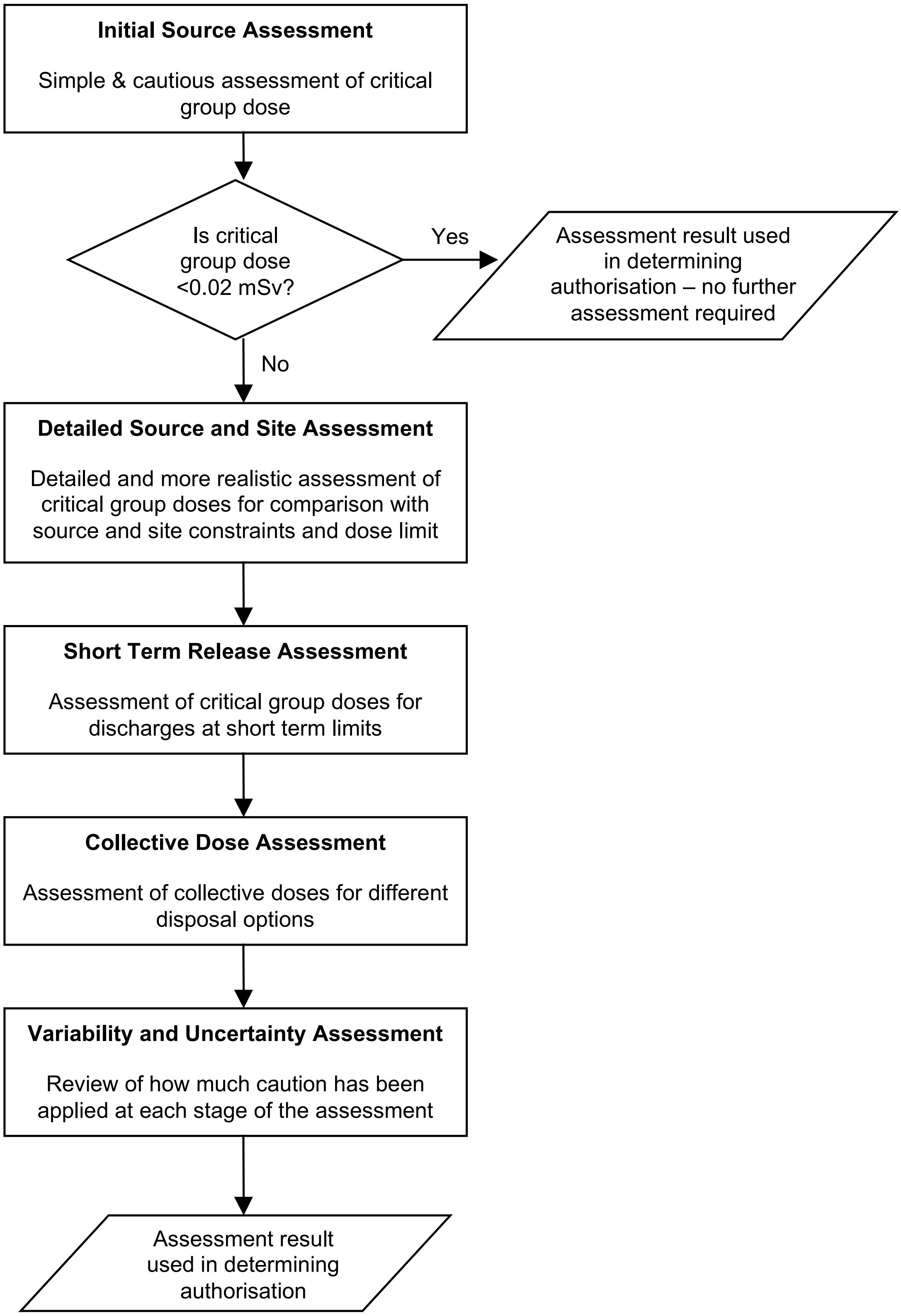
Table 12 continued

Parameter	Examples of site-specific information	Assessed using initial radiological assessment data
Releases to river		
Location of drinking water abstraction	The location of drinking water abstraction is 5 km downstream of the release point where the flow rate is much higher than that at the release point.	The DPUR factors are modified to take account of different river flow rates, by dividing by the river flow rate (m^3/s). The drinking water DPUR factor may be modified by a different river flow rate than the DPUR factor for consumption of fish and sediment.
Treatment of drinking water	Drinking water is treated and stored in reservoirs – there are no raw water uses.	The DPUR factors do not take account of removal of radionuclides by treatment processes or decay of radionuclides before consumption of water. The DPUR factors can be multiplied by drinking water treatment factors provided in Reference [8].
Habits – fish consumption rate	Habit survey data are available on the consumption of freshwater fish in the river. A site-specific consumption rate is likely to be lower than that assumed to derive the DPUR factors, unless there is a fish farm on the river.	The DPUR factor for fish can be multiplied by the known consumption rate divided by the consumption rate used in the assessment, which is detailed in Reference [6].
Irrigated food consumption	There is no abstraction of water for irrigation of food crops.	Exclude the assessment of doses to irrigated food consumers.
Releases to sewer		
Disposal route for sewage sludge	Sewage sludge incinerated.	The authorisation limits for disposal to sewer can be used with the DPUR factors for releases to air. A Stage 2 assessment to take account of the stack height may be required. The assessment may be refined further by only including the activity which is transferred to the sewage sludge in the assessment. The partitioning coefficients for sewage which give the fraction of activity retained on sewage sludge are detailed in Reference [6]. Decay of the radionuclides before incineration may be taken into account if site-specific information is available on the delay time between production of sewage sludge and its subsequent incineration.
Occupancy at sewage treatment works	The sewerage undertaker has provided information on occupancy of sewage treatment workers around sludge tanks and facilities containing raw sewage.	The DPUR factors for sewage treatment workers can be scaled by a factor to take account of the actual occupancy data. This factor is the maximum of: • occupancy around sludge tanks divided by 500 h/y; • occupancy around raw sewage facilities divided by 1,500 h/y. It may also be appropriate to disregard the external radiation from pure beta-emitting radionuclides, if there is no contact with sludge or raw sewage.
