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Guidance on the calculation, presentation and use of collective doses for routine discharges

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Foreword

The concept of collective dose was introduced by the International Commission on Radiological Protection (ICRP) as the sum of effective doses from a given practice or situation to all affected individuals, now and in the future. Quantities of collective dose take account of the group of persons exposed and the period of exposure.

Collective doses can play a role in both justification and optimisation decision-making in relation to practices. Optimisation of protection is the balancing of the benefit of reducing radiation doses against the resources expended. Most guidance on collective doses relates to its use in optimisation studies. It is a powerful tool for the assessment of the best option, allowing for the hypothesis that there is no threshold dose below which there would be no health detriment, and that the probability of inducing a stochastic health detriment in an individual is proportional to the dose.

Over recent decades concern has been expressed about the way in which collective doses have been used. In particular, it is generally agreed that the use of the fully aggregated collective dose masks a lot of useful information, that decision makers may consider important, on levels of individual dose and their distribution over time and space.

The concept has often been misused by integrating doses over the entire world population and over an infinite timescale. In some cases this leads to high values for the collective dose, which are, however, difficult to put in perspective. This approach also ignores the uncertainties involved in extrapolating over extremely long periods.

The Radiation Protection unit of DG TREN therefore launched a study (Dose Collect, contract no. TREN/04/NUCL/S07.39645) to investigate the possibility of disaggregating collective doses in different components, with the aim of offering a better basis for decision-making and risk communication. It was proposed to make a case study on routine discharges of a reprocessing plant. This study was carried out by HPA (UK Health Protection Agency) and CEPN (France, Centre d'études sur l'évaluation de la protection dans le domaine nucléaire). This publication is the outcome of the contractor's work and remains the responsibility of the authors.

The Group of Experts under Article 31 of the EURATOM Treaty established a Working Party on the concept of collective dose. The Working Party offered assistance to the Commission in formulating the terms of reference of the study and in preparing corrections to and commenting on intermediate reports. The final version of the document was discussed by the Group of Experts on 20-21 June 2006. The Experts confirmed the quality of the report and took note of the main conclusions. As these conclusions speak for themselves, the Group felt no further need to establish its own guidance on the topic.

The publication of this document will be of benefit to the ICRP and international agencies, as well as to the Commission, which is in the process of reviewing and revising the Basic Safety Standards in radiation protection (Council Directive 46/29/EURATOM).

I am pleased to acknowledge the efforts of the authors and the members of the Working Party in preparing this document.

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Head of the Radiation Protection unit

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ABSTRACT

Over recent decades concerns have been expressed about the way collective doses have been used. In particular, there is general agreement that using the fully aggregated collective dose masks a lot of useful information on levels of individual dose and their distribution over time and space, that decision makers may consider important. ICRP has suggested a 'dose matrix' approach as a solution to this. In this study some of the issues involved in the development and use of such 'matrices' have been explored. In particular, practical issues regarding the disaggregation of collective doses in relation to individual dose rates and the temporal and spatial distribution of exposures have been addressed. Calculations have been undertaken to illustrate ways in which the estimated collective dose from routine discharges can be broken down. The nuclear site chosen was the Sellafield reprocessing plant (UK) but additional calculations were also undertaken for the Cap de La Hague reprocessing plant (France) for comparative purposes. It was found that useful information on the temporal and spatial elements of collective doses can be obtained and that per-caput doses can be used to give an idea of the likely individual doses that make up the collective dose. At long times following discharges of radionuclides to the environment doses due to global circulation will dominate the collective dose and there is likely to be little requirement for obtaining information on individual dose distributions.

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EXECUTIVE SUMMARY

The collective dose is a measure of the radiation exposure in a population. In simple terms it is the integral of the distribution on individual doses within the population. Collective doses have been used since the 1970s both to indicate the radiation induced health detriments of sources of radiation exposure and as inputs to optimisation studies.

Over recent decades concerns have been expressed about the way collective doses have been used (ICRP, 2004). In particular, there is general agreement that using the fully aggregated collective dose masks a lot of useful information on levels of individual dose and their distribution over time and space, that decision makers may consider important.

The International Commission on Radiological Protection (ICRP) is currently developing general guidance on the way to use collective doses (ICRP, 2005). A group of experts established under Article 31 of the Euratom Treaty is also developing guidance on the use of collective doses in relation to radioactive discharges. The study reported here, funded by the European Commission (EC), is intended to input to this.

In the draft of the ICRP's foundation document on optimisation published for comment in 2005, (ICRP, 2005), the Commission recommends the separation of collective doses into various components, reflecting the attributes and the exposure characteristics of the exposed individuals, and the time and space distributions of exposures relevant for the decision making process. The disaggregating process results in a set of exposure characteristics and attributes that can be constructed on a case by case basis. The aim is to derive a dose 'matrix' where the disaggregation takes account of time, space and the characteristics of the exposed population.

It should be noted that optimisation studies generally form only one input into decisions regarding radioactive discharges. The need to use best available technologies (BAT) for discharge reduction, as is required under some national regulatory systems, and to take account of other wider social and political factors also form important inputs to decision-making in this area. One important factor in this respect is the 1992 OSPAR Convention for the Protection of the Marine Environment, as the OSPAR radioactive substances strategy has the objective of preventing pollution of the marine environment from radioactive substances through progressive and substantial reductions of discharges, with the ultimate aim of achieving concentrations in the environment close to zero for artificial radioactive substances. A combination of optimisation and these additional factors has lead to a significant reduction in radioactive discharges.

Although the definition of collective dose is straightforward, current established methods for the estimation of collective doses from routine discharges do not involve the explicit generation of an individual dose distribution. This is because of significant problems with their determination. Instead, in simple terms, such models determine the average dose within a population and the collective dose is then the product of the average dose and the number of people exposed. In most models a small number of such population groups are considered (eg, country, EU, World). This methodological approach has implications for the provision of more detailed information on levels of individual doses as might be required to define a dose matrix.

In this study some of the issues involved in the development and use of such ‘matrices’ have been explored. In particular, practical issues regarding the disaggregation of collective doses in relation to individual dose rates and the temporal and spatial distribution of exposures have been addressed. Calculations have been undertaken to illustrate ways in which the estimated collective dose from routine discharges can be broken down to give an idea of the associated individual doses as well as the breakdown with geographic region and time. Some preliminary suggestions are made of what can practicably be achieved in the way of a ‘dose matrix’.

The scope of the study was restricted to the use of collective doses from routine discharges in optimisation and options comparison. The objectives have been accomplished primarily by carrying out a case study to estimate collective doses from discharges to the environment from a major nuclear site to various populations at various times and associated information on individual dose rates. The nuclear site chosen was Sellafield in the UK, but additional calculations were also undertaken for Cap de La Hague in France for comparative purposes. The resulting doses are presented in Section 4.

A brief review of international guidance on the use of collective doses and of published assessments of collective doses was also undertaken to inform the process. The results of these reviews are also presented.

The following main conclusions can be drawn from this study:

- Current models and codes used for the estimation of collective doses can determine collective doses to a limited number of population groups over various temporal periods, and thus go some way to providing the required breakdown of collective dose into different geographical regions and times for a dose matrix.
- The ICRP’s suggested approach of looking at individual dose distributions within each group dose is not possible for significant population sizes if ingestion of food is an important exposure pathway.
- It is recommended that once global circulation dominates there is no requirement for information on individual dose distributions. In general the study results indicate that the complexity of a dose matrix would be expected to decrease with time.
- It is possible to estimate per-caput doses associated with different ‘group doses’. These could form a useful input to optimisation and option comparison decision-making.
- It is suggested that before any further work is undertaken in this area that some dialogue be developed first with relevant stakeholders and then potential decision-makers to establish the extent to which such information is required.

CONTENTS

1 INTRODUCTION

The collective dose is a measure of the radiation exposure in a population. In simple terms it is the integral of the distribution on individual doses within the population. Collective doses have been used since the 1970s both to indicate the radiation induced health detriments of sources of radiation exposure and as inputs to optimisation studies.

Over recent decades concerns have been expressed about the way collective doses have been used, particularly in relation to the estimation of collective doses from routine discharges of radionuclides to the environment (ICRP, 2004). In particular, there is general agreement that using the fully aggregated collective dose masks a lot of useful information on levels of individual dose and their distribution over time and space that decision makers may consider important.

The International Commission on Radiological Protection (ICRP) is currently developing general guidance on the way to use collective doses (ICRP, 2005). A group of experts established under Article 31 of the Euratom Treaty is also developing guidance on the use of collective doses in relation to radioactive discharges. The European Commission (EC) funded study reported here is intended to input to this.

Although the definition of collective dose is straightforward, current established methods for the estimation of collective doses from routine discharges do not involve the explicit generation of an individual dose distribution. This is because of significant problems with determination of such distributions, particularly for estimating collective doses from radionuclides in foods. Instead, in simple terms, such models determine the average dose within a population and the collective dose is then the product of the average dose and the number of people exposed. In most models a small number of such population groups are considered (eg, country, EU, World). This methodological approach has implications for the provision of more detailed information on levels of individual doses within populations as suggested by ICRP (ICRP, 2005).

The overall aim of this study was to carry out a case study to estimate collective doses from discharges to the environment from a major nuclear site to various populations at various times and associated information on individual dose rates. The main aim of this was to explore practical issues regarding the disaggregation of collective doses in relation to individual dose rates and the temporal and spatial distribution of exposures. The nuclear site chosen was Sellafield in the UK, but additional calculations were also undertaken for Cap de La Hague in France for comparative purposes. The emphasis is on the use of collective doses for optimisation purposes rather than for estimating the risks of radiation induced health effects.

The following section presents international guidance on the use of collective doses. Section 3 contains a review of published assessments of collective doses undertaken to explore the purposes of such assessments and the extent of collective dose disaggregation. Section 4 describes the calculations undertaken for this study and the resulting collective and individual doses. On the basis of information from earlier parts of the report, Section 5 provides comments and guidance on the determination, use and presentation of collective doses to members of the public from routine radionuclide discharges. A summary of the conclusions is provided in Section 6.

2 INTERNATIONAL GUIDANCE ON THE USE OF COLLECTIVE DOSE

The majority of international and national guidance on the use of collective doses originates from the ICRP. ICRP's current basic principles for radiological protection are defined in ICRP Publication 60 (ICRP, 1991). The principles differentiate between 'practices' and 'interventions'. This document is concerned with collective doses from planned radioactive discharges and therefore the relevant guidance is that for practices. The system of radiological protection recommended by the Commission for proposed and continuing practices is based on the following general principles: justification, optimisation and dose limitation. Collective doses can play a role in both justification and optimisation decision-making in relation to practices but the majority of ICRP guidance on collective doses relates to its use in optimisation studies and this is discussed below. Optimisation of protection for practices is the balancing of the benefit of the radiation dose against the resources expended. The process should take account of any additional harm (and benefit) involved in achieving that reduction and social factors.

It should be noted that optimisation studies generally form only one input into decisions regarding radioactive discharges. The need to use best available technologies (BAT) for discharge reduction, as is required under some national regulatory systems, and to take account of other wider social and political factors also form important inputs to decision-making in this area. One important factor in this respect is the 1992 OSPAR Convention for the Protection of the Marine Environment, as the OSPAR radioactive substances strategy has the objective of preventing pollution of the marine environment from radioactive substances through progressive and substantial reductions of discharges, with the ultimate aim of achieving concentrations in the environment close to zero for artificial radioactive substances. A combination of optimisation and these additional factors has lead to a significant reduction in radioactive discharges. For example, in 1975 Sellafield discharged 5.2 10^{15} Bq of ^{137}Cs to the marine environment (Bexon, 2000) but the annual average discharge in 2003 (Table B2) was down to 6.2 10^{12} Bq, a reduction of over a factor of 800.

The issue of truncation times for collective doses is an important and potentially contentious one and therefore, although it is clearly of relevance in relation to optimisation, it is dealt with separately below. Additional information on the use of collective doses can be found in various publications notably (IPSN, 2002; NCRP, 1995; Barraclough et al, 1996).

2.1 Collective doses for optimisation

Prior to its 1990 recommendations ICRP had produced detailed guidance on optimisation that included advice on the use of collective doses (ICRP, 1983; ICRP, 1989).

The earliest guidance on optimisation emphasised the use of quantitative approaches, in particular cost-benefit analysis, and the importance of total (ie, aggregated) collective doses (ICRP, 1983). This was considered appropriate especially in relation to doses to workers as these were generally limited in range. However, even at this stage it was recognised that there are some situations, such as when individual doses approach dose limits, where problems arise when adopting this approach because different options result in different distributions of doses within populations.

Later guidance on optimisation (ICRP, 1989) moved away from principally promoting quantitative approaches to a recognition of the need for a range of decision-making approaches, from simple 'judgements' to more complex approaches that allow the influence of qualitative factors to be more adequately reflected in the decision-making process. The guidance also recognised the problems with using a single collective dose to represent the radiation induced health detriment because decision-makers may consider that some components of the total are more important than others – '*the use of collective dose commitment as the sole measure of radiation detriment implies precise equality of value between collective doses to workers or members of the public, between collective doses made up of very large numbers of very small doses and small numbers of high doses, between collective doses made up of individual doses at 10% or 90% of the appropriate limit. Only if all these trade-offs are equally acceptable to the decision-makes will he find the simple approach useful*' (ICRP, 1989). For these reasons ICRP recommended that some disaggregation of collective doses would be useful under some circumstances. It was suggested that it could be useful to divide the collective dose into a number of individual dose bands. It was recognised, however, that under some circumstances it might be more useful to the decision maker to be aware of how close doses are to applicable limits or constraints and that the distribution of individual doses might then be better expressed as percentages of the appropriate limit.

ICRP guidance in Publication 55 (ICRP, 1989) also recognised the importance of appropriate truncation times for collective dose calculations. It was stated that the time integration of collective dose in optimisation should be terminated at the time when the subsequent contributions are common to all alternatives or it is no longer possible to distinguish between options. An alternative reason given for truncation was that in some situations large uncertainties associated with the long term components of the collective dose rate may prevent this measure being used as a discriminator between options. It was also recognised that the decision maker may give different weight to doses at different times. ICRP therefore recommended that, where possible, the information for optimisation studies should include the distribution of doses in time. The guidance in Publication 55 was also reflected in the 1990 recommendations of ICRP (ICRP, 1991).

As part of the development of its next set of basic recommendations, ICRP is producing a number of foundation documents, including one on optimisation. The draft of the optimisation document published for comment in 2005 (ICRP, 2005) gives advice on the use of collective doses. In essence the document advises on a move away from collective doses to 'group' doses, thus taking earlier guidance on disaggregation a step further. In particular ICRP makes it clear that under certain circumstances it is simply not appropriate to use collective doses when optimising - '*when the exposures occur over large populations, large geographical areas, and over large periods of time, the Commission now considers that the total collective effective dose, as defined … (ie the summation of all individual exposures in time and space), is not a useful tool for decision aiding because it may aggregate information excessively and could be misleading for selecting protection actions*'. Radiation exposures from discharges from nuclear plant clearly fall into this category. Essentially ICRP recommends that, in broad terms, the concept of collective dose is retained but within the context of a 'dose matrix'. The developing ICRP guidance is discussed in more detail in Sections 4 and 5.

2.2 Truncation times

The time at which collective doses are truncated is clearly important in relation to optimisation studies. As mentioned above, earlier advice from ICRP indicated that the time integration of collective doses in optimisation studies should be terminated at the time when the subsequent contributions are common to all alternatives or it is no longer possible to distinguish between options. Another reason given for truncation relates to uncertainties. In some situations the large uncertainties associated with the long term components of the collective dose rate may prevent this measure being used as a discriminator between options.

Although the primary focus of this study relates to the use of collective doses in optimisation studies it must be recognised that the collective dose is sometimes used simply as an absolute measure of the total radiation induced health detriment from a particular release, site or practice (UNSCEAR, 2000). The issue of truncation times is a very important one in this context. In particular, concerns have been raised about whether in these circumstances it is appropriate to integrate the collective dose to infinity (ie, not to truncate).

When using collective dose as a measure of total radiation induced health detriment, it has been suggested that the dose truncated at 500 years should be used (Barraclough et al, 1996). A similar conclusion has been reached by ICRP (ICRP, 1997). It is recognised that both the magnitude of the individual doses and the size of the exposed population become increasingly uncertain as the time increases (Barraclough, 1996). Also, current judgements about the relationship between a radiation dose and the consequent health effects may not be valid for future generations. Generally the rate of increment of collective dose is highest when discharges are occurring and begins to slow when discharges cease. The rate of increment of collective dose is highest in the first few hundred years. This therefore led to the recommendation that comparisons of process/disposal options should be on the basis of truncated collective doses (Barraclough, 1996). This advice has been implemented in the UK. For example, the draft Statutory Guidance to the UK Environment Agency (DETR and DoH, 2000) and the principles for the assessment of prospective public doses issued by the relevant UK authorities (EA et al, 2002) both state that collective doses should be truncated at 500 y.

However, others have stated that no truncation is appropriate. For example, it is argued in the WISE report (Schneider et al, 2001) that - '*given the very long term half-lives of some radionuclides released by reprocessing plants … and their global distribution, there should be no time limits and dose evaluations should be global. There is no reason why future generations or distant populations should be any less protected than current generations in the vicinity of the facilities'.* Fairlie and Sumner (2000), whilst acknowledging the difficulties with the use of untruncated time periods for the assessment of collective dose, question whether truncation at 500 years accords with the IAEA radioactive waste management principle requirement that it should not impose undue burdens on future generations (IAEA, 1995). They also argue that uncertainty is not a reason for avoiding the use of untruncated collective doses as this goes against the requirements of the precautionary principle.

One of the difficulties with the use of collective doses, truncated or otherwise, to represent the radiological impact to a *population,* is that health impacts from other environmental pollutants are usually considered on an individual basis. Even when studies are undertaken to investigate the impacts on populations these are generally over short timescales. Comparisons between radioactive and other releases are therefore not done on a similar basis.

3 CURRENT PRACTICE IN THE USE AND CALCULATION OF COLLECTIVE DOSES

As part of this study a review of existing published assessments of collective dose was undertaken. This review focussed primarily on the methodologies used, including geographical areas and time spans covered, and whether any disaggregation by individual dose had been undertaken. In line with the scope of the study, the review focussed on the use of collective dose in relation to routine radioactive discharges. The purpose of the collective dose assessments undertaken was also considered in the review. The literature reviewed is listed at Appendix A.

3.1 Assessment objectives

The purpose of the collective dose studies identified varied. For the majority of the studies the aim was simply to give an estimate of the overall radiological impact of discharges from particular sites to particular populations. At an EU level a number of studies of the radiological impact of routine discharges on the EU population have been undertaken which included the determination of collective doses. One of these (Smith et al, 2002) considered the radiological impact on the EU population of discharges from EU nuclear sites between 1987 and 1996. Collective doses to the EU population resulting from atmospheric and liquid discharges from all EU nuclear sites, including the reprocessing sites at Sellafield and La Hague were evaluated. The MARINA II study (EC, 2002) considered the radiation exposure of the EU population from radioactivity in North European waters. As part of the study collective doses to the EU population from discharges from nuclear sites and NORM industries, such as the oil and gas industry, were evaluated. Similar studies have also been undertaken at a national level. For example, within the UK a number of studies have been undertaken of the radiological impact of routine discharges from civil nuclear sites. The most recent of these considered releases from the mid 1990s (Bexon, 2000). Undertaking a series of such assessments allows the changes in radiological impact over time to be examined. In France collective doses from nuclear facilities have also been determined (Dreicer et al, 1995a). At a global level UNSCEAR has published a series of reports on the radiological impact of all sources of radiation including: natural radiation sources, the nuclear fuel cycle and medical exposures. As part of these assessments, the collective doses to the global population from these different sources were evaluated to compare their impact (UNSCEAR, 2000).

In some of the studies mentioned above comparisons were made between collective doses from different sources or sites or different discharge years. In some, comparisons with collective doses from natural sources were used to put the collective doses from man-made sources in context.

In other studies collective doses were determined as part of an option comparison exercise. For example, as part of a Nuclear Energy Agency (NEA) comparative study of the radiological impacts of spent nuclear fuel management options (NEA, 2000), collective doses were determined for each stage of the nuclear fuel cycle (Fayers et al, 2001). The fuel cycle was divided into the following four stages: uranium mining and milling; fuel fabrication and enrichment; power production and reprocessing. Collective doses were normalised to electricity production, ie, mansievert per gigawatt year. Another major study, ExternE, also examined the impact of the nuclear fuel cycle (Dreicer et al, 1995b), including routine discharges. The purpose of the study was to develop an impact assessment methodology for the nuclear fuel cycle, which could be used to look at options within the nuclear fuel cycle and also to allow comparisons with other, non-nuclear, options for electricity generation. Another study considering the radiological impact of the reprocessing plants at Sellafield and La Hague (the WISE report) determined collective doses from the sites and used these as inputs to discussions regarding the appropriateness or otherwise of nuclear fuel reprocessing (Schneider, 2001).

The majority of the reports identified in the literature review related to studies undertaken simply to give an indication of the overall radiological impact from a site or source, rather than assessments carried out as inputs to optimisation exercises. However, this should not be taken to imply that collective dose assessments are rarely carried out for optimisation studies. The majority of such assessments are carried out as part of the regulatory authorisation process and as such are rarely published.