Application rate of sludge to land	The sewerage undertaker has provided information on the quantity of sewage sludge produced each year and the area of land over which it is spread.	The spreading rate in units of $kg/m^2/y$ can be calculated. This can be divided by the values assumed in the assessment of 8 $kg/m^2/y$. This factor can then be multiplied by the DPUR factors for the farming family living on sludge conditioned land.
Decay before application	Information has been provided on the actual time between raw sewage entering the sewage treatment works and the time at which sludge is used to condition land.	The assessment assumes a time period of 656 h between raw sewage entering the sewage treatment works and the time at which sludge is used to condition land. Further decay of radionuclides beyond the 656 h may be taken into account.

Table 12 continued

Parameter	Examples of site-specific information	Assessed using initial radiological assessment data
Releases to sewer (continued)		
Food produced on sludge conditioned land	Sludge is only used to condition land upon which grain and cereal crops are produced.	It is normal to assume that grain is mixed from a variety of sources and any resultant doses will be small. However, it is necessary to know whether sludge could be used for conditioning pasture or soil on which vegetables are grown in the future. Identify the possible disposal routes for the sewage sludge for the type of treatment in place at the sewage treatment works, based on the Safe Sludge Matrix. Any plans by the sewerage undertaker to upgrade the sewage treatment works in the near future (3–5 years) should be taken into account. If sludge can be used for conditioning pasture or soil or will likely to be used in this way in the future, then the assessment remains valid. Otherwise, it can be assumed that only the external dose, inhalation and inadvertent ingestion pathways need to be included in the dose assessment.
Children playing in brook	Children may not be able to access the brook receiving treated effluent from a sewage treatment works, perhaps because it is culverted.	Exclude the assessment of doses to a child playing in a brook.
Angler family and irrigated food consumer	See releases to river.	
Fisherman family	See releases to estuary/coastal water.	

Figures



(diagram reproduced from Reference [5])