The focus of the current study is on the use of collective doses for optimisation and options comparison. However, it should be noted that collective doses have been used for other purposes including studying health impacts (eg, leukaemia cluster studies) around nuclear installations. The results of this work are not relevant to such studies.

3.2 Geographical area

The geographical areas considered in the determination of collective dose varied with the different studies. Studies for the EU, for example Smith et al (2002), generally considered the collective dose to the EU population, although in some a national breakdown was possible to some extent (EC, 2002). UNSCEAR reports, for example UNSCEAR (2000), generally considered the collective dose to the global population but for some exposure types breakdowns by geographical area (eg, Europe, Asia) were also given. The UK national studies considered collective doses to both the national and EU populations (Bexon, 2000). Other studies considered doses in different areas. For example, the ExternE study (Dreicer, 1995b) considered three geographical regions for atmospheric releases: local (0 – 100 km), regional (100 – 1000 km) and global (> 1000 km). For aquatic releases the local and regional areas were combined. In one study the collective doses from the 'first pass' of the plume were distinguished from the collective dose from global circulation (Smith et al, 2002).

3.3 Temporal distribution

The majority of the studies considered presented collective doses truncated at particular times rather than simply evaluated to all time. Many of the studies presented collective doses truncated at 500 years (Smith et al, 2002; Bexon, 2000; Fayers et al, 2001; Jones et al, 2004). In some cases these were presented in combination with collective doses estimated to all time, for example Bexon (2000). The MARINA II study (EC, 2002) also presented values for the collective dose rate (manSv/y). The Extern E study (Dreicer et al, 1995a) considered two timescales for collective doses; 10 years and 10,000 years. Few of the studies presented only total (ie, not truncated) collective doses, see Schneider (2001) and IAEA (2001).

3.4 Methodologies

The collective effective dose (generally referred to in this report as simply the collective dose) is defined as follows by the International Commission on Radiological Protection (ICRP)

$$S = \int_0^\infty E.\frac{dN}{dE}dE \quad or \sum_i \overline{E}_i .N_i$$

Where (dN/dE)dE is the number of individuals receiving an effective dose between E and E + dE, E_i is the mean effective dose to population subgroup i and N_i is the number of people in population subgroup i. Although the above equation appears superficially straightforward, in practice collective doses to members of the public are not estimated using it, primarily because, as will be discussed below, of issues regarding the determination of food doses. It should be noted that the linear no-threshold dose hypothesis is at the heart of the definition of collective dose. A small dose to a large number of people can be considered to imply the same overall population risk as a larger dose to a correspondingly smaller number of people, and, the integration and summation starts at zero. It is also possible to obtain doses per head of the population, known as per-caput doses. These per-caput doses are estimated by taking the estimated collective dose and dividing by the number of people. It can also be shown that the collective dose truncated at a particular time from one year's operation of a practice is numerically equal to the maximum annual collective dose-rate if the practice operated unchanged for that time period, provided all other factors remained the same.

In the literature a number of different methodologies for the determination of collective doses are presented (EC, 2002; Dreicer et al, 1995a; Mayall et al, 1997; EPA, 2002). For atmospheric releases the general approach (Dreicer et al, 1995a; Mayall et al, 1997; EPA, 2002) is to consider a radial grid around the release point. Atmospheric dispersion models are used to estimate the concentration of radionuclides in air for each of the radial grid elements (r, θ), and deposition models to estimate the deposition rates onto the ground for each grid element. Using additional models for the movement of radionuclides within soil and agricultural systems, concentrations of radionuclides in soil and foods can be determined for each grid element. All these grid element specific data can be generated as a function of time. This grid element environmental concentration data is then used in combination with other information, including the population and agricultural production within each grid element to estimate the collective dose. Collective dose is defined as the summation of individual doses over time and space. In essence this basic approach is used in the majority of models to estimate collective doses from inhalation and external irradiation exposure pathways. For example, for inhalation doses the air concentration for a grid element is multiplied by a breathing rate and a dose coefficient(s) to generate an individual dose. This is then multiplied by the population within a grid element to get a collective dose. Summing this over all grid elements gives an estimate of total collective dose. Clearly this is a simplistic description of the process, ignoring as it does factors such as age groups, time variation and location factors, but these do not affect the basic structure of the approach.

It is in the determination of collective doses from ingestion of foods that the models differ most markedly in their general approach. For releases to atmosphere PC-CREAM (Mayall et al, 1997) estimates collective doses from the ingestion of terrestrial foods as the product of the activity concentration in the food and the annual production of food in each element of a grid multiplied by the dose coefficient for ingestion and then summed over radionuclide and grid elements. It is assumed that someone eats the food but, as no information is available on who eats which food, it is stated that this approach is the only reasonable one. It is argued that in EU Member States and the EU as a whole there are significant movements of food from the points of production to the place of consumption. These food movements are not constant so cannot be mapped and it is therefore not possible to obtain a distribution of individual doses for these exposure pathways.

Other methodologies, although acknowledging the complicating factor of food distribution have made the simplifying assumption that the food produced within a particular area is also consumed within that area (Dreicer et al, 1995a; EPA, 2002). This might be done at a grid element level or on a larger scale. For example, for the ExternE study (Dreicer et al, 1995b) collective doses from atmospheric releases in three geographical regions were considered: local (0 – 100 km), regional (100 – 1000 km) and global (> 1000 km). Doses were determined using a standard grid approach assuming food produced within each geographical area was consumed within that area unless there was excess food (ie if average consumption rate multiplied by population was less than food produced in the area) in which case this was consumed within the next geographical region.

For aquatic releases the difficulty in determining collective dose as a summation of individual doses over time and space is even more apparent. For example, in the MARINA II study (EC, 2002) collective doses from the consumption of seafood were calculated as the product of the activity concentration in the edible fraction of seafood, the annual catch rate (also in terms of the edible fraction) and the dose coefficient for ingestion for each radionuclide, summed over radionuclide and marine compartment. This method uses data available on catches of different seafood and information on how much is consumed in the countries of the EU; it is assumed that someone eats the seafood but there is no information on who eats which food. This approach is also similar to that used in the ExternE study for doses from liquid discharges (Dreicer et al, 1995b).

IAEA has given guidance on generic models for assessing the impact of radioactive discharges (IAEA, 2001). The report gives estimates of collective doses for unit discharges of radionuclides to the atmosphere and to water bodies. These are intended for simple generic assessment purposes only. The estimates are based on the results of more complex models applied to locations in western Europe and on the results of simple models based on UNSCEAR methods (UNSCEAR, 2000) and using generic, global parameters. The collective dose estimates per unit discharge are integrated to infinity. UNSCEAR has developed a set of simple generic models to estimate collective doses. For atmospheric releases it is assumed that all the activity released will be deposited and that the collective dose is independent of the distribution of the deposited material. Three exposure pathways were considered for the IAEA work: inhalation, ingestion of terrestrial foods and external irradiation from deposited material. A population density is required and for the IAEA study a value of 35 people per km^2 was used, which represents a global average. Global average yields of foods were also used. For releases of radionuclides in liquid form the UNSCEAR model assumes simple dilution. The exposure pathways considered are the consumption of drinking water and aquatic foods. It is assumed that the number of people consuming the food divided by the volume of the receiving water is constant. The complex models used were those from Bexon (2000). The final recommended collective doses per unit discharge were determined by comparing the results from the two processes.

3.5 Individual doses

Very few of the studies reviewed considered collective doses in isolation. In the majority of cases information on individual doses was seen as an important component of the radiological impact and that it would not be appropriate to consider collective doses alone without some reference to individual doses. In some studies the individual doses were those to the critical group or an average member of the local population (EC, 2002; Smith et al, 2002; Bexon, 2000). These would thus represent doses at the higher end of the individual dose distribution that makes up the collective dose. In other studies the emphasis has been on per-caput doses, ie, the collective dose to a particular population divided by the total number of people in the population (Smith et al, 2001; Crockett, 2003). In only one of the studies identified was an attempt made to disaggregate collective doses into individual dose bands (Jones et al, 2004). This was a complex procedure and involved, as indicated above, making assumptions about the sources of food consumed.

4 COLLECTIVE DOSE CALCULATIONS

4.1 Introduction

As discussed briefly in Section 2, in the draft of the foundation document on optimisation published for comment in 2005 (ICRP, 2005) ICRP recommended that the concept of collective dose is retained but within the context of a 'dose matrix'. The Commission particularly recommended '*the maintenance of the distribution of individual doses related to a given source in components reflecting the characteristics of the exposed individuals and the time and space distributions of exposures, relevant for the decision making process considered*'.

Figure 1 represents an example of a 'dose matrix'; it is taken from the 2005 draft ICRP document and is likely to change in subsequent versions. The disaggregation is rather basic and could be extended in the time and space axes as well as in the characteristics of the exposed population axis.

As part of this study calculations have been undertaken to illustrate ways in which the estimated collective dose from routine discharges can be broken down to give an idea of the associated individual doses as well as the breakdown with geographic region and time. Some preliminary suggestions are made of what can practicably be achieved in the way of a 'dose matrix'.

As discussed in Section 3, although the definition of collective dose is straightforward, in practice methodologies for estimating collective dose do not necessarily sum individual doses (Simmonds et al, 1995) within a defined group. This is particularly the case for collective doses due to the consumption of foods where collective doses for food are normally based on distributions of food production. This then means that it is not straightforward to disaggregate the collective dose due to ingestion of food into the component individual doses.

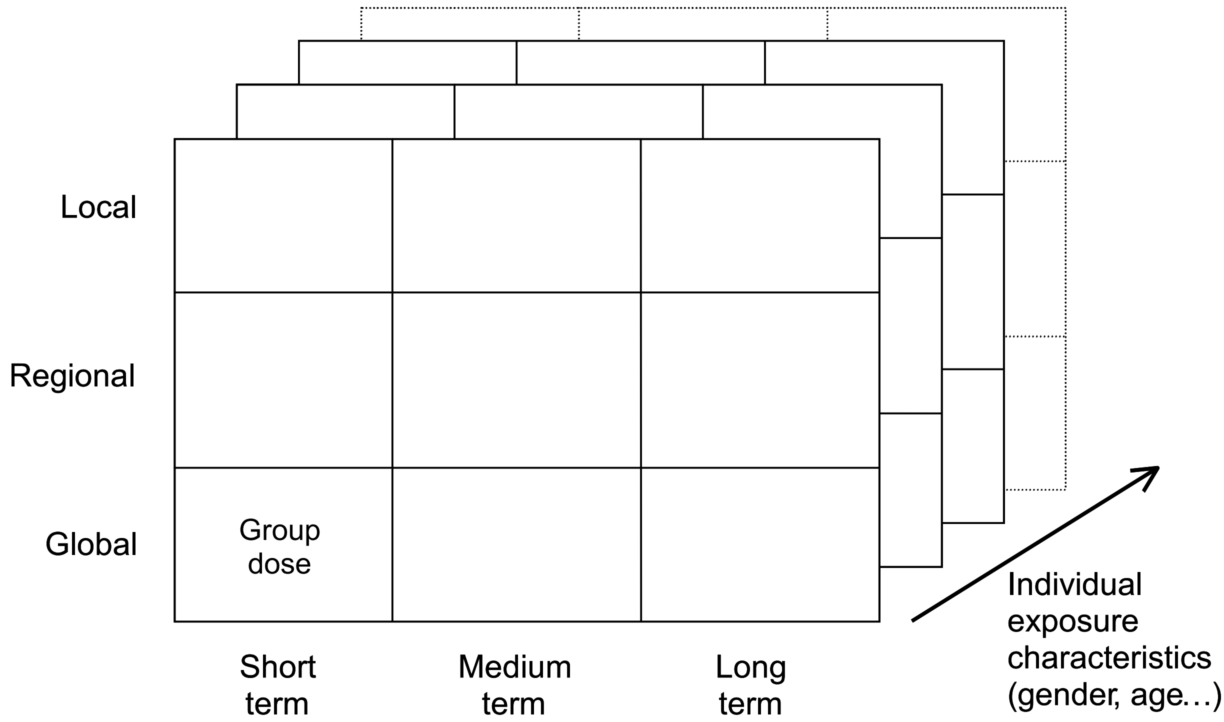

Figure 1 An example of a dose matrix (ICRP, 2005)

For releases to atmosphere an alternative approach would be to base the calculation on distributions of the population and assume that people obtain their food from where they live. However, this is incorrect, as the vast majority of people within areas such as the EU and the USA consume little or no locally produced food. There are significant movements of food from the point of production to the point of consumption. This can occur on a regional and national basis and there is also widespread movement of food from country to country. One possibility would be to map the movement and consumption of food and attempts have been made to look at food distribution patterns in the UK (Haywood et al, 1991). However, food movement is not constant with time and is extremely complex to model.

To illustrate the differences between where people live and where food is produced, population and agricultural production information was obtained for four locations in the UK. This was obtained from the population and agricultural production grids available for the EC (Simmonds et al, 1995). The four locations were chosen to represent different extremes. Two were close to the centre of major cities, London and Birmingham, while two were in rural areas in Norfolk and Essex. For each location the number of people living in a circle of radius 10 km (total area about 314 km^2) has been obtained together with the total area of crops grown and the production of green vegetables, grain and milk. The results are given in Table 1.

Table 1 Population and agricultural productions around different locations in the UK

Location	Population	Crop area (hectares)	Green vegetables (kg)	Grain (kg)	Milk (l)
Centre of London	$2.34\ 10^6$	0	0	0	0
Centre of Birmingham	$1.13\ 10^6$	$8.18\ 10^2$	$1.13\ 10^6$	$8.87\ 10^5$	$2.51\ 10^6$
Area in Norfolk	$2.58\ 10^4$	$2.01\ 10^4$	$2.16\ 10^6$	$2.16\ 10^7$	$1.05\ 10^7$
Area in Essex	$6.36\ 10^4$	$2.23\ 10^4$	$8.51\ 10^6$	$2.61\ 10^7$	$8.77\ 10^6$

Table 2 gives the population density around each location together with the percentage of the total area considered that is used to grow crops and the amount of each food produced per person living there.

Table 2 Population and agricultural production densities around different locations in the UK

Location	Population per km^2	Crop area (% total area)	Green vegetables (kg/person)	Grain (kg/person)	Milk (l/person)
Centre of London	7446	0	0	0	0
Centre of Birmingham	3599	2.6	1.0	0.8	2.2
Area in Norfolk	82	64	84	840	138
Area in Essex	202	71	134	410	406

From these tables it is seen that different locations can have very different numbers of people and produce very different amounts of food. The location in central London has a very high population density but produces no food. The 2 million people who live in this area will get their food from the whole of the UK and from other countries throughout the world. In contrast the location in Norfolk has a relatively low population density and produces food that is sold throughout the UK and further afield.

It is considered that such information indicates that in general assuming local production and consumption of food is not an appropriate way in which to generate estimates of individual dose associated with collective doses. In this study an alternative approach, that of generating per-caput doses has been investigated. Per-caput doses represent the dose received by an average member of the population being considered. It does not represent the distribution in exposure of individuals within a population owing to variations in individual habits and food distribution.

4.2 Methodology for calculating collective doses

Calculations have been performed for discharges to the environment from the Sellafield nuclear site in the UK and the Cap de la Hague site in France based on published annual discharge data (see Appendix B) averaged over the period 1999 to 2003. The Sellafield and Cap de la Hague sites both contain nuclear fuel reprocessing plants and associated waste treatment facilities. They both discharge relatively significant quantities of longer lived radionuclides to the environment and, as discussed in Section 3, have been considered in several past studies of collective doses. At both sites abatement technology has been introduced over the years they have been operating to significantly reduce discharges and hence doses so they are an interesting example to consider in the current study. Collective doses have been estimated at selected truncation times and the associated per-caput individual doses have been calculated. The general calculational approach is that adopted by Simmonds et al (2006) and is described in Appendix C with detailed results presented in Appendix D. It should be noted that the results are presented to two significant figures for comparison purposes and should not be taken to imply this degree of accuracy. Techniques are available to assess numerically the uncertainties in estimated doses but they require more resources and information than were available for this study. However, the uncertainty associated with the estimated doses should be borne in mind. Section 4.9 gives a qualitative discussion of the major sources of uncertainties associated with the estimated collective doses.

For discharges to atmosphere, the PC-CREAM code system (Mayall et al, 1997) was used to calculate the collective doses. PC-CREAM implements the EC methodology for assessing the radiological impact of routine releases of radionuclides to the environment (Simmonds et al, 1995) in a package for personal computers. The default version of PC-CREAM only gives collective doses for a limited number of times and it was necessary to run the individual models making up PC-CREAM and to make manual adjustments to the system in order to obtain results for additional times. For discharges to the marine environment, the MARINA II model (Simmonds et al, 2002) was run to calculate activity concentrations in the marine environment which were subsequently used to estimate collective doses using the EC methodology (Simmonds et al, 1995).

For most radionuclides the collective dose is estimated only due to exposure to the original discharge; this exposure can continue for many years following its deposition onto the ground or dispersion in the marine environment even after the discharge has stopped. Some radionuclides, due to the length of their radioactive half-lives and their behaviour in the environment, can also become globally dispersed and act as a long term source of exposure to both regional and world populations. PC-CREAM includes models for the global dispersion of ^{3}H, ^{14}C, ^{85}Kr (for atmosphere only) and ^{129}I and these were included in the estimates of collective dose given here. It is possible to distinguish between the collective dose due to the initial discharge (referred to as the first pass dose) and that due to global circulation.

These calculational tools were used to estimate collective doses truncated at 1, 50, 100, 500, 1000, 5000, 10000, 50000 and 100000 years for the average annual discharges from Sellafield and collective doses truncated at 1, 50, 500, 10000 and 100000 years for discharges from La Hague. The populations considered were the UK or France, European Union (pre-2004 enlargement) or Europe* and the world. A full set of exposure pathways was considered for atmospheric discharges (eg, inhalation of radionuclides in the plume, external irradiation from radionuclides in the plume, external irradiation from deposited radionuclides and ingestion of various terrestrial foods). Also, the main exposure pathways due to marine discharges were included, namely, consumption of fish, crustaceans and molluscs and external doses due to radionuclides in beach sediments.

As the truncation times for the estimates of collective dose are usually far in excess of the average lifetime, the truncated collective dose cannot simply be divided by the number of people in the chosen population group to obtain per-caput dose. However, the collective dose truncated at *n* years from a one-year discharge is numerically equivalent to the collective dose in year *n* following a continuous annual discharge, assuming all other factors remain constant (ICRP, 1999). Therefore in this study, the collective doses for a single year's discharge truncated at 50 and 100 years have been divided by the population number to obtain per-caput dose rates in the 50^{th} and 100^{th} year of a continuous discharge. In addition, the per-caput dose rate in the first year of discharge has been obtained by dividing the collective dose truncated at 1 year by the population number. Discharges are unlikely to continue for more than 100 years, therefore this approach is not used for longer times.

A further approach has been used to obtain indicative per-caput dose rates during selected time periods for the chosen population groups. This has been simplistically achieved by taking the collective dose truncated at time *j* and subtracting the collective dose truncated at time *i* and dividing this quantity by the time period considered (*j* – *i*) to obtain a representative annual collective dose rate. The resulting value can be divided by the number of population in the group of interest to obtain an indicative per-caput dose rate. This approach makes the crude assumption that collective doses increase linearly with time, which is generally not the case, particularly for the longer time periods. However, this approach does enable a broad estimate to be made of the levels of per-caput dose contributing to the collective dose.

4.3 Collective doses

4.3.1 Atmospheric discharges

Table 3 shows the collective dose truncated at various times due to the annual average discharges to atmosphere from Sellafield between 1999 and 2003. Results are given for the UK, Europe and world populations. The total collective dose is given together with the contribution due to the exposure following the release to atmosphere prior to global dispersion, referred to as the first pass. This includes exposure in subsequent years following deposition of radionuclides on land from the first pass. The difference between the total collective dose and the first pass is then due to the global circulation of radionuclides.

* For releases to atmosphere the population considered is that in Europe as a whole ($7\ 10^8$ people) while for discharge to the marine environment only the population of the European Union pre 2004 is considered ($3.59\ 10^8$ people).

Table 3 Collective doses due to annual discharges to atmosphere from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

	Collective dose (man Sv)					
	UK population ($5.5.10^7$ people)		European population ($7\ 10^8$ people)		World population ($1\ 10^{10}$ people)	
Integration period (y)	Total	(first pass*)	Total	(first pass*)	Total	(first pass*)
1	1.1	(1.0)	4.2	(4.1)	6.7	(4.1)
50	1.5	(1.3)	8.3	(5.7)	43	(5.7)
100	1.6	(1.4)	8.9	(6.0)	48	(6.0)
500	1.8	(1.5)	10	(6.2)	63	(6.2)
1000	1.9	(1.5)	11	(6.2)	74	(6.2)
5000	2.2	(1.5)	15	(6.2)	140	(6.2)
10000	2.4	(1.5)	18	(6.2)	180	(6.2)
50000	2.7	(1.5)	22	(6.2)	230	(6.2)
100000	2.7	(1.5)	22	(6.2)	230	(6.2)
Infinity	2.8	(1.5)	23	(6.2)	240	(6.2)

Notes:

* The first pass dose is that due to the initial discharge to the environment. The total also includes any contribution from the global circulation of relevant radionuclides (see Section 4.2).

Results presented to two significant figures.