Figure 1 Stages of dose assessment process for discharge authorisations

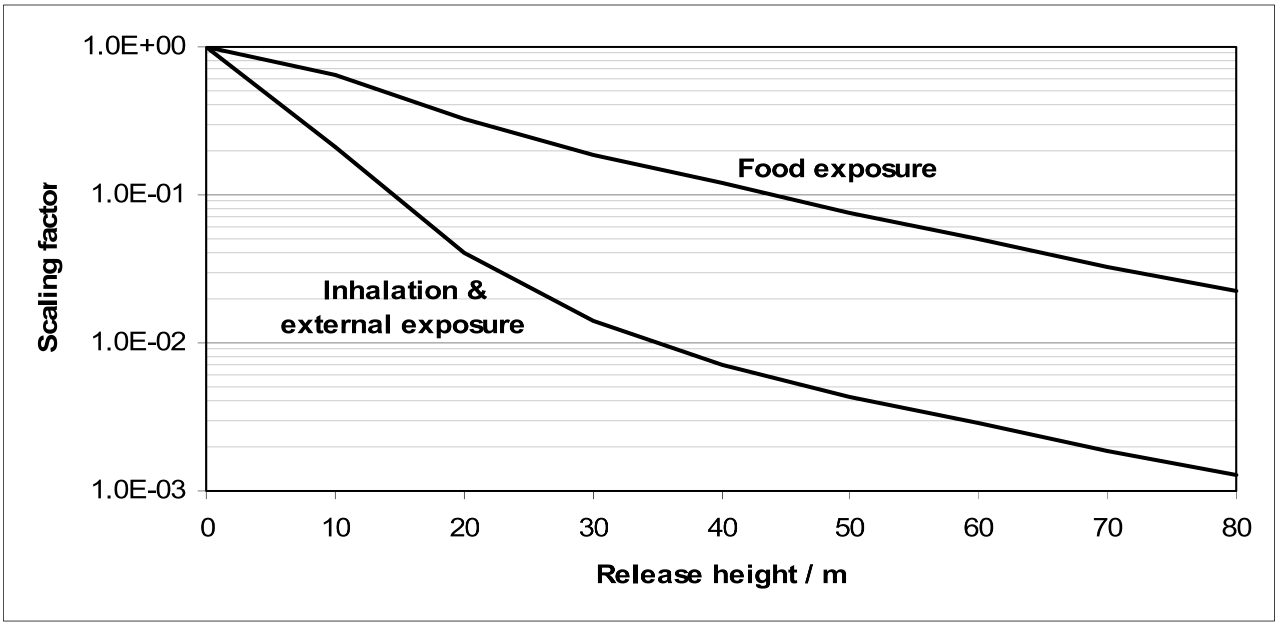


Figure 2 Scaling factors for different release heights for releases to air

The scaling factors for the inhalation and external dose pathways have been derived from the maximum ground-level concentration for each release height (at a distance no closer than 100 m to the release point) divided by the maximum ground-level concentration for a ground-level release at 100 m ($7\ 10^{-5}$ Bq/m^3 per Bq/s). Similarly, the scaling factors for the food dose pathway are derived from the maximum ground-level concentration for each release height (at a distance no closer than 500 m to the release point) divided by the maximum ground-level concentration for a ground-level release at 500 m ($4\ 10^{-6}$ Bq/m^3 per Bq/s).

Appendix A How to use dose per unit release values

The following pro forma can be used to help guide Stage 1 and Stage 2 assessments.

Stage 1 – Initial assessment using default data

Releases to air

Releases to air Exposure group – Local resident family [1]			
Radionuclide	**Discharge (Bq/y) [A]**	**Total DPUR from Table 2 (μSv/y per Bq/y) [B]**	**Dose (μSv/y) [C] = [A] x [B]**
		Total dose (μSv/y) Sum of [C]	

Releases to estuary/coastal water

Releases to estuary/coastal water Exposure group – Fisherman family [2]			
Radionuclide	**Discharge (Bq/y) [A]**	**Total DPUR from Table 3 (μSv/y per Bq/y) [B]**	**Dose# (μSv/y) [C] = [A] x [B]**
		Total dose (μSv/y) Sum of [C]	

The dose should be multiplied by 3.3 for small estuaries, particularly on the east coast of Britain (see Section 3.2)

Releases to river

Releases to river Exposure group – Angler family [3]			
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 5 (μSv/y per Bq/y) [B]	Dose (μSv/y) [C] = [A] x [B]
		Total dose (μSv/y) Sum of [C]	

Releases to river Exposure group – Irrigated food consumer family [4]			
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 6 (μSv/y per Bq/y) [B]	Dose (μSv/y) [C] = [A] x [B]
		Total dose (μSv/y) Sum of [C]	

Releases to sewer

Releases to sewer Exposure group – Sewage treatment workers [5]			
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 7 (μSv/y per Bq/y) [B]	Dose (μSv/y) [C] = [A] x [B]
		Total dose (μSv/y) Sum of [C]	

Releases to sewer Exposure group – Farming family on sludge conditioned land [6]			
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 8 (μSv/y per Bq/y) [B]	Dose (μSv/y) [C] = [A] x [B]
		Total dose (μSv/y) Sum of [C]	

Releases to sewer Exposure group – Children playing in brook [7]			
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 9 (μSv/y per Bq/y) [B]	Dose (μSv/y) [C] = [A] x [B]
		Total dose (μSv/y) Sum of [C]	

Releases to sewer Exposure group – Fisherman family [8]				
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 3 (μSv/y per Bq/y) [B]	STW discharge factor from Table 10 [C]	Dose# (μSv/y) [D] = [A] x [B] x [C]
			Total dose (μSv/y) Sum of [D]	

The dose should be multiplied by 3.3 for small estuaries, particularly on the east coast of Britain (see Section 3.2)

Releases to sewer Exposure group – Angler family [9]				
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 5 (μSv/y per Bq/y) [B]	STW discharge factor from Table 10 [C]	Dose (μSv/y) [D] = [A] x [B] x [C]
			Total dose (μSv/y) Sum of [D]	

Releases to sewer Exposure group – Irrigated food consumer family [10]				
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 6 (μSv/y per Bq/y) [B]	STW discharge factor from Table 10 [C]	Dose (μSv/y) [D] = [A] x [B] x [C]
			Total dose (μSv/y) Sum of [D]	

Stage 1 – Summary total dose

Release route	Exposure group	Total dose (μSv/y)	Worst total dose (μSv/y)	
Air	Local resident family [1]		[1]	
Estuary/coastal water	Fisherman family [2]		[2]	
River	Angler family [3]		[12] = Maximum of [3] or [4]	
	Irrigated food consumer family [4]			
Sewer	Sewage treatment workers [5]		[13] = Maximum of [5], [6], [7], [8], [9] or [10]	
	Farming family on sludge conditioned land [6]			
	Children playing in brook [7]			
	Fisherman family [8]			
	Angler family [9]			
	Irrigated food consumer family [10]			
Direct radiation[#]	Local resident family [11]		[11]	
Total critical group dose (μSv/y) [1] + [2] + [11] + [12] + [13]				

[#] Where significant off-site dose rates have been measured from sources on-site

Stage 2 – Initial assessment using refined data

Releases to air

Releases to air Exposure group – Local resident family [1]			Food dose scaling factor from Figure 2 [E]		
			Inhalation and external dose scaling factor from Figure 2 [F]		
Radionuclide	Discharge (Bq/y) [A]	Food DPUR from Table 2 (μSv/y per Bq/y) [B]	External DPUR from Table 2 (μSv/y per Bq/y) [C]	Inhalation DPUR from Table 2 (μSv/y per Bq/y) [D]	Dose (μSv/y) [G] = [A] x [B] x [E] + [A] x [C] x [F] + [A] x [D] x [F]
				Total dose (μSv/y) Sum of [G]	

Releases to estuary/coastal water

Releases to estuary/coastal water Exposure group – Fisherman family [2]		Exchange rate (m^3/s) [C] (see Table 4)#	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 3 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 100 / [C]
		Total dose (μSv/y) Sum of [D]	

For small estuaries, particularly on the east coast of Britain, the exchange rate should be set to 30 m^3/s (see Section 3.2)

Releases to river

Releases to river Exposure group – Angler family [3]		River flow rate (m^3/s) [C]	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 5 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 1 / [C]
		Total dose (μSv/y) Sum of [D]	

Releases to river Exposure group – Irrigated food consumer family [4]		River flow rate (m^3/s) [C]	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 6 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 1 / [C]
		Total dose (μSv/y) Sum of [D]	

Releases to sewer

Releases to sewer Exposure group – Sewage treatment workers [5]		Raw sewage flow rate (m^3/day) [C]	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 7 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 60 / [C]
		Total dose (μSv/y) Sum of [D]	

Releases to sewer Exposure group – Farming family on sludge conditioned land [6]		Raw sewage flow rate (m^3/day) [C]	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 8 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 60 / [C]
		Total dose (μSv/y) Sum of [D]	

Releases to sewer Exposure group – Children playing in brook [7]		Brook flow rate (m^3/s) [C]	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 9 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 0.1 / [C]
		Total dose (μSv/y) Sum of [D]	

Releases to sewer Exposure group – Fisherman family [8]			Exchange rate (m^3/s) [D] (see Table 10)#	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 3 (μSv/y per Bq/y) [B]	STW discharge factor from Table 10 [C]	Dose (μSv/y) [E] = [A] x [B] x [C] x 100 / [D]
			Total dose (μSv/y) Sum of [E]	

For small estuaries, particularly on the east coast of Britain, the exchange rate should be set to 30 m^3/s (see Section 3.2)

Releases to sewer Exposure group – Angler family [9]			River flow rate (m^3/s) [D]	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 5 (μSv/y per Bq/y) [B]	STW discharge factor from Table 10 [C]	Dose (μSv/y) [E] = [A] x [B] x [C] x 1 / [D]
			Total dose (μSv/y) Sum of [E]	

Releases to sewer Exposure group – Irrigated food consumer family [10]			River flow rate (m^3/s) [D]	
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 6 (μSv/y per Bq/y) [B]	STW discharge factor from Table 10 [C]	Dose (μSv/y) [E] = [A] x [B] x [C] x 1 / [D]
			Total dose (μSv/y) Sum of [E]	

Stage 2 - Summary total dose

Release route	Exposure group	Total dose (μSv/y)	Worst total dose (μSv/y)	
Air	Local resident family [1]		[1]	
Estuary/coastal water	Fisherman family [2]		[2]	
River	Angler family [3]		[12] = Maximum of [3] or [4]	
	Irrigated food consumer family [4]			
Sewer	Sewage treatment workers [5]		[13] = Maximum of [5], [6], [7], [8], [9] or [10]	
	Farming family on sludge conditioned land [6]			
	Children playing in brook [7]			
	Fisherman family [8]			
	Angler family [9]			
	Irrigated food consumer family [10]			
Direct radiation#	Local resident family [11]		[11]	
			Total critical group dose (μSv/y) [1] + [2] + [11] + [12] + [13]	

#Where significant off-site dose rates have been measured from sources on-site

Note – It may be possible to demonstrate that the doses from some groups should not be combined (see guidance on Stage 2 in Section 4.2)

Appendix B Worked examples

Example 1: A hospital in the Thames Valley

A hospital in the Thames Valley has an incinerator permitted to discharge 420 MBq/month (5.04 GBq/y) of carbon-14 to air and an authorisation permitting the discharge of 120 GBq/month (1.44 TBq/y) of iodine-131 to sewer.