Table 3 shows that the collective dose due to the first pass exposure is essentially all delivered in the first few hundred years following the discharge. The first pass dose is particularly important for the UK population while for the world population, it only makes a small contribution except in the first few years after the discharge. The contribution from the global circulation of long-lived radionuclides continues to increase for all times considered. The variation in collective dose with time for the three populations is illustrated in Figure 2. Doses due to ingestion of terrestrial foods are the largest contributor to the first pass collective dose. For example, for the UK population about 80% of the collective dose truncated at 500 y is due to ingestion.

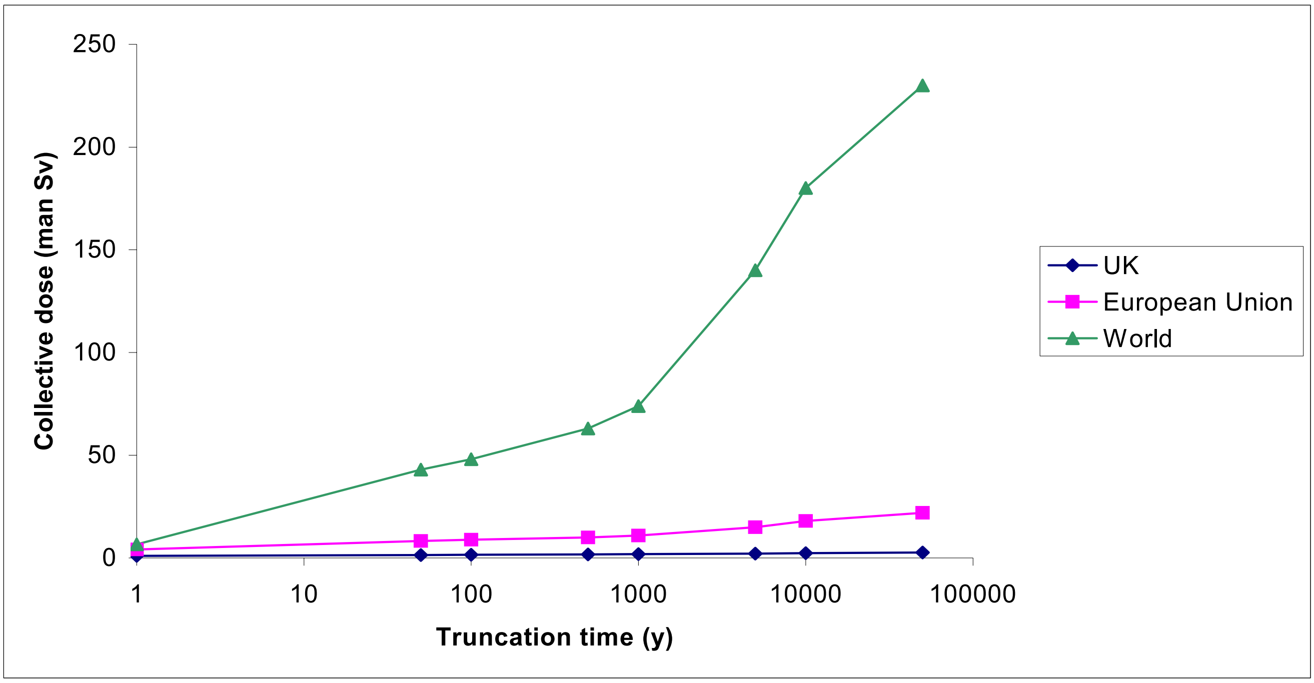

Figure 2 Collective doses due to annual discharges to atmosphere from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

Even at short times the collective dose is mainly due to discharges of ^{3}H, ^{14}C, ^{85}Kr and ^{129}I, the four relatively long-lived, mobile radionuclides that also contribute to the dose from global circulation. Their relative contribution varies with time and is also different for the different population groups considered. This is illustrated in Table 4, which shows the contribution of each of the four radionuclides to the total collective dose at different times for the UK and European populations. Full results for all radionuclides are given in Appendix D.

The contribution of ^{14}C increases with time reflecting its long radioactive half-life (about 5700 y) and its high mobility in the environment (Simmonds et al, 1995). Although ^{129}I has a longer half-life (10^{7} y) than ^{14}C, its contribution falls slightly at the very longest time; this is due to the importance of the first pass dose for ^{129}I, which affects the overall change in collective dose with time. The use of a specific activity approach (Simmonds et al, 1995) for ^{14}C means that the estimated first pass collective dose is all delivered in the year of deposition.

Table 4 Percentage contributions of different radionuclides to the total collective dose due to annual discharges to atmosphere from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

	% Contribution							
	1 y		500 y		5000 y		Infinity	
Radionuclide	UK	Europe	UK	Europe	UK	Europe	UK	Europe
3H	11	6.8	6.4	2.9	5.3	1.9	4.2	1.3
14C	12	20	16	28	30	51	43	64
85Kr	20	16	19	23	16	15	12	10
129I	45	53	51	44	43	30	36	24

Note:

These are rounded values and so can add up to more than 100%.

Similar results were found for discharges to atmosphere from Cap de la Hague as shown in Table 5.

Table 5 Collective doses due to annual discharges to atmosphere from the La Hague site (discharge is the average annual discharge between 1999 and 2003)

	Collective dose (man Sv)			
	European population ($7\ 10^{8}$ people)		World population ($1\ 10^{10}$ people)	
Integration period (y)	Total	(first pass*)	Total	(first pass*)
1	16	(15)	19	(15)
50	28	(15)	190	(15)
500	41	(15)	380	(15)
10000	120	(15)	1500	(15)
100000	160	(15)	2100	(15)

Notes:

* The first pass dose is that due to the initial discharge to the environment. The total also includes any contribution from the global circulation of relevant radionuclides (see Section 4.2).

Results presented to two significant figures.

Table 5 shows that the collective dose due to the first pass exposure is essentially all delivered in the first year following the discharge. This is because the dose is mainly due to carbon-14. The first pass dose for both populations only makes a small contribution except in the first year after the discharge. The contribution from the global circulation of long-lived radionuclides continues to increase for all times considered. At all times, the collective dose to the European population is mainly due to discharges of ^{14}C.

The patterns of collective doses for the two sites are broadly comparable with the majority of the contribution to dose at longer times being due to globally circulating radionuclides. The values of collective doses differ due to the composition of the discharges of radionuclides (see the radionuclide information presented in Appendix D). Iodine-129 is an important contributor to the doses for Sellafield but not for La Hague, while ^{14}C discharges to atmosphere are a factor of 10 greater for La Hague than Sellafield.

4.3.2 Marine discharges

The collective doses due to averaged annual discharges into the marine environment from the Sellafield site between 1999 and 2003 are shown in Table 6.

Table 6 Collective doses due to annual marine discharges from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

	Collective dose to population (man Sv)					
	UK (5.5 10^7 people)		European Union* (3.59 10^8 people)		World (1 10^{10} people)	
Truncation time (y)	*Total*	*(first pass†)*	*Total*	*(first pass†)*	*Total*	*(first pass†)*
1	0.44	(0.44)	1.0	(1.0)	1.3	(1.2)
50	2.3	(2.2)	6.4	(5.7)	29	(8.7)
100	2.4	(2.2)	7.1	(5.9)	45	(9.0)
500	2.9	(2.3)	9.9	(6.1)	120	(9.4)
1000	3.2	(2.3)	12	(6.1)	180	(9.5)
5000	5.2	(2.3)	24	(6.2)	540	(9.8)
10000	6.6	(2.4)	34	(6.3)	800	(10)
50000	8.3	(2.4)	44	(6.5)	1100	(10)
100000	8.4	(2.4)	45	(6.6)	1100	(11)

Notes:

* Pre-2004 enlargement.

† The first pass dose is that due to the initial discharge to the environment. The total also includes any contribution from the global circulation of relevant radionuclides (see section 4.2).

Results presented to 2 significant figures.

Table 6 shows that the dose due to the first pass is mainly delivered in the first 50 years after discharge. Over time, the globally circulating component increasingly becomes the majority contributor to the total dose. Carbon-14 is the highest contributor to the collective dose to the UK population at all truncation times. As with discharges to atmosphere, carbon-14 delivers a long-term dose due to global circulation. Other important contributors to collective dose in the first year are technetium-99, ruthenium-106, caesium-137 and plutonium-239. Long-lived radionuclides can continue to contribute to the collective dose over long time periods whether from the first pass or global circulation (see Appendix D).

The collective doses due to averaged annual discharges into the marine environment from the La Hague site between 1999 and 2003 are shown in Table 7. The contribution of the dose from global circulation to the total collective dose for each of the three populations is illustrated in Figure 3.

Table 7 Collective doses due to the annual marine discharges from the La Hague site (discharge is the average annual discharge between 1999 and 2003)

Truncation time (y)	Collective dose to population (man Sv)					
	France		European Union*		World	
	Total	*(first pass†)*	*Total*	*(first pass†)*	*Total*	*(first pass†)*
1	1.3	(1.3)	2.3	(2.3)	2.3	(2.3)
50	2.0	(1.9)	5.3	(4.7)	22	(5.2)
500	2.6	(2.1)	9.0	(5.7)	100	(7.1)
10000	7.4	(3.8)	40	(17)	660	(26)
100000	15	(4.3)	84	(20)	1500	(32)

Notes:

* Pre-2004 enlargement.

† The first pass dose is that due to the initial discharge to the environment. The total also includes any contribution from the global circulation of relevant radionuclides (see section 4.2).

Results presented to 2 significant figures.

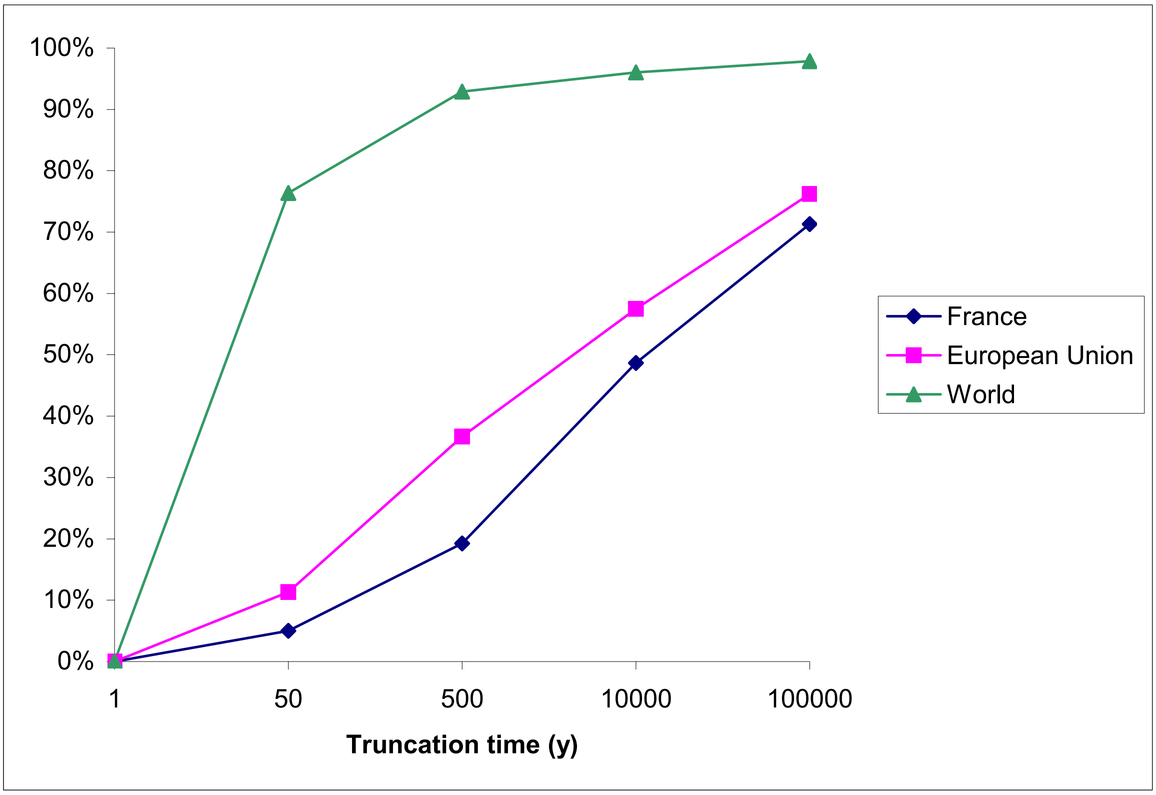

Figure 3 Contribution of the dose from global circulation to the total collective doses due to the annual marine discharges from the La Hague site (discharge is the average annual discharge between 1999 and 2003)

Table 7 shows that the dose due to the first pass increases over all times after discharge unlike for the Sellafield discharges. This difference is due to the more dominant percentage contribution of long-lived radionuclides to doses at La Hague than at Sellafield. For example, ^{14}C is a bigger relative contributor to the dose at La Hague than at Sellafield although the annual discharges to sea are slightly lower. The first pass dose due to discharges of ^{14}C to the marine environment does increase beyond the first year, unlike for the atmospheric releases, as ^{14}C is modelled in the same way as all other radionuclides. Over time, as illustrated in Figure 3, the globally circulating component increasingly becomes the majority contributor to the total dose. Carbon-14 is the highest contributor to the collective dose of the French population at all truncation times, ruthenium-106 contributes around 45% to the total collective dose in the first year. The percentage contribution of iodine-129 to the collective dose is around 37% at 100000 years due to its long half-life and global dispersion.

The values and trends in collective doses are very similar between the two sites. Slight differences in the delivery of dose exist due to differences in the dispersion of radioactivity away from the two sites and due to the composition of radionuclides comprising the total discharges from the two sites.

The above tables of collective doses from both atmospheric and marine discharges can be considered as examples of 'dose matrices', where the total collective dose is disaggregated according to time and space scales only, the first part of the matrix illustrated in Figure 1.

4.4 Per-caput doses

4.4.1 Atmospheric discharges

It is possible to obtain estimates of individual, per-caput doses from the collective doses. Table 8 shows the annual per-caput doses to the UK, European and world populations in the 1st, 50th and 100th year of continuous discharge from Sellafield at the discharge rates given in Appendix B.

Table 8 Maximum annual per-caput doses assuming continuous discharge to atmosphere from the Sellafield site

	Per-caput dose (Sv) to different populations		
Years of discharge	UK	Europe	World
1	$1.9\ 10^{-8}$	$6.1\ 10^{-9}$	$6.7\ 10^{-10}$
50	$2.8\ 10^{-8}$	$1.2\ 10^{-8}$	$4.3\ 10^{-9}$
100	$2.9\ 10^{-8}$	$1.3\ 10^{-8}$	$4.8\ 10^{-9}$

Notes:

Discharges are assumed to be at an annual rate obtained as an average value of the discharges between 1999 and 2003.

Results presented to two significant figures.

Table 9 shows the annual per-caput doses to the European and world populations in the 1st and 50th year of continuous discharge from La Hague at the discharge rates given in Appendix B. It is not possible using the methodology available to estimate doses in the country of discharge, France.

Table 9 Maximum annual per-caput doses assuming continuous discharge to atmosphere from the La Hague site

Years of discharge	Per-caput dose (Sv) to different populations	
	Europe	World
1	$2.2\ 10^{-8}$	$1.9\ 10^{-9}$
50	$3.9\ 10^{-8}$	$1.9\ 10^{-8}$

Notes:

Discharges are assumed to be at an annual rate obtained as an average value of the discharges between 1999 and 2003.

Results presented to two significant figures.

In all cases, the per-caput doses are very small and, as expected, increasing the number of years of discharge increases the per-caput dose in the final year of discharge, although the differences in dose are relatively small. For Sellafield, as the source is in the UK, then the per-caput doses are highest for the UK population. For La Hague, as the source is in France then the per-caput doses would be highest there if it had been possible to separate these from the total dose to the European population.

It is important to note that these are the average doses for the population and higher doses would be received by people living closest to the site as discussed in Section 4.8.

4.4.2 Marine discharges

The per-caput doses are estimated by dividing the collective doses truncated at the appropriate times by the population number of interest, thus representing the per-caput dose for these populations in the selected year. They are based on net seafood catches, ie, the seafood caught by a country less the seafood exported. When both of these numbers are large, the difference may not be a true representation of the actual individual intake in the country (Simmonds et al, 2002). The results of these calculations for the Sellafield site are presented in Table 10.

Table 10 Maximum annual per-caput doses due to a continuous discharge to the marine environment from Sellafield

Years of discharge (y)	Per-caput dose in population (Sv)		
	UK	European Union*	World
1	$8.0\ 10^{-9}$	$2.9\ 10^{-9}$	$1.3\ 10^{-10}$
50	$4.1\ 10^{-8}$	$1.8\ 10^{-8}$	$2.9\ 10^{-9}$
100	$4.4\ 10^{-8}$	$2.0\ 10^{-8}$	$4.5\ 10^{-9}$

Notes:

* Pre-2004 enlargement.

Presented to 2 significant figures.

Discharges are assumed to be at an annual rate obtained as an average value for discharges between 1999 and 2003.

The results of these calculations for discharges from the La Hague site are presented in Table 11. For marine discharges, the modelling approach enables collective doses to the French population to be estimated, unlike for atmospheric discharges.

Table 11 Maximum annual per-caput doses due to a continuous discharge to the marine environment from La Hague

Years of discharge (y)	Per-caput dose in population (Sv)		
	France	European Union*	World
1	2.3 10^{-8}	6.4 10^{-9}	2.3 10^{-10}
50	3.5 10^{-8}	1.5 10^{-8}	2.2 10^{-9}

Notes:

* Pre-2004 enlargement.

Presented to 2 significant figures.

Discharges are assumed to be at an annual rate obtained as an average value of discharges between 1999 and 2003.

For all examples presented, the per-caput doses are small. Increasing the number of years of discharge results in higher estimates of per-caput doses showing the tendency of marine discharges to take some years to build up in the environment dependent on the rates of transfer of radioactive material away from the originating site. This is especially true for European Union and world per-caput doses due to the longer travel distance from the discharge sites. For Sellafield discharges, as the discharges occur from a UK based site, the per-caput doses in the UK population are the highest, representing an average dose to a member of the UK population. The same is also true of doses to the French population from La Hague discharges. Higher doses would be received by individuals closer to the site should a full dose assessment be performed (eg, Environment Agency *et al*., 2004). Conversely, individuals at greatest distances from the site may be expected to receive lower than average doses.

4.5 Indicative per-caput annual dose rates

4.5.1 Atmospheric discharges

As discussed in Section 4.2 indicative per-caput dose rates are obtained by finding an average collective dose rate for the period of interest and dividing it by the total population. These together with the maximum annual per-caput annual doses can provide information on individual doses to contribute to the matrix shown in Figure 1. Table 12 shows indicative per-caput dose rates for the 3 population groups for different time periods following annual discharges to atmosphere from the Sellafield site obtained as an average of discharges between 1999 and 2003 The indicative per-caput dose rates are also presented graphically in Figure 4. Detailed results for each radionuclide considered are given in Appendix D.

Table 12 Indicative per-caput dose rates at different time periods following one year's discharge to atmosphere from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

Time period	Per-caput dose rate (Sv/y) for different populations		
Y	UK	Europe	World
1-50	$1.8\ 10^{-10}$	$1.2\ 10^{-10}$	$7.3\ 10^{-11}$
50-100	$3.1\ 10^{-11}$	$1.7\ 10^{-11}$	$1.0\ 10^{-11}$
100-500	$8.6\ 10^{-12}$	$4.5\ 10^{-12}$	$3.7\ 10^{-12}$
500-1000	$2.2\ 10^{-12}$	$2.2\ 10^{-12}$	$2.3\ 10^{-12}$
1000-5000	$1.5\ 10^{-12}$	$1.5\ 10^{-12}$	$1.5\ 10^{-12}$
5000-10000	$8.8\ 10^{-13}$	$8.7\ 10^{-13}$	$8.7\ 10^{-13}$
10000-50000	$1.3\ 10^{-13}$	$1.3\ 10^{-13}$	$1.3\ 10^{-13}$
50000-100000	$9.1\ 10^{-16}$	$9.3\ 10^{-16}$	$9.0\ 10^{-16}$

Note:

Results presented to 2 significant figures.