Stage 1 – Initial radiological assessment using default data

The initial radiological assessment results using default data are as follows:

Releases to air

Releases to air Exposure group – Local resident family [1]			
Radionuclide	**Discharge (Bq/y) [A]**	**Total DPUR from Table 2 (μSv/y per Bq/y) [B]**	**Dose (μSv/y) [C] = [A] x [B]**
C-14	5.04E+09	6.8E-11	3.4E-01
		Total dose (μSv/y) Sum of [C]	**3.4E-01**

Releases to sewer

Releases to sewer Exposure group – Sewage treatment workers [5]			
Radionuclide	**Discharge (Bq/y) [A]**	**Total DPUR from Table 7 (μSv/y per Bq/y) [B]**	**Dose (μSv/y) [C] = [A] x [B]**
I-131	1.44E+12	1.5E-08	2.2E+04
		Total dose (μSv/y) Sum of [C]	**2.2E+04**

Releases to sewer Exposure group – Farming family on sludge conditioned land [6]			
Radionuclide	**Discharge (Bq/y) [A]**	**Total DPUR from Table 8 (μSv/y per Bq/y) [B]**	**Dose (μSv/y) [C] = [A] x [B]**
I-131	1.44E+12	7.7E-10	1.1E+03
		Total dose (μSv/y) Sum of [C]	**1.1E+03**

Releases to sewer Exposure group – Children playing in brook [7]			
Radionuclide	**Discharge (Bq/y)** **[A]**	**Total DPUR from Table 9 (μSv/y per Bq/y)** **[B]**	**Dose (μSv/y)** **[C] = [A] x [B]**
I-131	1.44E+12	1.7E-10	2.4E+02
		Total dose (μSv/y) Sum of [C]	**2.4E+02**

Releases to sewer Exposure group – Fisherman family [8]				
Radionuclide	**Discharge (Bq/y)** **[A]**	**Total DPUR from Table 3 (μSv/y per Bq/y)** **[B]**	**STW discharge factor from Table 10** **[C]**	**Dose (μSv/y)** **[D] = [A] x [B] x [C]**
I-131	1.44E+12	2.5E-12	7.6E-01	2.7E+00
			Total dose (μSv/y) Sum of [D]	**2.7E+00**

Releases to sewer Exposure group – Angler family [9]				
Radionuclide	**Discharge (Bq/y)** **[A]**	**Total DPUR from Table 5 (μSv/y per Bq/y)** **[B]**	**STW discharge factor from Table 10** **[C]**	**Dose (μSv/y)** **[D] = [A] x [B] x [C]**
I-131	1.44E+12	1.7E-09	7.6E-01	1.9E+03
			Total dose (μSv/y) Sum of [D]	**1.9E+03**

Releases to sewer Exposure group – Irrigated food consumer family [10]				
Radionuclide	**Discharge (Bq/y)** **[A]**	**Total DPUR from Table 6 (μSv/y per Bq/y)** **[B]**	**STW discharge factor from Table 10** **[C]**	**Dose (μSv/y)** **[D] = [A] x [B] x [C]**
I-131	1.44E+12	3.8E-11	7.6E-01	4.2E+01
			Total dose (μSv/y) Sum of [D]	**4.2E+01**

Stage 1 – Summary total dose

Release route	Exposure group	Total dose (μSv/y)	Worst total dose (μSv/y)	
Air	Local resident family [1]	3.4E-01	[1]	3.4E-01
Sewer	Sewage treatment workers [5]	2.2E+04	[13] = Maximum of [5], [6], [7], [8], [9] or [10]	2.2E+04
	Farming family on sludge conditioned land [6]	1.1E+03		
	Children playing in brook [7]	2.4E+02		
	Fisherman family [8]	2.7E+00		
	Angler family [9]	1.9E+03		
	Irrigated food consumer family [10]	4.2E+01		
Total critical group dose (μSv/y) [1] + [13]				**2.2E+04**

For the release to air the dose is 0.34 μSv/y. For release to sewer, the highest dose of 22,000 μSv/y is predicted for the workers at the sewage treatment works. The resultant total dose of 22,000 μSv/y is much greater than 20 μSv/y. As a result, refined data should be used for the release to sewer (Stage 2).