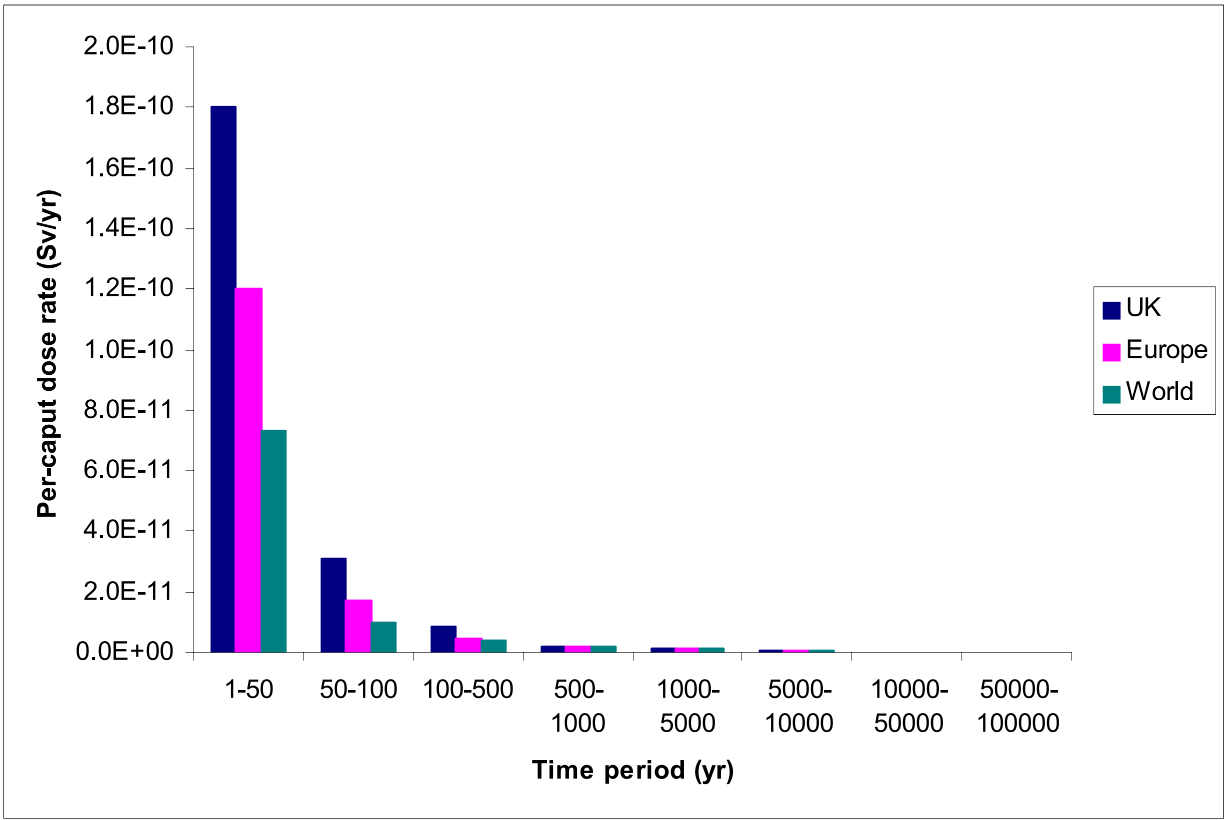

Figure 4 Indicative per-caput dose rates at different time periods following one year's discharge to atmosphere from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

Table 13 shows indicative per-caput dose rates for the European and world populations for a limited set of time periods following annual average discharges to atmosphere from the La Hague site between 1999 and 2003.

Table 13 Indicative per-caput dose rates at different time periods following one year's discharge to atmosphere from the La Hague site (discharge is the average annual discharge between 1999 and 2003)

Time period	Per-caput dose rate (Sv/y) for different populations	
Y	Europe	World
1-50	3.5 10^{-10}	3.5 10^{-10}
50-500	4.1 10^{-11}	4.1 10^{-11}
500-10000	1.2 10^{-11}	1.2 10^{-11}
10000-100000	5.9 10^{-13}	5.9 10^{-13}

Note:

Results presented to 2 significant figures.

For the Sellafield discharges, the per-caput dose rates show the expected trend of decreasing levels with time, with the UK receiving the highest per-caput doses in the first period following the discharge. However, from 500 y on there are no differences (except rounding errors) in the estimated per-caput doses between the three population groups as by this time the dose is dominated by that due to global circulation. For the La Hague discharges, the per-caput dose rates show no differences between the two population groups. All of the estimated annual per-caput dose rates are extremely small. The results presented are for a single year's discharge if the discharge continues for n years then the results can be multiplied by n to obtain the indicative per-caput dose rates for the total discharge, except for times less than n where a specific calculation would be required.

4.5.2 Marine discharges

Indicative per-caput dose rates were derived for selected time periods using the three population groups previously considered for the same average annual discharges (1999 to 2003). The results of these calculations for the Sellafield and La Hague sites are presented in Table 14 and Table 15, respectively. Again more detailed results, including the contribution by radionuclide are given in Appendix D.

Table 14 Indicative per-caput dose rates due to one year's marine discharge from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

	Per-caput dose rate in population (Sv/y)		
Time period (y)	UK	European Union*	World
1-50	$6.8\ 10^{-10}$	$3.0\ 10^{-10}$	$5.6\ 10^{-11}$
50-100	$4.9\ 10^{-11}$	$3.8\ 10^{-11}$	$3.3\ 10^{-11}$
100-500	$2.1\ 10^{-11}$	$2.0\ 10^{-11}$	$1.9\ 10^{-11}$
500-1000	$1.3\ 10^{-11}$	$1.3\ 10^{-11}$	$1.2\ 10^{-11}$
1000-5000	$9.1\ 10^{-12}$	$8.5\ 10^{-12}$	$9.0\ 10^{-12}$
5000-10000	$4.9\ 10^{-12}$	$5.1\ 10^{-12}$	$5.2\ 10^{-12}$
10000-50000	$7.9\ 10^{-13}$	$7.5\ 10^{-13}$	$8.1\ 10^{-13}$
50000-100000	$4.3\ 10^{-14}$	$3.6\ 10^{-14}$	$2.4\ 10^{-14}$

Notes:

* Pre-2004 enlargement.

Presented to 2 significant figures.

Table 15 Indicative per-caput dose rates due to annual marine discharges from the La Hague site (discharge is the average annual discharge between 1999 and 2003)

	Per-caput dose rate in population (Sv/y)		
Time period (y)	France	European Union*	World
1-50	$2.5\ 10^{-10}$	$1.7\ 10^{-10}$	$4.0\ 10^{-11}$
50-500	$2.4\ 10^{-11}$	$2.3\ 10^{-11}$	$1.8\ 10^{-11}$
500-10000	$8.8\ 10^{-12}$	$9.1\ 10^{-12}$	$5.9\ 10^{-12}$
10000-100000	$1.4\ 10^{-12}$	$1.4\ 10^{-12}$	$9.6\ 10^{-13}$

Notes:

* Pre-2004 enlargement.

Presented to 2 significant figures.

Table 14 and Table 15 show the indicative per-caput dose rates to decrease over time with the highest per-caput doses received by individuals in the UK and French populations, respectively. The per-caput dose rates converge to similar values across population groups (ignoring rounding errors) by 500 years indicating that the majority of the dose after this time is due to globally dispersed radionuclides. Differences between per-caput dose rates between the values of both the country of discharge and European Union and those of the world are due to the contribution of iodine-129. The modelling used for global dispersion of iodine-129 distinguishes between doses received by different population groups (Titley et al, 1995). For the Sellafield site, other differences between the UK and European Union per-caput dose rates during this time period are due to long-term doses delivered from the first pass of discharges of the long lived radionuclide technetium-99. The per-caput dose rates estimated in Table 14 and Table 15 are all at very low levels

4.6 Doses by distance

It has been possible to obtain estimated collective doses for broad geographical regions (UK, France, Europe and the world) but it would be of interest to also have results for smaller areas. In particular the collective and associated individual doses closer to the discharge site may be of interest. However, as discussed earlier in Section 4.1, this is difficult due to the need to take account of the food exposure pathways. An illustrative calculation was performed for the Sellafield site for discharges to atmosphere to examine the distribution of collective dose by distance from the site. The calculation was performed for five distance bands and detailed results are presented in Appendix D. For the non-food pathways the doses are based on the people living in the different distance bands assuming that they spend all of their time there. For the ingestion of terrestrial foods no account was taken of the consumption of locally produced food but rather it was assumed that the dose from food was the same for everyone in the UK. Hence, collective doses due to food consumption were based on the UK average for all distances considered weighted by the population number in the distance band of interest to get the collective dose. For the purposes of this illustrative calculation, doses due to globally circulating radionuclides were not considered and all doses are to the UK population only.

4.6.1 Collective doses

Collective doses by distance band are shown in Table 16. The majority of the collective dose is delivered in the distance band between 100 and 500 km. The percentage contribution of food pathways to the collective dose increases with increasing distance from the site (see Appendix D). Within 20 km of the site, the collective dose is dominated by the non-food pathways, ie, inhalation and external dose, as no account is taken of the consumption of locally produced food. There is little variation in the percentage contribution of food to total collective dose with increasing truncation time due to much of the dose being delivered in the first year. The values given here exclude the contribution from globally circulating radionuclides and so differ slightly from the results given previously.

4.6.2 Per-caput doses

Per-caput doses assuming continuous discharges for 1 and 50 y are presented by distance band and exposure pathway in Table 17. More detailed results are given in Appendix D. The per-caput doses are greatest in the distance band nearest the site and decrease by three orders of magnitude at the distance band furthest from the site. As identified for the results of collective doses by distance, as no account is taken of the consumption of locally produced food this is a minor contributor for distances less than 20 km from the site. However, food is the major contributor to dose at distances of 100 km or greater from the site. Values are also presented for the average per-caput doses over all distances. These indicate that ingestion of terrestrial foods contribute around two-thirds of the total dose at both integration times considered. The values given here exclude the contribution from globally circulating radionuclides and so differ slightly from the results given previously.

Table 16 Collective doses to the UK population by distance due to one year's discharge to atmosphere from Sellafield (discharge is the average annual discharge between 1999 and 2003) (first-pass dose only)

	Truncation time (y)				
Distance band	1	50	500	10000	100000
0-5 km	$1.2\ 10^{-2}$ (<1%)	$1.2\ 10^{-2}$ (<1%)	$1.2\ 10^{-2}$ (<1%)	$1.2\ 10^{-2}$ (<1%)	$1.2\ 10^{-2}$ (<1%)
5-20 km	$2.6\ 10^{-2}$ (3%)	$2.7\ 10^{-2}$ (4%)	$2.7\ 10^{-2}$ (4%)	$2.7\ 10^{-2}$ (4%)	$2.7\ 10^{-2}$ (4%)
20-100 km	$6.9\ 10^{-2}$ (29%)	$7.7\ 10^{-2}$ (37%)	$8.1\ 10^{-2}$ (39%)	$8.1\ 10^{-2}$ (40%)	$8.1\ 10^{-2}$ (40%)
100-500 km	$9.6\ 10^{-1}$ (73%)	$1.2\ 10^{0}$ (79%)	$1.4\ 10^{0}$ (81%)	$1.4\ 10^{0}$ (81%)	$1.4\ 10^{0}$ (81%)
500-1500 km	$7.7\ 10^{-4}$ (93%)	$1.1\ 10^{-3}$ (95%)	$1.2\ 10^{-3}$ (95%)	$1.2\ 10^{-3}$ (95%)	$1.2\ 10^{-3}$ (95%)

Notes:

Percentage contribution by food pathways shown in parentheses.

Results presented to 2 significant figures.

Table 17 Maximum annual per-caput doses by distance assuming continuous discharge to atmosphere from the Sellafield site.

	Breakdown by pathway							
	1 y integration time				50 y integration time			
Distance band	Non-food	Food	**Total**	% contribution of food	Non-food	Food	**Total**	% contribution of food
0-5 km	$2.7\ 10^{-6}$	$1.3\ 10^{-8}$	$\mathbf{2.7\ 10^{-6}}$	<1%	$2.7\ 10^{-6}$	$1.8\ 10^{-8}$	$\mathbf{2.7\ 10^{-6}}$	1%
5-20 km	$4.5\ 10^{-7}$	$1.3\ 10^{-8}$	$\mathbf{4.6\ 10^{-7}}$	3%	$4.5\ 10^{-7}$	$1.8\ 10^{-8}$	$\mathbf{4.7\ 10^{-7}}$	4%
20-100 km	$3.1\ 10^{-8}$	$1.39\ 10^{-8}$	$\mathbf{4.4\ 10^{-8}}$	29%	$3.2\ 10^{-8}$	$1.9\ 10^{-8}$	$\mathbf{5.0\ 10^{-8}}$	37%
100-500 km	$4.9\ 10^{-9}$	$1.3\ 10^{-8}$	$\mathbf{1.8\ 10^{-8}}$	73%	$5.0\ 10^{-9}$	$1.9\ 10^{-8}$	$\mathbf{2.3\ 10^{-8}}$	79%
500-1500 km	$1.0\ 10^{-9}$	$1.3\ 10^{-8}$	$\mathbf{1.4\ 10^{-8}}$	93%	$1.0\ 10^{-9}$	$1.8\ 10^{-8}$	$\mathbf{1.9\ 10^{-8}}$	95%
Over all distances	$\mathbf{6.3\ 10^{-9}}$	$\mathbf{1.3\ 10^{-8}}$	$\mathbf{1.9\ 10^{-8}}$	**67%**	$\mathbf{6.4\ 10^{-9}}$	$\mathbf{1.8\ 10^{-8}}$	$\mathbf{2.5\ 10^{-8}}$	**74%**

Notes:

Discharges are assumed to be at an annual rate obtained as an average value of discharges between 1999 and 2003.
Results presented to 2 significant figures.

4.6.3 Discussion of illustrative results by distance

The results obtained here show that it is possible to get an indication of the collective and per-caput doses as a function of distance from the discharge point, which may be of interest in building up a collective dose matrix. However, the results may of limited use because they do not properly account for the variation in food doses between individuals. Here it has been assumed that food is distributed throughout the UK and so the average UK dose is applicable in all distance bands. An alternative approach would have been to assume that people obtained all of their food from where they lived but, as discussed in Section 4.1, this is also unrealistic. A more realistic approach would take account of the extent to which people consume locally produced food but information on this is very limited.

4.7 Applicability of approach

Examples have been given in this section of approaches that can be used to disaggregate collective dose estimates. As an example of the applicability of such approaches to dose estimation studies, this subsection considers the application of these approaches to a previously published study, MARINA II (Simmonds et al, 2002).

The MARINA II study considered the radiological impact of radioactivity in North European waters. This study considered the historical discharge patterns from the considered sites in estimating integrated collective doses, collective dose rates and per-caput dose rates up to the year 2500. This differs from the illustrative calculations presented here where a single year of discharge was considered. Using historical discharges over a period of years means that to estimate collective doses a fixed year must be chosen to integrate to, eg, 2500 in the case of the MARINA II study, rather than integrating over a fixed number of years. Also, if additional truncation times for collective dose are required then the fixed years must be chosen at the start of the study.

The MARINA II study considered the likely annual per-caput dose rates received in the individual member states of the European Union. These were estimated by dividing the collective dose rate received by each country by the population. As discussed in the Marina II report (Simmonds et al, 2002), the country and per-caput doses are based on net seafood catches, ie, the seafood caught by the country minus the seafood exported. Where both of these numbers are large the difference may not be a true representation of the actual seafood intake in the country and so the per-caput doses must be regarded as particularly uncertain. The MARINA II study was only concerned with the impact on the population of the EU and so doses to the world population were not considered. However, it would be possible to extend the MARINA II study to give similar types of results for per-caput doses for different population groups as those illustrated earlier in this report. In studies, such as MARINA II, involving discharges to the marine environment it is hard to see how collective doses could be obtained for population groups smaller than those for each country. This is due to the use of seafood catch data in the calculation and the limitations of the data available.

4.8 Comparison against published individual dose data

It is of interest to compare the results obtained in this study with published individual doses for relevant population groups. In the UK information on radioactivity in food and the environment is published annually by Government Agencies (EA, EHS, FSA, SEPA, 2004). For 2003 the published results indicate that a typical individual living near to Sellafield would have received a dose of less than 5 μSv due to marine pathways (no similar data were available for typical individual doses for atmospheric pathways). The report also gives estimated critical group doses for discharges from Sellafield; in 2003 these are given as about 200 μSv for marine exposure pathways and about 35 μSv for terrestrial exposure pathways. As expected these doses are significantly higher than the per-caput doses presented here.

For the Cap de la Hague site individual doses have been estimated by the operator of the site, COGEMA, and reviewed by the Groupe Radioécologie Nord Cotentin (GRNC, 2003). In 2003 the doses estimated by the GRNC for different groups of people ranged from 4 to 35 μSv. The highest estimated dose was for a hypothetical farmer living and working in Pont-Durand and was considered very cautious. A more realistic estimate of the highest dose was given as 16 μSv for an adult living in Digulleville. Again these doses are significantly higher than the per-caput doses presented here. This shows the importance of also presenting critical group or typical local individual doses in a complete dose assessment study, as individual doses close to the site of discharges will not be adequately represented in a calculation to estimate average individual doses to a population of a country.

4.9 Discussion

4.9.1 Uncertainties in the results

The results presented here were obtained using a series of models using a wide range of data and a number of assumptions. Each of these inputs to the assessment has an associated uncertainty and the estimated doses are also uncertain. Although the results are presented to two significant figures for comparison purposes, this should not be taken to imply this degree of accuracy in the values given. Techniques are available to assess numerically the uncertainties in estimated doses but they require more resources and information than were available for this study. However, the uncertainty associated with the estimated doses should be borne in mind. The following is a qualitative discussion of some of the particular sources of uncertainty for assessing collective doses.

In estimating collective doses it has been assumed that the population size remains the same for all time periods considered. Increasing the population size will increase the collective dose provided that the amount of food produced also increases (as the collective dose from the ingestion of food is based on food production data rather than size of the population). For discharge to the marine environment the collective doses due to ingestion of seafood are based on data for seafood catches for 1998 and their use at later times must be regarded as increasingly uncertain with amounts, types and sources of seafood catches all likely to change. For terrestrial food production the data used are for past agricultural practices and again the amounts, types and sources of foods are likely to change. However, the effect of this might not be as great as might be thought as the collective doses in the long term are dominated by the ingestion of carbon-14. Carbon is found in all foods and so changing the type of food may have limited effects on the resulting collective doses.

The importance of carbon-14 introduces another uncertainty when considering collective doses into the future, the effect of carbon emissions from various industries. The modelling of carbon-14 is based on the movement of stable carbon and assumes a specific activity approach where the carbon-14 is related to the amount of stable carbon in different parts of the environment. Increases in the amount of stable carbon will have an effect on this model and hence on the collective doses from carbon-14. The increased amount of carbon in the environment may also lead to global warming and this could again have an impact on the models used to assess collective doses. For example, the MARINA II model has been well validated based on past environmental measurements (Simmonds et al, 2002) but the marine transfers are likely to be affected by future changes in sea levels and water movements.

4.9.2 General points

Comparison of the collective dose truncated at a range of times can provide an indication of the time period when the majority of the collective dose is delivered. Much of the collective dose due to the first pass is delivered within the first 50 years following discharge, although there is a continuing residual dose delivered over the remaining time periods considered due to long-lived radionuclides, which is of particular relevance for the marine discharges from La Hague (Table 7). The contribution due to globally circulated radionuclides increases over time to represent the greatest contributor to total collective dose to the world population by 50 years and the European Union population by between 500 and 10,000 years (varying with site and differing for marine and atmospheric discharges). The collective dose rate from global circulation dominates the total collective dose rate by 500 years following discharge at the latest for all populations considered. The global component represents a uniform dose to the population group considered. In most cases, it can be shown that the annual rate of collective dose is greatest whilst discharges are continuing and that this rate decreases when discharges cease as continued environmental transfer and decay processes occur.

The collective doses presented here can be compared with those that are received from other sources of radioactivity. Of particular interest is the collective dose received from naturally occurring carbon-14 due to the importance of this radionuclide in the current study. In the UK the ionising radiation exposure of the UK population was reviewed in 2005 (Watson et al, 2005). This study reported that the average individual dose in the UK from naturally occurring carbon-14 was about 8.8 µSv per year. Multiplying this by the UK population used elsewhere in the current study, $5.5.10^7$ gives an annual collective dose of about 480 man Sv per year to the UK population. This is significantly greater than the total UK collective dose from both atmospheric and marine discharges of all radionuclides from Sellafield integrated over all time (10 man Sv from Tables 3 and 6).

The per-caput doses estimated following 1, 50 and 100 years of continuous discharge show the average individual doses comprising the collective dose. The per-caput doses in the 50th and 100th year of continuous discharge show the greatest values assuming that the practice continues during this time. Additional information can be obtained from the indicative per-caput dose rates, which show that the rate of dose delivery is greatest in the first 50 years reducing by approximately an order of magnitude in the next 50 years for the UK and European Union populations. The per-caput dose rates broadly show convergence of dose rates between population groups after 500 years. In all considered cases, the per-caput individual doses are less than 10^{-5} Sv, representing a trivial level of individual risk (IAEA, 1988; ICRP, 2004). It should be noted that the per-caput doses presented here would form only part of an assessment of the complete radiological impact of a practice. In addition, there is a continued requirement to consider the most exposed group within a population, referred to as the critical group or the reference group. An additional input to the assessment may be the consideration of individuals living close to the site, who have typical behaviour and consumption habits, referred to as typical individuals (Bexon, 2000).

5 GUIDANCE ON THE CALCULATION, PRESENTATION AND USE OF COLLECTIVE DOSES

5.1 ICRP foundation document on optimisation

In the draft of the ICRP's foundation document on optimisation published for comment in 2005 (ICRP, 2005), the Commission recommends the separation of collective doses into various components, reflecting the attributes and the exposure characteristics of the exposed individuals, and the time and space distributions of exposures relevant for the decision making process. The disaggregating process results in a set of exposure characteristics and attributes that can be constructed on a case by case basis. To define these elements, it is stated that the most straightforward approach is, very often, to ask *'when, how and by whom are exposures received*'. In some situations, eg, those having far-future components, it is further noted that the definition of the elements may be driven by ethical and intergenerational issues.

A list of useful aspects to be potentially considered in the disaggregation process is presented in ICRP's report. This list covers characteristics of both the exposed population and their exposures. The main characteristics of the exposed populations considered by ICRP are: gender; age; health status; sensitive groups (eg, pregnant women); and habits. The characteristics of the exposure are: distribution of exposures in time and space; number of individuals; minimum individual dose; maximum individual dose; mean individual dose; statistical deviations; total group dose; likelihood of occurrence (potential exposures); and pre-existing radiological conditions (eg, high natural background, post-accident). Consideration of the above attributes is expected to lead to the derivation of a dose 'matrix' (see Figure 1 for an example).

5.2 Development of a dose matrix

A single aggregated collective dose masks information on the distribution of doses within different population groups and over time and space that might be potentially useful to decision-makers. The use of a dose matrix, as proposed by ICRP, would resolve this issue. There are, however, a number of practical issues and problems with the determination of a dose matrix for routine releases of radionuclides to both the atmosphere and aquatic environment.

5.2.1 Temporal and spatial elements of collective dose

Current models and codes used for the estimation of collective doses (eg, PC CREAM (Mayall et al, 1997) and MARINA (EC, 2002)) determine collective doses to a limited number of population groups over various temporal periods, and thus go some way to providing the required 'group doses'* for a dose matrix. In some cases, as in this study, minor changes may be required to the model and/or code to obtain information on the desired temporal frame. Such problems are not expected to be a significant hindrance to the development of dose matrices. The majority of such models consider national and supra national populations (eg, EU and World). They could, in theory, be modified to address collective doses to smaller groups, for example, a region within a country. This would, however, require information on the transfer of food into and out of such a region. It is unlikely that such information would be available for areas below the country level. If 'group doses' are required for smaller groups then alternative approaches may need to be developed.

5.2.2 Individual dose distributions

As indicated in this report, the current methodologies and models used to estimate collective doses to members of the public from radioactive discharges are not designed to determine all elements of the suggested dose matrix. One of the main issues relates to the derivation of information on the distribution of individual doses within a population group.

As indicated in Section 4, it is possible when considering atmospheric releases to derive doses as a function of distance from the release point for the majority of exposure pathways (inhalation, external, resuspension). Using such information in combination with information on populations within particular distance bands it would be possible to derive a distribution on individual dose†. Unfortunately the same is not possible in relation to doses from the consumption of contaminated food because of the importance of food distribution. Given the global market in food, assuming food is consumed where it is produced is very simplistic (for the development of the Codex Alimentarius guidance, for example, it is assumed that a country imports 10% of the foods consumed in its territory). Improving this would require very detailed modelling and associated information on food distributions. It would be very difficult to collect such information and, because markets change over quite short timescales it would be impossible to predict future patterns. This conclusion is also applicable to models for the determination of collective doses from aquatic discharges because of the wide scale movement of fish and the global fish market (EC, 2002).

Given the importance of the food pathway (see discussion in Section 4) it is clear that the methodologies and models currently available for the evaluation of collective doses do not allow the meaningful evaluation of individual dose distributions within each spatial

* ICRP draft guidance on optimisation refers to collective doses within particular population subgroups as 'group doses' (ICRP, 2005).

† Clearly factors such as indoor and outdoor occupancies and the shielding offered by different building types would also impact on this distribution, but the influence of such factors would be significantly less than the impact of differences in distance from release point.

and temporal element of collective dose that make up the total collective dose. Some groups have tried to estimate individual dose distributions including doses from food by making assumptions about food distribution (Dreicer et al, 1995; Jones et al, 2004). However, for the reasons discussed in Section 3, in general it is considered that estimating individual dose distributions by assuming that locally produced food is consumed locally is problematic.

The importance to decision-makers of distributions on individual doses within population groups will clearly depend upon the context. However, it is likely that if the average doses are very low, and the range is narrow, then detailed information on the form of the distributions will be of limited value.

It is worth noting in this context that at times when global circulation dominates, because of the ubiquitous nature of the radionuclides, individual differences in diet and food distribution have little impact on doses and thus the distribution on doses is expected to be narrow. Such doses are very small and therefore the distribution within a group during a particular temporal period may be adequately represented by an indication of the average level of dose.

For example, for releases to atmosphere from Sellafield the collective dose from the first pass exposure is essentially all delivered in the first few hundred years following the discharge. Individual doses beyond this time are from global circulation and therefore (for the reasons given above) the distribution on doses will be narrow. The estimated indicative per-caput doses beyond 500 years are less than 3 10^{-12} Sv (for the UK, EU and World). Under these circumstances it is difficult to imagine that further information on the distribution of individual doses within the population would be a useful input to the decision making process. To confirm this it may be useful for studies to be undertaken to scope the likely distribution on individual doses when global circulation dominates.

The calculations undertaken for this study showed that the temporal variation in doses is also very limited at times beyond 500 years. Indicative per-caput doses reduce by only about an order of magnitude between 500 years and 50,000 years. Thus detailed temporal modelling is not needed at this stage, with the significant timescales depending upon the half-lives of the important radionuclides. Although only discharges from two sites were considered there is no reason to suppose that this conclusion will not be more generally true.

At long time periods when global circulation dominates, the per-caput dose rate is similar for all geographical populations and thus there is little point in considering a detailed matrix at this stage. In general, it appears that the complexity of the matrix should decrease with time and beyond a particular point it may be appropriate to simply look at the total remaining collective dose when comparing options.

It is also important to note that current collective dose models assume constant population sizes, agricultural production patterns and habits. Clearly the potential for all these to change over the vast time periods considered is significant. The collective doses estimated using these models at long time periods can therefore only give an indication of the relative sizes of collective doses in comparison with other options rather than absolute values.

5.2.3 Use of per-caput doses

An alternative approach to maintaining information on individual dose levels for a dose matrix has been explored in this study. This involved determining per-caput doses to various population groups at various times. The group doses and associated per-caput doses could form a useful input to optimisation and option comparison decision-making, especially, as discussed above, when the individual doses are very small and the distribution is also so narrow that even at the extremes the individual doses are very low.

5.2.4 Critical group doses and doses to the local population

It is not clear whether, when discussing group doses and the dose matrix, ICRP intends that doses to the representative individual* and the general group of most exposed individuals should form one 'group' for the matrix. Studies have been undertaken of the distribution of doses within the critical group (Jones K A et al, 2003) but no method for determining a 'group dose' for the critical group has been considered. There is a clear need for more guidance in this area and, potentially, methodological development. It is obviously important to evaluate critical group doses as part of a radiological impact assessment but considering the contribution of the critical group to the total collective dose is difficult to do and may have little value.

5.2.5 Disaggregation by gender and age

In the current draft of the ICRP optimisation document, ICRP suggests that disaggregation of group doses could be performed for different attributes such as gender and age.

As far as disaggregation by gender is concerned, this proposal raises two problems. On the practical side, current dose coefficients do not distinguish between the sexes, so disaggregation would require the production of dose coefficients for both sexes. It would also be necessary to have information on the number of men and women present within each population and also information on habits for each. On the ethical side, it would be difficult for decision makers to value exposures to men and women differently (except perhaps if exposures to specific organs are concerned for which different health effects are expected).

Disaggregation by age would require the use of age specific dose coefficients and information on the age distribution of the population and their habits and would thus complicate the calculations required. However, age specific dose coefficients are currently evaluated for a number of ages of infants and children and adults and it would be possible to estimate the age distribution of the population from currently available data. The value of the resulting age specific group doses is however questionable. At long times following the release individuals will be exposed throughout their lives.

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* In the ICRP's draft revised recommendations (ICRP, 2004) the representative individual concept is intended to replace that of the critical group in relation to exposure control.

Disaggregating on the basis of age would appear to be more relevant in relation to doses in the short term to local populations.

5.2.6 Presentation of dose information

There are a number of ways in which dose matrix information could be presented. In practical terms these include various forms of tables and various figures. Given the large amount of information which could be generated it is important to explore, especially with relevant stakeholders and potential decision-makers, practical ways to present information. It is also important to consider approaches that allow group and individual doses to be put into context. This could include comparison with natural background levels.

Given the long time scales over which exposures occur from routine discharges one approach might be to consider the collective doses received within a population during an individual lifetime and the implied impact upon health of the population. For example, the results in Table 12 can be used to indicate that for an individual born 500 years after discharges to atmosphere had ceased the total collective dose received by the world population during their lifetime would be in the region of 2 manSv*. This implies that during that individual's lifetime about 0.1 people would contract fatal cancer as a result of the discharges. Clearly this is a simplistic analysis as it assumes that the world population remains constant but it serves as an example of an alternative approach stakeholders and decision-makers may find useful. It avoids some of the problems that have been caused by simply multiplying the total collective dose by the risk factor. It is suggested that the potential use of such approaches be further explored.

Another approach that stakeholders might find useful would be to consider doses within generations. Thus, instead of considering collective doses truncated at, for example, 5000 or 10 000 years, doses received by a generation or a series of generations (for instance three - covering approximately 90 years) at various times could be evaluated. This cell 'generation' could then be moved along the time axis.

It is important to remember that the primary use of collective dose is in relation to optimisation and option comparison. In both situations this involves comparing impacts for a number of options to find the 'best' option. For this, presentation methods must allow for ease of comparison between options. At long time periods there may be minimal difference between the impact of the different options and so it unnecessarily complicates the comparison if detailed dose breakdowns are provided at these times.

It should also be remembered that in many circumstances the options may involve some element of solid waste disposal. For example, the available options for a particular liquid waste stream may range from immediate discharge to treatment and encapsulation followed by storage and, ultimately, deep disposal, with various intermediate positions possible. To allow the comparison of such options, models and tools must be available

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* From Table 12 the per-caput individual dose rate between 500 and 1000 years is $2.3\ 10^{-12}$ Sv y^{-1}, multiplying this by 70 y for an individual lifetime and $1\ 10^{10}$ for the World population gives a collective dose of 1.6 man Sv. Using a risk factor of $5\ 10^{-2}$ Sv^{-1} for fatal cancers gives 0.1 fatal cancers.

to produce relevant comparable dose endpoints for both discharges and solid waste disposals. Presentational approaches must also facilitate such comparisons. It is important to note in this context that although doses to members of the public would be significantly lower in the short term for disposal options, for mobile long-lived radionuclides the individual doses may be very similar for all options at long times following discharge/disposal.

One way to explore possible presentational approaches would be to undertake a case study.

5.3 Use of a dose matrix

In the draft ICRP guidance on optimisation, it is stated that '*Once the collective dimension of the exposures is disaggregated, the relative importance of each element of the dose matrix can be individually assessed based on environmental, technical, economic and social considerations and values, and the preferences of those involved in the decision-making process*'. ICRP considers that the transparency of the process, with a clear separation of the various attributes, characteristics and values considered to compare the protection options, is an important aspect for confidence in the final decisions.

When using a collective dose matrix in a decision-making context (eg, optimisation), weighting factors for the various elements of the collective dose matrix would need to be considered on a case by case basis, and would be arrived at by the deliberations of the relevant stakeholders.

Particular concern would for instance arise where the collective dose transgresses national and intergenerational boundaries. A dose could be considered insignificant in a society benefiting from the process causing the exposure but this could not necessarily be the case for a population in a different country or for future generations, or particular affected populations.

One method of dealing with weighting factors is to discount by varying degrees in multi-attribute analyses (MAA), as suggested in ICRP Publication 55 (ICRP, 1989). This methodology appears to be useful for comparing options which have numerous attributes, some of which are advantageous to some groups and others not, and where it is not immediately clear which is the best (or the least worst) option for all. The problem is that the weightings or discounts given to various attributes depend on one's viewpoint.

For instance, in a case where weights have to be assigned according to the time, one could consider the time at which the exposure would take place or the exposed generation. Progressively, less importance could be given to individual exposures received in the far future due to increasing uncertainties both in the estimation of dose and in the associated detriment. Conversely, in particular exposure situations, more importance could be given to exposures occurring in the future based on intergenerational equity considerations. Another judgement could be that exposures should be equally weighted in time.

However, it should not be forgotten that the main advantage of the use of a dose matrix is the provision of information on the distribution of doses within different population groups and over time and space relevant for decision-making process. Use of MAA with weighting factors could lead to an aggregated dose quantity.

To help with the use of dose matrices, one possibility is the development of graphical tools that would allow a dose matrix and the different cells within it to be presented in different ways according to the opinion of the different stakeholders. These tools could then be regarded as bridges between the remote issue of collective dose and more tangible aspects of everyday life in order to initiate debates about different options.

They could help to inform dialogues, debates and deliberations (TIDDDs*). Issues of content structuring, information presentation, knowledge quality and tool functionality would be then seen as major determinants of the tool's ability to support dialogues among non-scientific stakeholders

In the course of the report, we have seen that the 2005 draft ICRP recommendations on the use of collective dose are not easy to apply with the existing calculation methodologies. If some modifications are made in the calculation tools, it could be possible to produce something that can help to inform dialogues, debates and deliberation (TIDDDs). In this way, new methodologies could help to interpret and understand a dose matrix via graphical representations.

One issue to note is that preventing discharges may result in more solid waste disposal which may result ultimately in collective doses from another source.

The possibility of performing a comparison study (perhaps by revisiting waste treatment options that have been taken) to explore the effect of options chosen for the different collective dose elements could be considered for a future study. To explore the use of disaggregated doses in decision-making it may be useful to undertake an options comparison study. This would look at the importance of the various elements of the dose matrix and help identify useful decision-making tools and presentational approaches.

6 SUMMARY AND CONCLUSIONS

Over recent decades concerns have been expressed about the way collective doses have been used (ICRP, 2004). In particular, there is general agreement that using the fully aggregated collective dose masks a lot of useful information on levels of individual dose and their distribution over time and space, that decision makers may consider

* TIDDDs are tools that deploy new information and communication technology (namely internet, multi-media and 3D virtual reality interfaces) in order to organise the information that feeds into a dialogue processes about a governance issue. TIDDDs are designed to support participatory processes.

important. This is an issue on which ICRP is currently developing guidance (ICRP, 2005).

In the draft of the ICRP's foundation document on optimisation published for consultation in 2005 (ICRP, 2005), the Commission recommends the separation of collective doses into various components, reflecting the attributes and the exposure characteristics of the exposed individuals, and the time and space distributions of exposures relevant for the decision making process. The disaggregating process results in a set of exposure characteristics and attributes that can be constructed on a case by case basis. The aim is to construct a dose 'matrix' as illustrated in Figure 1.

In this study some of the issues involved in the development and use of such 'matrices' have been explored. In particular, practical issues regarding the disaggregation of collective doses in relation to individual dose rates and the temporal and spatial distribution of exposures have been addressed. The scope of the study was restricted to the use of collective doses from routine discharges in optimisation and options comparison.

The objectives have been accomplished primarily by carrying out a case study to estimate collective doses from discharges to the environment from a major nuclear site to various populations at various times and associated information on individual dose rates. The nuclear site chosen was Sellafield but additional calculations were also undertaken for Cap de La Hague for comparative purposes. The resulting doses were presented in Section 4.

Current models and codes used for the estimation of collective doses can determine collective doses to a limited number of population groups over various temporal periods, and thus go some way to providing the required 'group doses'* for a dose matrix. In some cases, as in this study, minor changes may be required to the model and/or code to obtain information on the desired temporal frame. Such problems are not expected to be a significant hindrance to the development of dose matrices. The majority of such models consider national and supra national populations (eg, EU and World). They could, in theory, be modified to address collective doses to smaller groups, for example, a region within a country. This would, however, require information on the transfer of food into and out of such a region. It is unlikely that such information would be available for areas below the country level. If 'group doses' are required for smaller population groups then alternative approaches may need to be developed.

In the example calculations undertaken for this study the most important exposure pathway was ingestion of contaminated food. Under these circumstances it is not possible using the current collective dose models to determine the individual dose distributions within a population because the patterns of food distribution are not known (see Sections 2 and 5 for more discussion). It is considered that this is not a problem that can be solved through improved modelling or data collection. Food distribution patterns change on a very short timescale and therefore even if they could be established for a single month, which is unlikely, it would not be possible to use these to

* ICRP draft guidance on optimisation refers to collective doses within particular population subgroups as 'group doses' (ICRP, 2005).

predict patterns of exposure over long time periods. The ICRP's suggested approach of looking at individual dose distributions within each group dose is therefore not possible for significant population sizes, except perhaps for rare cases where collective dose is dominated by other pathways. However this does not rule out the use of dose matrices as will be discussed later. For radionuclides that are globally circulated (the most important in this study being ^{129}I and ^{14}C) individual doses are likely to be reasonably predictable for long time periods as contamination will be in all major foods so changes to dietary habits are unlikely to have a significant impact. Such doses also tend to be low. So when global circulation doses dominate both the absolute levels of dose are low and the distribution is expected to be narrow. Under these conditions it is unlikely that decision-makers would find the distribution of individual doses of use. It is therefore recommended that once global circulation dominates there is no requirement for information on individual dose distributions.

A possible approach to maintaining information on individual dose levels for a dose matrix has been explored in this study. This involved determining per-caput doses to various population groups at various times. The group doses and associated per-caput doses could form a useful input to optimisation and option comparison decision-making.

Doses from global circulation are clearly an important input to any options comparison or optimisation study. However, the results of this study indicate that in general the benefits of disaggregating such doses are minimal. At long time periods it is likely that in many cases the collective doses from various options will converge. In general the study results indicate that the complexity of a dose matrix would be expected to decrease with time.

It is not clear how the dose matrix should include the dose to the critical (or representative) group. These doses are an important part of any radiological impact assessment and need to be considered as well as collective and per-caput doses. It is likely that the distribution of individual doses will be of most importance to a decision maker mainly when doses are at their highest. It is suggested that before any further work is undertaken in this area that some dialogue be developed first with relevant stakeholders and then potential decision-makers to establish whether such information would be of use. It would also be useful to establish whether more detailed information on dose distributions to regional or country populations are required for the times (up to a few hundred years at most) before global collective dose dominates. It would also be useful to explore whether, if the average/or per-caput dose is below a certain level, then such additional information is not required.

The following main conclusions can be drawn from this study:

- Current models and codes used for the estimation of collective doses can determine collective doses to a limited number of population groups over various temporal periods, and thus go some way to providing the required breakdown of collective dose into different geographical regions and times for a dose matrix.

- The ICRP's suggested approach of looking at individual dose distributions within each group dose is not possible for significant population sizes if ingestion of food is an important exposure pathway.

- It is recommended that once global circulation dominates there is no requirement for information on individual dose distributions. In general the study results indicate that the complexity of a dose matrix would be expected to decrease with time.
- It is possible to estimate per-caput doses associated with different 'group doses'. These could form a useful input to optimisation and option comparison decision-making.
- It is suggested that before any further work is undertaken in this area that some dialogue be developed first with relevant stakeholders and then potential decision-makers to establish the extent to which such information is required.

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APPENDIX A Current practice in the calculation and use of collective dose – literature review

As part of this study a review of existing published assessments of collective dose was undertaken. This review focussed primarily on the methodologies used, including geographical areas and time spans covered, and whether any disaggregation by individual dose had been undertaken. In line with the scope of the study, the review focussed on the use of collective dose in relation to routine radioactive discharges. The purpose of the collective dose assessments undertaken was also considered in the review. The results of the review are presented in Section 3. All the documents considered in the review are listed below, with brief notes on their content.

Bexon AP (2000). Radiological impact of routine discharges from UK civil nuclear sites in the mid 1990s. Chilton, NRPB-R312. This report gives information on the radiological impact of routine atmospheric and liquid discharges from UK civil nuclear sites. Calculations of collective effective doses, collective doses truncated at 500 years and typical annual individual doses were performed for discharges from each site in 1975, 1985 and 1993-1995. Collective doses to the UK and European populations were estimated. The collective doses were calculated using the NRPB radiological impact assessment software PC CREAM except for collective doses from river or lake releases for which alternative approaches were used. This report is one of a series which has indicated how collective doses have changed over time with variations in discharges, etc.

Crocket G et al. Radiological impact on the UK population of industries which use or produce materials containing enhanced levels of naturally occurring radionuclides - Part II: The steel production industry. Chilton, NRPB-W48 (2003). Individual doses to the hypothetical critical group and average local inhabitants are presented along with collective doses from the operation of steel plant. In association with the collective doses per-caput doses are presented.

Dreicer M, Tort V and Manen P (1995). Report 234: Nuclear Fuel Cycle – Estimation of Physical Impacts and Monetary Evaluations for priority pathways (February 1995). This report is the final deliverable of the ExternE Study whose aim was to develop an impact pathway methodology for the nuclear fuel cycle. In this report, the nuclear fuel cycle is divided into 8 separate stages (mining and milling, conversion, enrichment, fabrication of the fuel, electricity generation, reprocessing of spent fuel, disposal of two classifications of waste – low/intermediate level and high level waste). The general methodology adopted is based on a sequence of evaluations from source terms to the potential effects on man and the environment, and then to their monetary evaluation. The study considers routine emissions and gives priority to releases of radioactive material to the environment (atmospheric and liquid releases as well as solid waste) which potentially impact public health. The following collective dose impacts were assessed for atmospheric releases: collective doses from inhalation; collective doses from external exposure (from the cloud); collective doses from external exposure (from the deposition on the ground); and collective doses from ingestion. For liquid releases only collective doses from ingestion were estimated.