Stage 2 – Initial radiological assessment using refined data

The refinements required relate to discharges to sewer. The main refinements are to determine which sewage treatment works receives the releases to sewer and establish the average annual raw sewage flow. The treated effluent from the sewage treatment works flows to a brook, which then enters the lower reaches of the freshwater Thames and then goes into the Thames Estuary. After periods of dry weather the brook flow is maintained by the treated effluent from the sewage treatment works. Downstream of where the brook joins the freshwater Thames, the Thames is a source of drinking water and is used by a large number of anglers for coarse fishing. The coarse fish are mostly thrown back.

Refined flow-rate data have been established are as follows:

Raw throughput of sewage to sewage treatment works:	30,000 m^3/d
Average volumetric flow rate in the brook:	0.3 m^3/s
Average volumetric flow rate in River Thames:	30 m^3/s
Average water exchange rate in the Thames Estuary:	380 m^3/s

The flow through the works is 5,000 times higher than the default for the initial assessment of 60 m^3/d. The greater dilution means that the estimated doses will be much reduced.

Releases to sewer Exposure group – Sewage treatment workers [5]		Raw sewage flow rate (m^3/day) [C]	30,000
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 7 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 60 / [C]
I-131	1.44E+12	1.5E-08	4.3E+01
		Total dose (μSv/y) Sum of [D]	**4.3E+01**

Releases to sewer Exposure group – Farming family on sludge conditioned land [6]		Raw sewage flow rate (m^3/day) [C]	30,000
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 8 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 60 / [C]
I-131	1.44E+12	7.7E-10	2.2E+00
		Total dose (μSv/y) Sum of [D]	**2.2E+00**

Releases to sewer Exposure group – Children playing in brook [7]		Brook flow rate (m^3/s) [C]	0.3
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 9 (μSv/y per Bq/y) [B]	Dose (μSv/y) [D] = [A] x [B] x 0.1 / [C]
I-131	1.44E+12	1.7E-10	8.2E+01
		Total dose (μSv/y) Sum of [D]	**8.2E+01**

Releases to sewer Exposure group – Fisherman family [8]			Exchange rate (m^3/s) [D]	380
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 3 (μSv/y per Bq/y) [B]	STW discharge factor from Table 10 [C]	Dose (μSv/y) [E] = [A] x [B] x [C] x 100 / [D]
I-131	1.44E+12	2.5E-12	7.6E-01	7.2E-01
			Total dose (μSv/y) Sum of [E]	**7.2E-01**

Releases to sewer Exposure group – Angler family [9]			River flow rate (m^3/s) [D]	30
Radionuclide	**Discharge (Bq/y)** **[A]**	**Total DPUR from Table 5 (μSv/y per Bq/y)** **[B]**	**STW discharge factor from Table 10** **[C]**	**Dose (μSv/y)** **[E] = [A] x [B] x [C] x 1 / [D]**
I-131	1.44E+12	1.7E-09	7.6E-01	6.2E+01
			Total dose (μSv/y) Sum of [E]	**6.2E+01**

Releases to sewer Exposure group – Irrigated food consumer family [10]			River flow rate (m^3/s) [D]	30
Radionuclide	**Discharge (Bq/y)** **[A]**	**Total DPUR from Table 6 (μSv/y per Bq/y)** **[B]**	**STW discharge factor from Table 10** **[C]**	**Dose (μSv/y)** **[E] = [A] x [B] x [C] x 1 / [D]**
I-131	1.44E+12	3.8E-11	7.6E-01	1.4E+00
			Total dose (μSv/y) Sum of [E]	**1.4E+00**

Stage 2 – Summary total dose

Release route	Exposure group	Total dose (μSv/y)	Worst total dose (μSv/y)	
Air	Local resident family [1]	3.4E-01	[1]	3.4E-01
Sewer	Sewage treatment workers [5]	4.3E+01	[13] = Maximum of [5], [6], [7], [8], [9] or [10]	8.2E+01
	Farming family on sludge conditioned land [6]	2.2E+00		
	Children playing in brook [7]	8.2E+01		
	Fisherman family [8]	7.2E-01		
	Angler family [9]	6.2E+01		
	Irrigated food consumer family [10]	1.4E+00		
			Total critical group dose (μSv/y) [1] + [13]	8.2E+01

The highest dose is now for children playing in the brook at 82 μSv/y. The second highest dose is 62 μSv/y to the angler family and the third highest is 43 μSv/y to the sewage treatment workers. As these are still greater than 20 μSv/y, it is necessary to consider whether a separate detailed site-specific assessment is required (Stage 3).

Stage 3 – Determine need for a separate site-specific radiological assessment

A Stage 3 review will help determine a number of key facts such as what the actual disposal routes are for sewage sludge; whether there is access to the brook such that children can play in the stream; what proportion of the fish caught by anglers is kept for consumption; whether there is drinking water abstraction downstream of the discharge of treated effluent from the sewage treatment works into the River Thames; whether any treatment is applied to the drinking water which could have an effect on radionuclide concentrations; and whether there are any other exposure pathways, such as the production and consumption of watercress.