For atmospheric releases collective doses in three geographical regions were considered: local (0 – 100 km), regional (100 – 1000 km) and global (> 1000 km). Doses were determined using a standard grid approach assuming food produced within each geographical area was consumed within that area unless there was excess food (ie if average consumption rate multiplied by population was less than food produced in the area) in which case this was consumed within the next geographical region. For liquid discharges only two geographical areas were considered regional (including local) and global. It was assumed that the edible portion of food harvested in northern European waters was consumed by the European population. Two truncation times were considered for collective doses, 10 years and 10,000 years. This study highlighted that the most important choices for the assessment of the nuclear fuel cycle concern the definition of temporal and spatial boundaries. It should be noticed that the calculations are provided for the production of one TWh (ie, collective doses presented in terms of manSv per TWh). The logic in this study is not based on the impact of one specific site but rather on the contribution of the different steps of the fuel cycle.

Dreicer M, Tort V and Margerie H (1995). Report 238: The external costs of the nuclear fuel cycle – Implementation in France (August 1995). This report is an application of the above report to the French nuclear fuel cycle and an assessment of the electricity stage to include various sites for a 1300 MW reactor. Different reference sites were selected, and La Hague was selected as far as the reprocessing stage is concerned. To calculate the impact of the reprocessing stage, the data used were those of 1991 (source term). The calculations show that the reprocessing stage contributes to 79% of the total collective dose.

Dreicer M and Tort V. (1995). Temporal and spatial distribution of the environmental impact of radioactive releases from nuclear fuel cycle facilities – IN Environmental impact of radioactive releases (Symposium organised by IAEA, held in Vienna, 8-12 May 1995). Presents collective doses from the above two reports focussing on the variation of collective dose with space and time.

EPA. Radiation Risk Assessment Software. CAP88-PC Version 3.0 User Guide (2002). PC code for determining individual and collective doses. Assumes food is consumed where produced and thus generates collective doses broken down by ‘individual’ dose bands.

EPA. Cancer risk coefficients for environmental exposure to radionuclides. Federal Guidance Report No 13. EPA 402-R-99-001 (1999). Gives background to some of the data used in CAP88-PC.

Fayers C, Boyer FHC, Jones AL and Cooper JR (2001). Generic critical group and collective dose assessment of the nuclear fuel cycle. Chilton, NRPB-M1283. Collective doses are presented for each stage of the nuclear fuel cycle. The calculations were undertaken as part of a Nuclear Energy Agency comparative study of spent fuel management options. The collective doses determined were for a single year’s discharge and were truncated at 500 years they were normalised for unit power production ie presented in terms of manSv per Gwa.

IAEA (2001). Generic models for use in assessing the impact of discharges of radioactive substances to the environment. IAEA Safety Report No 19. This report provides simple methodologies for the determination of individual and collective doses.

Jones SR, Lambers B and Stevens A (2004). Disaggregation of collective dose – a worked example based on future discharges from the Sellafield nuclear fuel reprocessing site, UK. J Radiol Prot, 24, 13-27. The purpose of this study was to explore the concept of disaggregating collective doses through a worked example. Two alternative discharge scenarios for Sellafield were considered in this study, a '*stop reprocessing early, minimum discharge'* scenario and a '*reprocessing beyond current contracts'* scenario. PC-CREAM98 was used to determine collective doses for the two discharge scenarios. As part of the study the collective dose was disaggregated into different individual dose bands (related to some extent to geographical areas). This allowed the following type of statements to be made – '*for aerial discharges, collective dose at individual dose rates exceeding 0.015 μSvy^{-1} is only incurred within the UK, and at an effective dose exceeding 1.5 μSvy^{-1} is only incurred within about 20 km of Sellafield'*. The authors make it clear that disaggregation is not straightforward, because it 'places much greater demands on the models used for the calculation than does the more conventional calculation of collective dose'. A model allowing disaggregation would need to be able to track both spatial and temporal profiles of individual dose and to continually adjust the boundaries within which individual doses are aggregated. There are currently no models available for the calculation of collective dose which allow this. In the study PC-CREAM (the 1998 update) was used to separately evaluate individual and collective doses to approximately disaggregate the collective doses. The main issue in relation to disaggregation relates to ingestion doses, as most food is not consumed close to the production site but is widely distributed. The assumption made in this study was that food was consumed locally. The output of the study was collective doses integrated to 500 years (or in some cases infinity) broken down into individual effective dose bands. The results indicated that for the discharge scenarios considered the bulk of the collective dose was delivered at individual effective dose rates < 0.015 μSv y^{-1}.

Lochard J and Tort V (1997). L'impact radiologique des installations du cycle éléctronucléaire (Contrôle, June 1997). A paper on the ExternE study.

MARINA II. Update of the MARINA Project on the radiological exposure of the European Community from radioactivity in North European marine waters. Radiation Protection 132, European Commission Report (2002). Mayall A et al. PC-CREAM. Installing and using the PC system for assessing the radiological impact of routine releases. EUR 17791 EN, NRPB-SR296 (1997).

Schieber C and Schneider T (2001). The external cost of the nuclear fuel cycle - In Workshop on Externalities and Energy Policy: the Life Cycle Analysis Approach, held in Paris, 15-16 November 2001). This paper is based on the ExternE study. The aim is to describe the main results of this study and to discuss the meaning of the different indicators and assumptions adopted in the evaluation of external costs. Some further developments are presented, especially on the integration of risk aversion in the evaluations.

Schneider M ed (2001). Possible toxic effects from the nuclear reprocessing plants at Sellafield (UK) and Cap de la Hague (France) – Final Report from the STOA study project. Wise Paris Report for the EC Contract No. EP/IV/A/STOA/2000/17/0. Section 7.3 of this report addressed collective doses from reprocessing releases. The report gives long term collective doses (ie not truncated) to the European and world populations from discharges in 1999 from the nuclear fuel reprocessing sites at Sellafield and Cap de la Hague. The collective doses are summed to all times and are for aerial and liquid discharges of radionuclides that are sufficiently long lived and mobile in the environment that they are globally circulated: tritium, carbon-14, krypton-85 and iodine-129.

Schneider T (2001). Pricing the environment? An update on ExternE presented at Eurelectric Seminar, held in Paris, 26 January 2001. This paper is based on the ExternE study. It shows what “is behind” the external costs of the nuclear fuel cycle and especially gives information about exposure at the different time scales and space dimensions. It focuses too on problems concerning long-term effects.

Smith J G et al. Assessment of the radiological impact on the population of the European Union of discharges from European Union nuclear sites between 1987 and 1996. Radiation Protection 128, European Commission (2002). The report describes an assessment of the radiological impact on the population of the European Union (pre 2004 enlargement) from EU nuclear sites between 1987 and 1996. This study included calculations of collective and individual doses resulting from liquid and atmospheric discharges from all nuclear sites in the EU of that period, including the two major reprocessing sites, Sellafield and Cap de la Hague. The dose calculations were undertaken using PC CREAM. The collective doses were truncated at 500 years. Individual doses indicative of those received by members of the critical group were also determined for each site. Exposures were broken down by site and form of discharge ie liquid and atmospheric. Radionuclide and exposure pathway breakdowns of individual and collective doses were also provided on an accompanying CD. The collective doses are to the entire population of the EU at the time of the study (377 million), ie no more local information. Truncated at 500 years. However, for atmospheric releases the collective dose was divided into two components, termed, respectively, “non-global” and “global”. Non-global included doses arising from the ‘first pass’ of the plume, before radionuclides become globally dispersed. Conversely, global included doses arising from the global dispersion of radionuclides and not from the ‘first pass’ of the plume. For aquatic discharges this distinction was not made and simply totals to 500 years determined.

Smith KR et al. Radiological impact on the UK population of industries which use or produce materials containing enhanced levels of naturally occurring radionuclides - Part I: Coal-fired electricity generation. Chilton, NRPB-R327 (2001). Individual doses to the hypothetical critical group and average local inhabitants are presented along with collective doses from the operation of coal-fired power stations. In association with the collective doses per-caput doses are presented.

Tort V and Dreicer M (1995). External costs of the nuclear fuel cycle – IN Proceedings of International symposium, held in Vienna, 16-19 October 1995. Another paper on the ExternE study.

UNSCEAR (2000). Sources and effects of ionizing radiation. Volume 1: Sources. UN, New York. Provides estimates of collective doses from man-made and natural sources and per-caput doses. In the majority of cases the collective doses are to the global population although in some cases some regional breakdown is given.

APPENDIX B Discharge data

The representative calculations performed in this study required annual discharge data broken down by radionuclide. Such data were obtained for the Sellafield site in the United Kingdom and the La Hague site in France. Discharges may fluctuate between years, therefore an annual average of discharges between 1999 and 2003 was taken to reduce the effect of such fluctuations.

For both sites, the collated discharge data were compared, where possible, against the EC Bilcom database (EC, 2000). This comparison indicated that the collated data approximated closely to that in Bilcom.

B1 SELLAFIELD

Annual discharge data for 1999 to 2003 were obtained from BNFL (now British Nuclear Group) annual discharge reports (BNFL, 2003). Discharge data for 2003 were obtained from the RIFE series of reports (EA et al, 2004). Discharges to atmosphere are given in Table B1 and liquid discharges are given in Table B2.

Table B1 Annual gaseous discharges from the Sellafield site between 1999 and 2003

Radionuclide	Annual Discharge (Bq)					Average annual discharge (Bq)
	1999	2000	2001	2002	2003	1999-2003
^{3}H	$2.50\ 10^{14}$	$2.20\ 10^{14}$	$2.40\ 10^{14}$	$2.50\ 10^{14}$	$3.73\ 10^{14}$	$2.67\ 10^{14}$
^{14}C	$2.90\ 10^{12}$	$2.90\ 10^{12}$	$9.50\ 10^{11}$	$8.10\ 10^{11}$	$7.11\ 10^{11}$	$1.65\ 10^{12}$
^{35}S	$1.00\ 10^{11}$	$1.20\ 10^{11}$	$1.20\ 10^{11}$	$1.60\ 10^{10}$	$6.51\ 10^{9}$	$7.25\ 10^{10}$
^{41}Ar	$2.60\ 10^{15}$	$2.50\ 10^{15}$	$1.90\ 10^{15}$	$3.30\ 10^{14}$	$1.53\ 10^{14}$	$1.50\ 10^{15}$
^{60}Co	$4.00\ 10^{7}$	$3.30\ 10^{7}$	$3.00\ 10^{7}$	$6.00\ 10^{6}$	$1.89\ 10^{6}$	$2.22\ 10^{7}$
^{85}Kr	$1.00\ 10^{17}$	$7.40\ 10^{16}$	$1.00\ 10^{17}$	$1.00\ 10^{17}$	$1.20\ 10^{17}$	$9.88\ 10^{16}$
^{90}Sr	$6.30\ 10^{7}$	$5.40\ 10^{7}$	$5.00\ 10^{7}$	$5.00\ 10^{7}$	$5.26\ 10^{7}$	$5.39\ 10^{7}$
^{106}Ru	$9.50\ 10^{8}$	$1.10\ 10^{9}$	$1.10\ 10^{9}$	$1.30\ 10^{9}$	$1.43\ 10^{9}$	$1.18\ 10^{9}$
^{125}Sb	$2.50\ 10^{8}$	$1.80\ 10^{8}$	$5.40\ 10^{8}$	$3.80\ 10^{8}$	$1.06\ 10^{9}$	$4.82\ 10^{8}$
^{129}I	$2.50\ 10^{10}$	$2.50\ 10^{10}$	$2.00\ 10^{10}$	$2.10\ 10^{10}$	$1.70\ 10^{10}$	$2.16\ 10^{10}$
^{131}I	$4.00\ 10^{9}$	$2.70\ 10^{9}$	$2.30\ 10^{9}$	$4.50\ 10^{8}$	$6.00\ 10^{8}$	$2.01\ 10^{9}$
^{137}Cs	$5.70\ 10^{8}$	$5.70\ 10^{8}$	$3.30\ 10^{8}$	$4.30\ 10^{8}$	$4.95\ 10^{8}$	$4.79\ 10^{8}$
^{239}Pu	$1.00\ 10^{8}$	$4.40\ 10^{7}$	$3.00\ 10^{7}$	$2.00\ 10^{7}$	$6.51\ 10^{7}$	$5.18\ 10^{7}$
^{241}Pu	$8.30\ 10^{8}$	$2.60\ 10^{8}$	$1.80\ 10^{8}$	$1.00\ 10^{8}$	$3.94\ 10^{8}$	$3.53\ 10^{8}$
^{241}Am	$7.00\ 10^{7}$	$4.30\ 10^{7}$	$4.00\ 10^{7}$	$2.00\ 10^{7}$	$3.82\ 10^{7}$	$4.22\ 10^{7}$

Table B2 Annual liquid discharges from the Sellafield site between 1999 and 2003

Radionuclide	Annual Discharge (Bq)					Average annual discharge (Bq) 1999-2003
	1999	2000	2001	2002	2003	
^{3}H	$2.50\ 10^{15}$	$2.30\ 10^{15}$	$2.60\ 10^{15}$	$3.32\ 10^{15}$	$3.90\ 10^{15}$	$2.92\ 10^{15}$
^{14}C	$5.80\ 10^{12}$	$4.60\ 10^{12}$	$9.50\ 10^{12}$	$1.30\ 10^{13}$	$1.70\ 10^{13}$	$9.98\ 10^{12}$
^{35}S	$3.20\ 10^{11}$	$3.60\ 10^{11}$	$1.60\ 10^{11}$	$1.70\ 10^{11}$		$2.53\ 10^{11}$
^{54}Mn	$4.00\ 10^{10}$	$1.00\ 10^{10}$	$3.00\ 10^{10}$	$2.00\ 10^{10}$		$2.50\ 10^{10}$
^{55}Fe	$2.00\ 10^{10}$	$4.00\ 10^{10}$	$2.00\ 10^{10}$	$3.00\ 10^{10}$		$2.75\ 10^{10}$
^{60}Co	$8.90\ 10^{11}$	$1.20\ 10^{12}$	$1.20\ 10^{12}$	$8.90\ 10^{11}$	$4.30\ 10^{11}$	$9.22\ 10^{11}$
^{63}Ni	$5.80\ 10^{11}$	$4.30\ 10^{11}$	$2.70\ 10^{11}$	$4.60\ 10^{11}$		$4.35\ 10^{11}$
^{65}Zn	$7.00\ 10^{10}$	$3.00\ 10^{10}$	$5.00\ 10^{10}$	$3.00\ 10^{10}$		$4.50\ 10^{10}$
^{89}Sr	$6.00\ 10^{11}$	$6.40\ 10^{11}$	$7.60\ 10^{11}$	$5.20\ 10^{11}$		$6.30\ 10^{11}$
^{90}Sr	$3.10\ 10^{13}$	$2.00\ 10^{13}$	$2.60\ 10^{13}$	$2.00\ 10^{13}$	$1.40\ 10^{13}$	$2.22\ 10^{13}$
^{95}Zr	$1.00\ 10^{11}$	$1.00\ 10^{11}$	$1.30\ 10^{11}$	$1.70\ 10^{11}$	$1.32\ 10^{11}$	$1.26\ 10^{11}$
^{95}Nb	$8.00\ 10^{10}$	$9.00\ 10^{10}$	$1.40\ 10^{11}$	$2.50\ 10^{11}$	$1.74\ 10^{11}$	$1.47\ 10^{11}$
^{99}Tc	$6.90\ 10^{13}$	$4.40\ 10^{13}$	$7.90\ 10^{13}$	$8.50\ 10^{13}$	$3.70\ 10^{13}$	$6.28\ 10^{13}$
^{103}Ru	$1.30\ 10^{11}$	$1.10\ 10^{11}$	$1.50\ 10^{11}$	$1.80\ 10^{11}$		$1.43\ 10^{11}$
^{106}Ru	$2.70\ 10^{12}$	$2.70\ 10^{12}$	$3.90\ 10^{12}$	$6.00\ 10^{12}$	$1.15\ 10^{13}$	$5.36\ 10^{12}$
^{110m}Ag	$9.00\ 10^{10}$	$8.00\ 10^{10}$	$1.00\ 10^{11}$	$1.10\ 10^{11}$		$9.50\ 10^{10}$
^{125}Sb	$7.90\ 10^{12}$	$7.80\ 10^{12}$	$1.30\ 10^{13}$	$1.70\ 10^{13}$		$1.14\ 10^{13}$
^{129}I	$4.80\ 10^{11}$	$4.70\ 10^{11}$	$6.30\ 10^{11}$	$7.30\ 10^{11}$	$5.54\ 10^{11}$	$5.73\ 10^{11}$
^{134}Cs	$3.40\ 10^{11}$	$2.30\ 10^{11}$	$4.80\ 10^{11}$	$4.90\ 10^{11}$	$3.92\ 10^{11}$	$3.86\ 10^{11}$
^{137}Cs	$9.10\ 10^{12}$	$6.90\ 10^{12}$	$9.60\ 10^{12}$	$7.70\ 10^{12}$	$6.24\ 10^{12}$	$7.91\ 10^{12}$
^{144}Ce	$6.00\ 10^{11}$	$5.50\ 10^{11}$	$7.90\ 10^{11}$	$9.70\ 10^{11}$	$8.85\ 10^{11}$	$7.59\ 10^{11}$
^{147}Pm	$4.10\ 10^{11}$	$3.50\ 10^{11}$	$4.20\ 10^{11}$	$7.90\ 10^{11}$		$4.93\ 10^{11}$
^{152}Eu	$1.10\ 10^{11}$	$7.00\ 10^{10}$	$1.10\ 10^{11}$	$1.30\ 10^{11}$		$1.05\ 10^{11}$
^{154}Eu	$5.00\ 10^{10}$	$6.00\ 10^{10}$	$8.00\ 10^{10}$	$1.30\ 10^{11}$		$8.00\ 10^{10}$
^{155}Eu	$4.00\ 10^{10}$	$5.00\ 10^{10}$	$7.00\ 10^{10}$	$1.00\ 10^{11}$		$6.50\ 10^{10}$
^{234}U			$4.88\ 10^{9}$	$5.50\ 10^{9}$	$6.05\ 10^{9}$	$5.48\ 10^{9}$
^{238}U			$4.88\ 10^{9}$	$5.50\ 10^{9}$	$6.05\ 10^{9}$	$5.48\ 10^{9}$
^{237}Np	$4.00\ 10^{10}$	$3.00\ 10^{10}$	$4.00\ 10^{10}$	$6.00\ 10^{10}$		$4.25\ 10^{10}$
^{239}Pu	$1.10\ 10^{11}$	$1.10\ 10^{11}$	$1.60\ 10^{11}$	$3.40\ 10^{11}$	$3.58\ 10^{11}$	$2.16\ 10^{11}$
^{241}Pu	$2.90\ 10^{12}$	$3.20\ 10^{12}$	$4.60\ 10^{12}$	$1.00\ 10^{13}$	$1.01\ 10^{13}$	$6.16\ 10^{12}$
^{241}Am	$3.00\ 10^{10}$	$3.00\ 10^{10}$	$4.00\ 10^{10}$	$4.00\ 10^{10}$	$5.90\ 10^{10}$	$3.98\ 10^{10}$
^{242}Cm	$3.00\ 10^{9}$	$3.00\ 10^{9}$	$6.00\ 10^{9}$	$2.00\ 10^{10}$		$8.00\ 10^{9}$
^{243}Cm	$2.00\ 10^{9}$	$3.00\ 10^{9}$	$3.00\ 10^{9}$	$5.00\ 10^{9}$		$3.25\ 10^{9}$

B2 LA HAGUE

Annual discharge data for 1999 to 2003 were obtained from a report produced by the Groupe Radioécologie Nord-Cotentin (GRNC) (GRNC, 2003). Discharges to atmosphere are given in Table B3 and liquid discharges are given in Table B4.

Table B3 Annual gaseous discharges from the La Hague site between 1999 and 2003

Radionuclide	Annual Discharge (Bq)					Average annual discharge (Bq) 1999-2003
	1999	2000	2001	2002	2003	
^{3}H	$7.95\ 10^{13}$	$6.70\ 10^{13}$	$6.20\ 10^{13}$	$6.32\ 10^{13}$	$6.70\ 10^{13}$	$6.77\ 10^{13}$
^{14}C	$1.87\ 10^{13}$	$1.87\ 10^{13}$	$1.30\ 10^{13}$	$1.69\ 10^{13}$	$1.65\ 10^{13}$	$1.68\ 10^{13}$
^{60}Co	$1.20\ 10^{4}$					$1.20\ 10^{4}$
^{85}Kr	$3.19\ 10^{17}$	$2.44\ 10^{17}$	$2.10\ 10^{17}$	$2.62\ 10^{17}$	$2.51\ 10^{17}$	$2.57\ 10^{17}$
$^{106}Ru + {}^{106}Rh$	$1.50\ 10^{8}$	$1.40\ 10^{8}$	$3.10\ 10^{8}$	$1.40\ 10^{8}$	$8.50\ 10^{7}$	$1.65\ 10^{8}$
^{125}Sb	$2.10\ 10^{4}$	$1.70\ 10^{4}$	$3.10\ 10^{6}$	$8.90\ 10^{4}$	$3.80\ 10^{7}$	$8.25\ 10^{6}$
^{131}I	$5.50\ 10^{8}$	$3.70\ 10^{8}$	$1.50\ 10^{8}$	$1.60\ 10^{8}$	$2.10\ 10^{8}$	$2.88\ 10^{8}$
^{133}I	$2.10\ 10^{8}$	$7.00\ 10^{7}$	$2.90\ 10^{7}$	$1.60\ 10^{8}$	$4.70\ 10^{7}$	$1.03\ 10^{8}$
^{134}Cs	$1.10\ 10^{4}$	$8.80\ 10^{3}$	$7.00\ 10^{3}$	$7.90\ 10^{4}$	$6.60\ 10^{6}$	$1.34\ 10^{6}$
$^{137}Cs + {}^{137m}Ba$	$1.52\ 10^{5}$	$1.14\ 10^{5}$	$1.04\ 10^{5}$	$1.66\ 10^{6}$	$1.58\ 10^{7}$	$3.57\ 10^{6}$
^{239}Pu	$4.80\ 10^{3}$	$2.35\ 10^{3}$	$3.25\ 10^{3}$	$3.55\ 10^{3}$	$4.25\ 10^{3}$	$3.64\ 10^{3}$
^{241}Pu	$1.00\ 10^{6}$	$5.10\ 10^{5}$	$7.50\ 10^{5}$	$9.00\ 10^{5}$	$9.20\ 10^{5}$	$8.16\ 10^{5}$
^{241}Am	$1.90\ 10^{4}$	$8.70\ 10^{3}$	$1.40\ 10^{4}$	$1.20\ 10^{4}$	$1.60\ 10^{4}$	$1.39\ 10^{4}$

Table B4 Annual liquid discharges from the La Hague site between 1999 and 2003

Radionuclide	Annual Discharge (Bq)					Average annual discharge (Bq) 1999-2003
	1999	2000	2001	2002	2003	
^{3}H	$1.29\ 10^{16}$	$1.05\ 10^{16}$	$9.64\ 10^{15}$	$1.19\ 10^{16}$	$1.19\ 10^{16}$	$1.14\ 10^{16}$
^{14}C	$9.93\ 10^{12}$	$8.52\ 10^{12}$	$7.23\ 10^{12}$	$7.85\ 10^{12}$	$8.65\ 10^{12}$	$8.44\ 10^{12}$
^{60}Co	$3.21\ 10^{11}$	$3.01\ 10^{11}$	$3.55\ 10^{11}$	$3.80\ 10^{11}$	$3.60\ 10^{11}$	$3.43\ 10^{11}$
^{65}Zn	$2.42\ 10^{8}$	$1.19\ 10^{8}$	$6.32\ 10^{7}$	$2.60\ 10^{7}$	$3.42\ 10^{8}$	$1.58\ 10^{8}$
^{89}Sr	$3.01\ 10^{2}$	$1.84\ 10^{2}$	$1.28\ 10^{2}$	$1.50\ 10^{2}$	$1.81\ 10^{2}$	$1.89\ 10^{2}$
$^{90}Sr + {}^{90}Y$	$1.70\ 10^{12}$	$1.04\ 10^{12}$	$7.10\ 10^{11}$	$9.00\ 10^{11}$	$1.03\ 10^{12}$	$1.08\ 10^{12}$
^{99}Tc	$4.27\ 10^{11}$	$3.88\ 10^{11}$	$2.47\ 10^{11}$	$1.40\ 10^{11}$	$1.77\ 10^{11}$	$2.76\ 10^{11}$
^{103}Ru	$3.13\ 10^{4}$	$2.76\ 10^{4}$	$8.17\ 10^{4}$	$6.20\ 10^{3}$	$1.64\ 10^{4}$	$3.26\ 10^{4}$
$^{106}Ru + {}^{106}Rh$	$1.38\ 10^{13}$	$2.05\ 10^{13}$	$1.69\ 10^{13}$	$1.13\ 10^{13}$	$1.40\ 10^{13}$	$1.53\ 10^{13}$
^{125}Sb	$5.13\ 10^{11}$	$3.50\ 10^{11}$	$3.82\ 10^{11}$	$5.08\ 10^{11}$	$3.36\ 10^{11}$	$4.18\ 10^{11}$
^{129}I	$1.83\ 10^{12}$	$1.36\ 10^{12}$	$1.18\ 10^{12}$	$1.33\ 10^{12}$	$1.27\ 10^{12}$	$1.39\ 10^{12}$
^{134}Cs	$1.82\ 10^{11}$	$1.34\ 10^{11}$	$1.98\ 10^{11}$	$2.22\ 10^{11}$	$1.66\ 10^{11}$	$1.80\ 10^{11}$
$^{137}Cs + {}^{137m}Ba$	$2.58\ 10^{12}$	$1.74\ 10^{12}$	$2.98\ 10^{12}$	$9.59\ 10^{11}$	$1.52\ 10^{12}$	$1.96\ 10^{12}$
$^{144}Ce + {}^{144}Pr$	$1.81\ 10^{9}$	$1.80\ 10^{9}$	$1.50\ 10^{7}$	$1.60\ 10^{9}$	$1.03\ 10^{8}$	$1.07\ 10^{9}$
^{234}U	$6.04\ 10^{9}$	$3.31\ 10^{9}$	$3.56\ 10^{9}$	$2.83\ 10^{9}$	$2.71\ 10^{9}$	$3.69\ 10^{9}$
^{235}U	$9.59\ 10^{7}$	$5.26\ 10^{7}$	$4.99\ 10^{7}$	$4.40\ 10^{7}$	$4.12\ 10^{7}$	$5.67\ 10^{7}$
^{238}U	$1.88\ 10^{9}$	$1.03\ 10^{9}$	$1.13\ 10^{9}$	$9.10\ 10^{8}$	$8.60\ 10^{8}$	$1.16\ 10^{9}$
^{239}Pu	$2.00\ 10^{9}$	$1.66\ 10^{9}$	$1.71\ 10^{9}$	$2.29\ 10^{9}$	$1.10\ 10^{9}$	$1.75\ 10^{9}$
^{241}Pu	$4.49\ 10^{11}$	$3.71\ 10^{11}$	$3.90\ 10^{11}$	$5.78\ 10^{11}$	$2.61\ 10^{11}$	$4.10\ 10^{11}$
^{241}Am	$7.79\ 10^{9}$	$6.30\ 10^{9}$	$7.44\ 10^{9}$	$7.74\ 10^{9}$	$4.09\ 10^{9}$	$6.67\ 10^{9}$

B3 REFERENCES

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APPENDIX C Calculation methodology

C1 INTRODUCTION

This appendix describes the methodology for calculating the collective doses, dose rates and per capita dose rates for this study. The discharging sites chosen were Sellafield and Cap de la Hague; discharges from these sites are described in Appendix B. Doses from both atmospheric and liquid discharges were considered, as described below.

C2 SELLAFIELD

C2.1 Marine Calculations

Activity concentrations in seawater and sediment from discharges by Sellafield were estimated using the MARINA II model, a compartment model of the North European waters (European Commission, 2002). A subset of the radionuclides modelled, namely ^{3}H, ^{14}C, and ^{129}I, are globally dispersed, as a consequence of their mobility in the environment and their long half-lives. Simplified versions of published compartment models were used to model this behaviour, as described in (Simmonds et al, 1995). Activity concentrations were calculated at times 1, 50, 100, 500, 1000, 5000, 10000, 50000, 100000 and 10^{8} years, in line with the requirements set out for the collective dose calculations.

All doses were calculated for the UK, European Union and world populations. Collective doses to these population groups from non-globally circulating radionuclides were calculated using SEADOSE, an in-house, program based on the marine dose calculations carried out in PC CREAM (Mayall et al, 1997). Collective doses to the same population groups from globally circulating radionuclides were calculated using PC CREAM by substituting the default data in the program's data libraries with those calculated in this study and then running the dose calculation code, ASSESSOR, using the program defaults. Both contributions were summed for each radionuclide and population group in a spreadsheet. It is worth noting that the non-global contributions to doses are only estimated for the EU population and are taken to also represent the world population.

Per-caput doses were calculated for the 1, 50 and 100-year integrals by dividing the collective doses, for each of the population groups, by the population size. The resulting doses represent the maximum per-capita doses for each time period for a continuous and uniform discharge over that time period.

Indicative per-caput dose rates were also calculated using a linear backward difference method. The collective dose truncated at time *j* minus the collective dose truncated at time *i* was divided be the time period considered (*j-I)* to obtain a representative annual collective dose rate. The resulting value was then divided by the population in the group of interest to obtain an indicative per-caput dose rate. The time-step is dependent on the output times, as shown above, and therefore increases as a function of time. The suitability of this approximation is therefore dependent on the calculated collective doses, as a function of time and represents the gradient between any one time and that time which preceded it. This approach, although simplistic, does enable a broad estimate to be made of the levels of per-caput doses contributing to the collective dose.

C2.2 Atmospheric Calculations

The PC-CREAM suite of programs was used to calculate collective doses, truncated at 1, 50, 100, 500, 1000, 5000, 10000, 50000, 100000 and 10^8 years for Sellafield discharges to the UK, European and the world populations. Some of the times are not currently available in the atmospheric modules of PC-CREAM. It was therefore necessary to create new library files for all dose pathways with a time dependency and substitute the model-calculated results in the default files. Dose results were tested with standard PC CREAM results, where times overlapped, to ensure this was done correctly.

Activity concentrations of globally circulating radionuclides, ^{3}H, ^{14}C, ^{85}Kr and ^{129}I, were again modelled using the simplified compartment model described in (Simmonds et al, 1995) and substituted in PC CREAM data files. Dose rates and per-caput dose rates were then calculated, for each radionuclide and population group, in the usual way.

Additionally, collective doses by distance bands, centred at the point of discharge, were calculated. Bands with radial extents of 1, 5, 20, 100, 500 and 1500 km were used. Again this type of calculation is not available in PC CREAM and therefore could be achieved only by segregating the gridded UK population data file into these bands in turn and running each separately. Checks were performed to ensure the collective dose from the combined total of these bands agreed with the collective dose calculated over all bands.

C3 LA HAGUE

Collective doses to the French, European Union and world populations were calculated for both atmospheric and marine pathways using PC CREAM. Doses were calculated at default times of 1, 50, 500, 10000 and 100000 years, for both globally and non-globally circulating radionuclides, using the supplied default data. Per-caput doses and dose rates were calculated, for each radionuclide and population group, in a spreadsheet using the method described in Section C2.1.

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APPENDIX D Detailed results

D1 COLLECTIVE DOSES

D1.1 Atmosphere

Sellafield

UK

TABLE D1 Collective doses (man Sv) to the UK population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (first-pass plus global circulation)

Radio-	Truncation time (y)									
nuclide	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$
^{14}C	$1.26\ 10^{-1}$	$1.86\ 10^{-1}$	$2.07\ 10^{-1}$	$2.86\ 10^{-1}$	$3.45\ 10^{-1}$	$6.70\ 10^{-1}$	$9.06\ 10^{-1}$	$1.19\ 10^{0}$	$1.19\ 10^{0}$	$1.19\ 10^{0}$
^{35}S	$1.92\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$
^{41}Ar	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$
^{60}Co	$9.96\ 10^{-6}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$
^{85}Kr	$2.12\ 10^{-1}$	$3.37\ 10^{-1}$	$3.43\ 10^{-1}$	$3.43\ 10^{-1}$	$3.43\ 10^{-1}$	$3.43\ 10^{-1}$	$3.43\ 10^{-1}$	$3.43\ 10^{-1}$	$3.43\ 10^{-1}$	$3.43\ 10^{-1}$
^{90}Sr	$2.53\ 10^{-5}$	$9.33\ 10^{-5}$	$1.01\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$
^{106}Ru	$1.80\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$
^{125}Sb	$3.82\ 10^{-5}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$
^{129}I	$4.73\ 10^{-1}$	$7.58\ 10^{-1}$	$8.16\ 10^{-1}$	$9.25\ 10^{-1}$	$9.27\ 10^{-1}$	$9.37\ 10^{-1}$	$9.42\ 10^{-1}$	$9.47\ 10^{-1}$	$9.50\ 10^{-1}$	$1.00\ 10^{0}$
^{131}I	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$
^{137}Cs	$5.28\ 10^{-4}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$
^{239}Pu	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$
^{241}Pu	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$
^{241}Am	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$
Total	**$1.06\ 10^{0}$**	**$1.53\ 10^{0}$**	**$1.62\ 10^{0}$**	**$1.80\ 10^{0}$**	**$1.87\ 10^{0}$**	**$2.20\ 10^{0}$**	**$2.44\ 10^{0}$**	**$2.73\ 10^{0}$**	**$2.73\ 10^{0}$**	**$2.78\ 10^{0}$**

TABLE D2 Collective doses (man Sv) to the UK population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (first-pass only)

Radio-nuclide	Truncation time (y)									
	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$	$1.16\ 10^{-1}$
^{14}C	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$	$1.26\ 10^{-1}$
^{35}S	$1.92\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$	$1.98\ 10^{-2}$
^{41}Ar	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$	$1.01\ 10^{-1}$
^{60}Co	$9.96\ 10^{-6}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$	$8.49\ 10^{-5}$
^{85}Kr	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$	$2.05\ 10^{-1}$
^{90}Sr	$2.53\ 10^{-5}$	$9.33\ 10^{-5}$	$1.01\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$	$1.04\ 10^{-4}$
^{106}Ru	$1.80\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$	$2.51\ 10^{-4}$
^{125}Sb	$3.82\ 10^{-5}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$	$2.03\ 10^{-4}$
^{129}I	$4.65\ 10^{-1}$	$7.48\ 10^{-1}$	$8.06\ 10^{-1}$	$9.14\ 10^{-1}$	$9.14\ 10^{-1}$	$9.14\ 10^{-1}$	$9.14\ 10^{-1}$	$9.14\ 10^{-1}$	$9.14\ 10^{-1}$	$9.14\ 10^{-1}$
^{131}I	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$	$1.58\ 10^{-3}$
^{137}Cs	$5.28\ 10^{-4}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$	$1.57\ 10^{-3}$
^{239}Pu	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.66\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$
^{241}Pu	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$	$5.80\ 10^{-4}$
^{241}Am	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$	$3.23\ 10^{-3}$
Total	**$1.04\ 10^{0}$**	**$1.33\ 10^{0}$**	**$1.39\ 10^{0}$**	**$1.49\ 10^{0}$**	**$1.49\ 10^{0}$**	**$1.49\ 10^{0}$**	**$1.49\ 10^{0}$**	**$1.49\ 10^{0}$**	**$1.49\ 10^{0}$**	**$1.49\ 10^{0}$**

TABLE D3 Collective doses (man Sv) to the UK population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (global circulation only)

Radio-nuclide	Truncation time (y)									
	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$1.77\ 10^{-4}$	$4.79\ 10^{-4}$	$4.79\ 10^{-4}$	$4.79\ 10^{-4}$	$4.79\ 10^{-4}$	$4.79\ 10^{-4}$	$4.79\ 10^{-4}$	$4.79\ 10^{-4}$	$4.79\ 10^{-4}$	$4.79\ 10^{-4}$
^{14}C	$4.67\ 10^{-4}$	$6.07\ 10^{-2}$	$8.16\ 10^{-2}$	$1.60\ 10^{-1}$	$2.19\ 10^{-1}$	$5.45\ 10^{-1}$	$7.80\ 10^{-1}$	$1.06\ 10^{0}$	$1.06\ 10^{0}$	$1.06\ 10^{0}$
^{85}Kr	$6.14\ 10^{-3}$	$1.32\ 10^{-1}$	$1.38\ 10^{-1}$	$1.38\ 10^{-1}$	$1.38\ 10^{-1}$	$1.38\ 10^{-1}$	$1.38\ 10^{-1}$	$1.38\ 10^{-1}$	$1.38\ 10^{-1}$	$1.38\ 10^{-1}$
^{129}I	$7.95\ 10^{-3}$	$9.89\ 10^{-3}$	$1.01\ 10^{-2}$	$1.16\ 10^{-2}$	$1.33\ 10^{-2}$	$2.28\ 10^{-2}$	$2.79\ 10^{-2}$	$3.34\ 10^{-2}$	$3.59\ 10^{-2}$	$8.64\ 10^{-2}$
Total	**$1.47\ 10^{-2}$**	**$2.03\ 10^{-1}$**	**$2.30\ 10^{-1}$**	**$3.10\ 10^{-1}$**	**$3.71\ 10^{-1}$**	**$7.06\ 10^{-1}$**	**$9.47\ 10^{-1}$**	**$1.24\ 10^{0}$**	**$1.24\ 10^{0}$**	**$1.29\ 10^{0}$**

EU

TABLE D4 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (first-pass plus global circulation)

Radio-nuclide	Truncation time (y)									
	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$2.87\ 10^{-1}$	$2.91\ 10^{-1}$	$2.91\ 10^{-1}$	$2.91\ 10^{-1}$	$2.91\ 10^{-1}$	$2.91\ 10^{-1}$	$2.91\ 10^{-1}$	$2.91\ 10^{-1}$	$2.91\ 10^{-1}$	$2.91\ 10^{-1}$
^{14}C	$8.44\ 10^{-1}$	$1.61\ 10^{0}$	$1.88\ 10^{0}$	$2.87\ 10^{0}$	$3.63\ 10^{0}$	$7.78\ 10^{0}$	$1.08\ 10^{1}$	$1.44\ 10^{1}$	$1.44\ 10^{1}$	$1.44\ 10^{1}$
^{35}S	$5.81\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$
^{41}Ar	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$
^{60}Co	$2.18\ 10^{-5}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$
^{85}Kr	$6.75\ 10^{-1}$	$2.28\ 10^{0}$	$2.35\ 10^{0}$	$2.35\ 10^{0}$	$2.35\ 10^{0}$	$2.35\ 10^{0}$	$2.35\ 10^{0}$	$2.35\ 10^{0}$	$2.35\ 10^{0}$	$2.35\ 10^{0}$
^{90}Sr	$1.38\ 10^{-4}$	$4.95\ 10^{-4}$	$5.18\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$
^{106}Ru	$3.23\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$
^{125}Sb	$6.49\ 10^{-5}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$
^{129}I	$2.26\ 10^{0}$	$3.95\ 10^{0}$	$4.20\ 10^{0}$	$4.47\ 10^{0}$	$4.49\ 10^{0}$	$4.61\ 10^{0}$	$4.68\ 10^{0}$	$4.74\ 10^{0}$	$4.78\ 10^{0}$	$5.42\ 10^{0}$
^{131}I	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$
^{137}Cs	$2.36\ 10^{-3}$	$4.16\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$
^{239}Pu	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$
^{241}Pu	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$
^{241}Am	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$
Total	**$4.24\ 10^{0}$**	**$8.31\ 10^{0}$**	**$8.89\ 10^{0}$**	**$1.02\ 10^{1}$**	**$1.09\ 10^{1}$**	**$1.52\ 10^{1}$**	**$1.83\ 10^{1}$**	**$2.20\ 10^{1}$**	**$2.20\ 10^{1}$**	**$2.26\ 10^{1}$**

TABLE D5 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (first-pass only)

Radio-nuclide	Truncation time (y)									
	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$
^{14}C	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$
^{35}S	$5.81\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$
^{41}Ar	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$
^{60}Co	$2.18\ 10^{-5}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$
^{85}Kr	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$
^{90}Sr	$1.38\ 10^{-4}$	$4.95\ 10^{-4}$	$5.18\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$
^{106}Ru	$3.23\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$
^{125}Sb	$6.49\ 10^{-5}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$
^{129}I	$2.16\ 10^{0}$	$3.82\ 10^{0}$	$4.07\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$
^{131}I	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$
^{137}Cs	$2.36\ 10^{-3}$	$4.16\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$
^{239}Pu	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$
^{241}Pu	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$
^{241}Am	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$
Total	**$4.06\ 10^{0}$**	**$5.72\ 10^{0}$**	**$5.97\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**

TABLE D6 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (global circulation only)

Radio-nuclide	Truncation time (y)									
	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$2.26\ 10^{-3}$	$6.10\ 10^{-3}$	$6.10\ 10^{-3}$	$6.10\ 10^{-3}$	$6.10\ 10^{-3}$	$6.10\ 10^{-3}$	$6.10\ 10^{-3}$	$6.10\ 10^{-3}$	$6.10\ 10^{-3}$	$6.10\ 10^{-3}$
^{14}C	$5.95\ 10^{-3}$	$7.70\ 10^{-1}$	$1.04\ 10^{0}$	$2.04\ 10^{0}$	$2.79\ 10^{0}$	$6.94\ 10^{0}$	$9.94\ 10^{0}$	$1.35\ 10^{1}$	$1.35\ 10^{1}$	$1.35\ 10^{1}$
^{85}Kr	$7.82\ 10^{-2}$	$1.68\ 10^{0}$	$1.75\ 10^{0}$	$1.75\ 10^{0}$	$1.75\ 10^{0}$	$1.75\ 10^{0}$	$1.75\ 10^{0}$	$1.75\ 10^{0}$	$1.75\ 10^{0}$	$1.75\ 10^{0}$
^{129}I	$1.01\ 10^{-1}$	$1.25\ 10^{-1}$	$1.28\ 10^{-1}$	$1.48\ 10^{-1}$	$1.69\ 10^{-1}$	$2.90\ 10^{-1}$	$3.56\ 10^{-1}$	$4.25\ 10^{-1}$	$4.57\ 10^{-1}$	$1.10\ 10^{0}$
Total	**$1.88\ 10^{-1}$**	**$2.58\ 10^{0}$**	**$2.92\ 10^{0}$**	**$3.94\ 10^{0}$**	**$4.72\ 10^{0}$**	**$8.99\ 10^{0}$**	**$1.20\ 10^{1}$**	**$1.57\ 10^{1}$**	**$1.58\ 10^{1}$**	**$1.64\ 10^{1}$**