An initial radiological assessment for releases to air may be undertaken if the sewage sludge is incinerated (see Table 12). The doses to children playing in a brook may be ignored, if there is no physical access to the brook. The water consumption doses may be excluded for the angler family group, if there is no drinking water abstraction downstream of the discharge point from the sewage treatment works or modified if it is subject to water treatment processes. The dose to the angler family from the consumption of freshwater fish may be scaled by lower consumption rates.

Example 2: A university research department

A research department in a large university is seeking an authorisation to discharge radionuclides to air. The following discharge limits are to be included: 2 MBq/month (24 MBq/y) of tritium, 4.2 MBq/month (50.4 MBq/y) of carbon-14, 4.2 MBq/month (50.4 MBq/y) of sulphur-35, 1.5 MBq/month (18 MBq/y) of iodine-125 and 260 MBq/month (3.12 GBq/y) of iodine-131.

Stage 1 – Initial radiological assessment using default data

The initial radiological assessment results using default data are as follows:

Releases to air

Releases to air Exposure group – Local resident family [1]			
Radionuclide	**Discharge (Bq/y) [A]**	**Total DPUR from Table 2 (μSv/y per Bq/y) [B]**	**Dose (μSv/y) [C] = [A] x [B]**
H-3	2.40E+07	9.6E-13	2.3E-05
C-14	5.04E+07	6.8E-11	3.4E-03
S-35	5.04E+07	8.4E-11	4.2E-03
I-125	1.80E+07	3.1E-09	5.6E-02
I-131	3.12E+09	4.5E-09	1.4E+01
		Total dose (μSv/y) Sum of [C]	**1.4E+01**

The total dose for the local resident family from releases to air is 14 μSv/y, which is below 20 μSv/y. As a result, no further assessments should be warranted.

Example 3: A nuclear power station

A nuclear power station is licensed, under authorisation, to discharge radionuclides to air and to sea. The following rolling 12-month limits for discharges to air are included in the authorisation: 6 TBq of tritium, 5 TBq of carbon-14, 160 GBq of sulphur-35, 60 TBq of argon-41, 5 GBq of iodine-131 and 1 GBq of ‘beta particulates’, here represented by cobalt-60. The following rolling 12-month limits for discharges to sea are included: 1.2 PBq of tritium, 3 TBq of sulphur-35, 30 GBq of cobalt-60 and 300 GBq of ‘other’, here represented by caesium-137.

Stage 1 – Initial radiological assessment using default data

The initial radiological assessment results using default data are as follows:

Releases to air

Releases to air Exposure group – Local resident family [1]			
Radionuclide	**Discharge (Bq/y) [A]**	**Total DPUR from Table 2 (μSv/y per Bq/y) [B]**	**Dose (μSv/y) [C] = [A] x [B]**
H-3	6.0E+12	9.6E-13	5.8E+00
C-14	5.0E+12	6.8E-11	3.4E+02
S-35	1.6E+11	8.4E-11	1.3E+01
Ar-41	6.0E+13	3.2E-12	1.9E+02
I-131	5.0E+09	4.5E-09	2.3E+01
Co-60	1.0E+09	1.2E-08	1.2E+01
		Total dose (μSv/y) Sum of [C]	**5.9E+02**

Releases to estuary/coastal water

Releases to estuary/coastal water Exposure group – Fisherman family [2]			
Radionuclide	**Discharge (Bq/y) [A]**	**Total DPUR from Table 3 (μSv/y per Bq/y) [B]**	**Dose (μSv/y) [C] = [A] x [B]**
H-3	1.2E+15	8.9E-16	1.1E+00
S-35	3.0E+12	7.9E-15	2.4E-02
Co-60	3.0E+10	2.8E-09	8.4E+01
Cs-137	3.0E+11	1.5E-10	4.5E+01
		Total dose (μSv/y) Sum of [C]	**1.3E+02**

Stage 1 – Summary total dose

Release route	Exposure group	Total dose (μSv/y)	Worst total dose (μSv/y)	
Air	Local resident family [1]	390	[1]	590
Estuary/coastal water	Fisherman family [2]	130	[2]	130
Direct radiation	Local resident family [11]	19	[11]	19
			Total critical group dose (μSv/y) [1] + [2] + [11]	**739**

For releases to air the dose is 590 μSv/y and for releases to sea it is 130 μSv/y. There is an additional contribution from direct radiation, of 19 μSv/y. The resultant total dose of 739 μSv/y is greater than 20 μSv/y. As a result, refined data should be used for both the releases to atmosphere and the coastal environment (Stage 2).

Stage 2 – Initial radiological assessment using refined data

For the releases to atmosphere the main refinement is to determine which effective stack height the releases are made from. For this site the effective stack height is 20 m. This will have the effect of reducing air concentrations and deposition rates at the receptor locations and, in turn, doses to the local resident family.

For the liquid discharges the main refinement is to determine the characteristics of the releases and the receiving environment. At this site releases are via pipeline directly to the sea. Local beaches are used for bait digging and recreational use. Some fish and seafood are caught locally and sold on regionally. The water exchange rate of the the receiving water is 130 m^3/s, which is higher than the 100 m^3/s assumed in Stage 1. The resulting greater dilution will result in a reduction in estimated doses.

The fishermen do not live close to the site so it is not appropriate to sum the doses for the fisherman family and the local resident family.

Releases to air

Releases to air Exposure group – Local resident family [1]			Food dose scaling factor from Figure 2 [E]		0.27
			Inhalation and external dose scaling factor from Figure 2 [F]		0.04
Radionuclide	Discharge (Bq/y) [A]	Food DPUR from Table 2 (µSv/y per Bq/y) [B]	External DPUR from Table 2 (µSv/y per Bq/y) [C]	Inhalation DPUR from Table 2 (µSv/y per Bq/y) [D]	Dose (µSv/y) [G] = [A] x [B] x [E] + [A] x [C] x [F] + [A] x [D] x [F]
H-3	6.0E+12	2.7E-13	0.0E+00	6.9E-13	6.0E-01
C-14	5.0E+12	3.3E-11	6.4E-17	3.5E-11	5.2E+01
S-35	1.6E+11	6.0E-11	7.6E-17	2.4E-11	2.7E+00
Ar-41	6.0E+13	0.0E+00	3.2E-12	0.0E+00	7.7E+00
I-131	5.0E+09	4.1E-09	3.8E-11	3.9E-10	5.6E+00
Co-60	1.0E+09	5.3E-11	1.1E-08	2.2E-10	4.6E-01
				Total dose (µSv/y) Sum of [G]	**6.9E+01**

Releases to estuary/coastal water

Releases to estuary/coastal water Exposure group – Fisherman family [2]		Exchange rate (m^3/s) [C] (see Table 4)	130
Radionuclide	Discharge (Bq/y) [A]	Total DPUR from Table 3 (µSv/y per Bq/y) [B]	Dose (µSv/y) [D] = [A] x [B] x 100/ [C]
H-3	1.2E+15	8.9E-16	8.2E-01
S-35	3.0E+12	7.9E-15	1.8E-02
Co-60	3.0E+10	2.8E-09	6.5E+01
Cs-137	3.0E+11	1.5E-10	3.5E+01
		Total dose (µSv/y) Sum of [D]	**1.0E+02**

Stage 2 – Summary total dose

Release route	Exposure group	Total dose (µSv/y)	Worst total dose (µSv/y)	
Air	Local resident family [1]		[1]	69
Direct radiation	Local resident family [11]		[11]	19
			Total dose (µSv/y) [1] + [11]	**88**
Estuary/coastal water	Fisherman family [2]		[2]	100
			Total dose (µSv/y) [2]	**100**
			Maximum critical group dose (µSv/y)	**100**

The maximum dose to the exposure groups is now 100 μSv/y. As this is still greater than 20 μSv/y, it is necessary to consider if a separate detailed site-specific assessment is required (Stage 3).

Stage 3 – Determine need for a site-specific radiological assessment

Most of the dose from the atmospheric discharges results from the consumption of terrestrial foods. Important factors which should be reviewed are which of the foods included in the DPUR data are actually produced locally and at what distances from the release point. Other factors that are likely to have a large influence on the food consumption doses are the consumption rates of local produce. In the initial assessment it is assumed that all foodstuffs are consumed at statistically critical rates. Actual consumption rates, such as determined by a local habit survey, could be much lower.

External irradiation from argon-41 in the effluent cloud results in the second highest dose to the atmospheric exposure group. The greatest factors influencing this is the distance of the exposure group from the discharge point and the total occupancy time of members of the group at that location, so these should also be considered when making a further assessment.

There could be the need for site-specific air dispersion modelling to take account of building, coastal and terrain effects.

For the liquid discharges most of the dose arises from external irradiation from sediments deposited on local beaches. Any further assessment should consider the actual occupancy time of the exposure group on beaches within a few kilometres of the site. The second highest dose arises from caesium-137 in seafood. This should be reviewed bearing in mind actual consumption rates of locally caught fish and seafood.

For both the atmospheric and coastal assessments, ‘surrogate’ radionuclides were selected to represent ‘other’ discharges. As part of any detailed assessment it should be ascertained which are the most appropriate radionuclides to use.

We welcome views from our users, stakeholders and the public, including comments about the content and presentation of this report. If you are happy with our service, please tell us about it. It helps us to identify good practice and rewards our staff. If you are unhappy with our service, please let us know how we can improve it.