World

TABLE D7 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (first-pass plus global circulation)

Radio-nuclide	Truncation time (y)									
	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$3.17\ 10^{-1}$	$3.72\ 10^{-1}$	$3.72\ 10^{-1}$	$3.72\ 10^{-1}$	$3.72\ 10^{-1}$	$3.72\ 10^{-1}$	$3.72\ 10^{-1}$	$3.72\ 10^{-1}$	$3.72\ 10^{-1}$	$3.72\ 10^{-1}$
^{14}C	$9.23\ 10^{-1}$	$1.19\ 10^{1}$	$1.57\ 10^{1}$	$3.00\ 10^{1}$	$4.09\ 10^{1}$	$1.00\ 10^{2}$	$1.43\ 10^{2}$	$1.94\ 10^{2}$	$1.94\ 10^{2}$	$1.94\ 10^{2}$
^{35}S	$5.81\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$
^{41}Ar	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$
^{60}Co	$2.18\ 10^{-5}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$
^{85}Kr	$1.71\ 10^{0}$	$2.46\ 10^{1}$	$2.56\ 10^{1}$	$2.56\ 10^{1}$	$2.56\ 10^{1}$	$2.56\ 10^{1}$	$2.56\ 10^{1}$	$2.56\ 10^{1}$	$2.56\ 10^{1}$	$2.56\ 10^{1}$
^{90}Sr	$1.38\ 10^{-4}$	$4.95\ 10^{-4}$	$5.18\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$
^{106}Ru	$3.23\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$
^{125}Sb	$6.49\ 10^{-5}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$
^{129}I	$3.61\ 10^{0}$	$5.62\ 10^{0}$	$5.90\ 10^{0}$	$6.43\ 10^{0}$	$6.74\ 10^{0}$	$8.47\ 10^{0}$	$9.40\ 10^{0}$	$1.04\ 10^{1}$	$1.08\ 10^{1}$	$2.00\ 10^{1}$
^{131}I	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$
^{137}Cs	$2.36\ 10^{-3}$	$4.16\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$
^{239}Pu	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$
^{241}Pu	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$
^{241}Am	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$
Total	**$6.73\ 10^{0}$**	**$4.26\ 10^{1}$**	**$4.78\ 10^{1}$**	**$6.26\ 10^{1}$**	**$7.39\ 10^{1}$**	**$1.35\ 10^{2}$**	**$1.78\ 10^{2}$**	**$2.31\ 10^{2}$**	**$2.31\ 10^{2}$**	**$2.41\ 10^{2}$**

TABLE D8 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (first-pass only)

Radio-nuclide	Truncation time (y)									
	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$	$2.85\ 10^{-1}$
^{14}C	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$	$8.38\ 10^{-1}$
^{35}S	$5.81\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$	$5.99\ 10^{-2}$
^{41}Ar	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$	$9.67\ 10^{-2}$
^{60}Co	$2.18\ 10^{-5}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$	$1.37\ 10^{-4}$
^{85}Kr	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$	$5.97\ 10^{-1}$
^{90}Sr	$1.38\ 10^{-4}$	$4.95\ 10^{-4}$	$5.18\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$	$5.30\ 10^{-4}$
^{106}Ru	$3.23\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$	$4.22\ 10^{-4}$
^{125}Sb	$6.49\ 10^{-5}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$	$3.18\ 10^{-4}$
^{129}I	$2.16\ 10^{0}$	$3.82\ 10^{0}$	$4.07\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$	$4.32\ 10^{0}$
^{131}I	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$	$9.46\ 10^{-4}$
^{137}Cs	$2.36\ 10^{-3}$	$4.16\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$	$4.27\ 10^{-3}$
^{239}Pu	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$	$1.04\ 10^{-2}$
^{241}Pu	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$	$1.27\ 10^{-3}$
^{241}Am	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$	$7.11\ 10^{-3}$
Total	**$4.06\ 10^{0}$**	**$5.72\ 10^{0}$**	**$5.97\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**	**$6.22\ 10^{0}$**

TABLE D9 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (global circulation only)

Radio-nuclide	Truncation time (y)									
	1	50	100	500	1000	5000	10000	50000	100000	$1\ 10^{8}$
^{3}H	$3.22\ 10^{-2}$	$8.71\ 10^{-2}$	$8.71\ 10^{-2}$	$8.71\ 10^{-2}$	$8.71\ 10^{-2}$	$8.71\ 10^{-2}$	$8.71\ 10^{-2}$	$8.71\ 10^{-2}$	$8.71\ 10^{-2}$	$8.71\ 10^{-2}$
^{14}C	$8.50\ 10^{-2}$	$1.10\ 10^{1}$	$1.48\ 10^{1}$	$2.91\ 10^{1}$	$4.01\ 10^{1}$	$9.92\ 10^{1}$	$1.42\ 10^{2}$	$1.94\ 10^{2}$	$1.94\ 10^{2}$	$1.94\ 10^{2}$
^{85}Kr	$1.12\ 10^{0}$	$2.40\ 10^{1}$	$2.50\ 10^{1}$	$2.50\ 10^{1}$	$2.50\ 10^{1}$	$2.50\ 10^{1}$	$2.50\ 10^{1}$	$2.50\ 10^{1}$	$2.50\ 10^{1}$	$2.50\ 10^{1}$
^{129}I	$1.45\ 10^{0}$	$1.79\ 10^{0}$	$1.83\ 10^{0}$	$2.11\ 10^{0}$	$2.42\ 10^{0}$	$4.15\ 10^{0}$	$5.08\ 10^{0}$	$6.07\ 10^{0}$	$6.52\ 10^{0}$	$1.57\ 10^{1}$
Total	**$2.68\ 10^{0}$**	**$3.69\ 10^{1}$**	**$4.18\ 10^{1}$**	**$5.64\ 10^{1}$**	**$6.77\ 10^{1}$**	**$1.28\ 10^{2}$**	**$1.72\ 10^{2}$**	**$2.25\ 10^{2}$**	**$2.25\ 10^{2}$**	**$2.34\ 10^{2}$**

TABLE D10 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to atmosphere from La Hague between 1999 and 2003 (first-pass plus global circulation)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$9.86\ 10^{-2}$	$9.96\ 10^{-2}$	$9.96\ 10^{-2}$	$9.96\ 10^{-2}$	$9.96\ 10^{-2}$
^{14}C	$1.31\ 10^{1}$	$2.08\ 10^{1}$	$3.37\ 10^{1}$	$1.14\ 10^{2}$	$1.51\ 10^{2}$
^{60}Co	$1.10\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$
^{85}Kr	$2.40\ 10^{0}$	$6.57\ 10^{0}$	$6.75\ 10^{0}$	$6.75\ 10^{0}$	$6.75\ 10^{0}$
^{106}Ru	$5.00\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$
^{125}Sb	$1.20\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$
^{131}I	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$
^{133}I	$4.60\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$
^{134}Cs	$8.10\ 10^{-6}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$
^{137}Cs	$1.60\ 10^{-5}$	$2.90\ 10^{-5}$	$3.00\ 10^{-5}$	$3.00\ 10^{-5}$	$3.00\ 10^{-5}$
^{239}Pu	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$
^{241}Pu	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$
^{241}Am	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$
Total	**$1.56\ 10^{1}$**	**$2.75\ 10^{1}$**	**$4.05\ 10^{1}$**	**$1.21\ 10^{2}$**	**$1.58\ 10^{2}$**

TABLE D11 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to atmosphere from La Hague between 1999 and 2003 (first-pass only)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$9.80\ 10^{-2}$	$9.80\ 10^{-2}$	$9.80\ 10^{-2}$	$9.80\ 10^{-2}$	$9.80\ 10^{-2}$
^{14}C	$1.30\ 10^{1}$	$1.30\ 10^{1}$	$1.30\ 10^{1}$	$1.30\ 10^{1}$	$1.30\ 10^{1}$
^{60}Co	$1.10\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$
^{85}Kr	$2.20\ 10^{0}$	$2.20\ 10^{0}$	$2.20\ 10^{0}$	$2.20\ 10^{0}$	$2.20\ 10^{0}$
^{106}Ru	$5.00\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$
^{125}Sb	$1.20\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$
^{131}I	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$
^{133}I	$4.60\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$
^{134}Cs	$8.10\ 10^{-6}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$
^{137}Cs	$1.60\ 10^{-5}$	$2.90\ 10^{-5}$	$3.00\ 10^{-5}$	$3.00\ 10^{-5}$	$3.00\ 10^{-5}$
^{239}Pu	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$
^{241}Pu	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$
^{241}Am	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$
Total	**$1.53\ 10^{1}$**	**$1.53\ 10^{1}$**	**$1.53\ 10^{1}$**	**$1.53\ 10^{1}$**	**$1.53\ 10^{1}$**

TABLE D12 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to atmosphere from La Hague between 1999 and 2003 (global circulation only)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$5.73\ 10^{-4}$	$1.55\ 10^{-3}$	$1.55\ 10^{-3}$	$1.55\ 10^{-3}$	$1.55\ 10^{-3}$
^{14}C	$6.04\ 10^{-2}$	$7.84\ 10^{0}$	$2.07\ 10^{1}$	$1.01\ 10^{2}$	$1.38\ 10^{2}$
^{85}Kr	$2.03\ 10^{-1}$	$4.37\ 10^{0}$	$4.55\ 10^{0}$	$4.55\ 10^{0}$	$4.55\ 10^{0}$
Total	**$2.64\ 10^{-1}$**	**$1.22\ 10^{1}$**	**$2.53\ 10^{1}$**	**$1.06\ 10^{2}$**	**$1.43\ 10^{2}$**

World

TABLE D13 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to atmosphere from La Hague between 1999 and 2003 (first-pass plus global circulation)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$1.06\ 10^{-1}$	$1.20\ 10^{-1}$	$1.20\ 10^{-1}$	$1.20\ 10^{-1}$	$1.20\ 10^{-1}$
^{14}C	$1.39\ 10^{1}$	$1.25\ 10^{2}$	$3.09\ 10^{2}$	$1.45\ 10^{3}$	$1.98\ 10^{3}$
^{60}Co	$1.10\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$
^{85}Kr	$5.10\ 10^{0}$	$6.47\ 10^{1}$	$6.72\ 10^{1}$	$6.72\ 10^{1}$	$6.72\ 10^{1}$
^{106}Ru	$5.00\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$
^{125}Sb	$1.20\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$
^{131}I	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$
^{133}I	$4.60\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$
^{134}Cs	$8.10\ 10^{-6}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$
^{137}Cs	$1.60\ 10^{-5}$	$2.90\ 10^{-5}$	$3.00\ 10^{-5}$	$3.00\ 10^{-5}$	$3.00\ 10^{-5}$
^{239}Pu	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$
^{241}Pu	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$
^{241}Am	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$
Total	**$1.91\ 10^{1}$**	**$1.90\ 10^{2}$**	**$3.76\ 10^{2}$**	**$1.52\ 10^{3}$**	**$2.05\ 10^{3}$**

TABLE D14 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to atmosphere from La Hague between 1999 and 2003 (first-pass only)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$9.80\ 10^{-2}$	$9.80\ 10^{-2}$	$9.80\ 10^{-2}$	$9.80\ 10^{-2}$	$9.80\ 10^{-2}$
^{14}C	$1.30\ 10^{1}$	$1.30\ 10^{1}$	$1.30\ 10^{1}$	$1.30\ 10^{1}$	$1.30\ 10^{1}$
^{60}Co	$1.10\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$	$7.20\ 10^{-8}$
^{85}Kr	$2.20\ 10^{0}$	$2.20\ 10^{0}$	$2.20\ 10^{0}$	$2.20\ 10^{0}$	$2.20\ 10^{0}$
^{106}Ru	$5.00\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$	$6.50\ 10^{-5}$
^{125}Sb	$1.20\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$	$5.40\ 10^{-6}$
^{131}I	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$	$1.30\ 10^{-4}$
^{133}I	$4.60\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$	$4.70\ 10^{-6}$
^{134}Cs	$8.10\ 10^{-6}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$	$1.00\ 10^{-5}$
^{137}Cs	$1.60\ 10^{-5}$	$2.90\ 10^{-5}$	$3.00\ 10^{-5}$	$3.00\ 10^{-5}$	$3.00\ 10^{-5}$
^{239}Pu	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$	$8.80\ 10^{-7}$
^{241}Pu	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$	$3.50\ 10^{-6}$
^{241}Am	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$	$2.80\ 10^{-6}$
Total	**$1.53\ 10^{1}$**	**$1.53\ 10^{1}$**	**$1.53\ 10^{1}$**	**$1.53\ 10^{1}$**	**$1.53\ 10^{1}$**

TABLE D15 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to atmosphere from La Hague between 1999 and 2003 (global circulation only)

Radionuclide	Truncation time (y)				
	1	50	500	10000	100000
^{3}H	$8.19\ 10^{-3}$	$2.21\ 10^{-2}$	$2.21\ 10^{-2}$	$2.21\ 10^{-2}$	$2.21\ 10^{-2}$
^{14}C	$8.64\ 10^{-1}$	$1.12\ 10^{2}$	$2.96\ 10^{2}$	$1.44\ 10^{3}$	$1.97\ 10^{3}$
^{85}Kr	$2.90\ 10^{0}$	$6.25\ 10^{1}$	$6.50\ 10^{1}$	$6.50\ 10^{1}$	$6.50\ 10^{1}$
Total	**$3.77\ 10^{0}$**	**$1.75\ 10^{2}$**	**$3.61\ 10^{2}$**	**$1.51\ 10^{3}$**	**$2.04\ 10^{3}$**

D1.2 Marine

Sellafield

UK

TABLE D16 Collective doses (man Sv) to the UK population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (first-pass plus global circulation)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	$1.42\ 10^{-4}$	$1.30\ 10^{-3}$	$1.30\ 10^{-3}$	$1.30\ 10^{-3}$	$1.30\ 10^{-3}$	$1.30\ 10^{-3}$	$1.30\ 10^{-3}$	$1.30\ 10^{-3}$	$1.30\ 10^{-3}$
^{14}C	$2.57\ 10^{-1}$	$1.72\ 10^{0}$	$1.84\ 10^{0}$	$2.28\ 10^{0}$	$2.63\ 10^{0}$	$4.62\ 10^{0}$	$5.95\ 10^{0}$	$7.57\ 10^{0}$	$7.57\ 10^{0}$
^{35}S	$6.66\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$
^{54}Mn	$5.31\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$
^{55}Fe	$5.56\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$
^{60}Co	$2.53\ 10^{-3}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$
^{63}Ni	$2.19\ 10^{-5}$	$6.23\ 10^{-5}$	$8.09\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$
^{65}Zn	$2.74\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$
^{89}Sr	$2.16\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$
^{90}Sr	$2.32\ 10^{-3}$	$1.55\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$
^{95}Zr	$2.56\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$
^{95}Nb	$2.29\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$
^{99}Tc	$5.44\ 10^{-2}$	$1.61\ 10^{-1}$	$1.61\ 10^{-1}$	$1.63\ 10^{-1}$	$1.63\ 10^{-1}$	$1.65\ 10^{-1}$	$1.67\ 10^{-1}$	$1.81\ 10^{-1}$	$1.95\ 10^{-1}$
^{103}Ru	$7.17\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$
^{106}Ru	$6.48\ 10^{-2}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$
^{110m}Ag	$2.41\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$
^{125}Sb	$5.46\ 10^{-3}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$
^{129}I	$1.61\ 10^{-3}$	$1.07\ 10^{-2}$	$1.09\ 10^{-2}$	$1.16\ 10^{-2}$	$1.23\ 10^{-2}$	$1.95\ 10^{-2}$	$3.13\ 10^{-2}$	$1.24\ 10^{-1}$	$2.27\ 10^{-1}$
^{134}Cs	$1.06\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$
^{137}Cs	$1.63\ 10^{-2}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$
^{144}Ce	$6.71\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$
^{147}Pm	$3.92\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$
^{152}Eu	$9.05\ 10^{-5}$	$9.87\ 10^{-4}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$
^{154}Eu	$7.64\ 10^{-5}$	$6.37\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$
^{155}Eu	$5.33\ 10^{-6}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$
^{234}U	$8.76\ 10^{-6}$	$2.54\ 10^{-5}$	$2.54\ 10^{-5}$	$2.56\ 10^{-5}$	$2.56\ 10^{-5}$	$2.59\ 10^{-5}$	$2.64\ 10^{-5}$	$2.84\ 10^{-5}$	$3.06\ 10^{-5}$
^{238}U	$8.06\ 10^{-6}$	$2.35\ 10^{-5}$	$2.36\ 10^{-5}$	$2.38\ 10^{-5}$	$2.38\ 10^{-5}$	$2.41\ 10^{-5}$	$2.45\ 10^{-5}$	$2.66\ 10^{-5}$	$2.91\ 10^{-5}$
^{237}Np	$1.98\ 10^{-3}$	$5.56\ 10^{-3}$	$5.60\ 10^{-3}$	$5.63\ 10^{-3}$	$5.64\ 10^{-3}$	$5.69\ 10^{-3}$	$5.75\ 10^{-3}$	$6.08\ 10^{-3}$	$6.40\ 10^{-3}$
^{239}Pu	$1.78\ 10^{-2}$	$4.21\ 10^{-2}$	$5.31\ 10^{-2}$	$6.87\ 10^{-2}$	$6.92\ 10^{-2}$	$6.93\ 10^{-2}$	$6.94\ 10^{-2}$	$6.96\ 10^{-2}$	$6.97\ 10^{-2}$
^{241}Pu	$9.61\ 10^{-3}$	$1.62\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$
^{241}Am	$9.05\ 10^{-4}$	$5.07\ 10^{-3}$	$8.87\ 10^{-3}$	$1.81\ 10^{-2}$	$1.89\ 10^{-2}$	$1.90\ 10^{-2}$	$1.90\ 10^{-2}$	$1.90\ 10^{-2}$	$1.90\ 10^{-2}$
^{242}Cm	$1.53\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$
^{243}Cm	$8.22\ 10^{-5}$	$1.42\ 10^{-4}$	$1.51\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$
Total	**$4.42\ 10^{-1}$**	**$2.28\ 10^{0}$**	**$2.41\ 10^{0}$**	**$2.88\ 10^{0}$**	**$3.23\ 10^{0}$**	**$5.23\ 10^{0}$**	**$6.58\ 10^{0}$**	**$8.30\ 10^{0}$**	**$8.42\ 10^{0}$**

TABLE D17 Collective doses (man Sv) to the UK population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (first-pass only)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	$1.31\ 10^{-4}$	$7.46\ 10^{-4}$	$7.46\ 10^{-4}$	$7.46\ 10^{-4}$	$7.46\ 10^{-4}$	$7.46\ 10^{-4}$	$7.46\ 10^{-4}$	$7.46\ 10^{-4}$	$7.46\ 10^{-4}$
^{14}C	$2.57\ 10^{-1}$	$1.61\ 10^{0}$	$1.65\ 10^{0}$	$1.68\ 10^{0}$	$1.69\ 10^{0}$	$1.72\ 10^{0}$	$1.75\ 10^{0}$	$1.77\ 10^{0}$	$1.77\ 10^{0}$
^{35}S	$6.66\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$	$9.17\ 10^{-7}$
^{54}Mn	$5.31\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$	$7.22\ 10^{-5}$
^{55}Fe	$5.56\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$	$7.27\ 10^{-5}$
^{60}Co	$2.53\ 10^{-3}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$	$1.21\ 10^{-2}$
^{63}Ni	$2.19\ 10^{-5}$	$6.23\ 10^{-5}$	$8.09\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$	$9.83\ 10^{-5}$
^{65}Zn	$2.74\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$	$3.49\ 10^{-3}$
^{89}Sr	$2.16\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$	$2.63\ 10^{-6}$
^{90}Sr	$2.32\ 10^{-3}$	$1.55\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$	$1.56\ 10^{-2}$
^{95}Zr	$2.56\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$	$3.23\ 10^{-5}$
^{95}Nb	$2.29\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$	$3.02\ 10^{-5}$
^{99}Tc	$5.44\ 10^{-2}$	$1.61\ 10^{-1}$	$1.61\ 10^{-1}$	$1.63\ 10^{-1}$	$1.63\ 10^{-1}$	$1.65\ 10^{-1}$	$1.67\ 10^{-1}$	$1.81\ 10^{-1}$	$1.95\ 10^{-1}$
^{103}Ru	$7.17\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$	$8.20\ 10^{-5}$
^{106}Ru	$6.48\ 10^{-2}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$
^{110m}Ag	$2.41\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$	$3.96\ 10^{-3}$
^{125}Sb	$5.46\ 10^{-3}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$	$3.11\ 10^{-2}$
^{129}I	$1.59\ 10^{-3}$	$1.03\ 10^{-2}$	$1.04\ 10^{-2}$	$1.06\ 10^{-2}$	$1.06\ 10^{-2}$	$1.09\ 10^{-2}$	$1.13\ 10^{-2}$	$1.40\ 10^{-2}$	$1.73\ 10^{-2}$
^{134}Cs	$1.06\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$	$4.94\ 10^{-3}$
^{137}Cs	$1.63\ 10^{-2}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$	$1.31\ 10^{-1}$
^{144}Ce	$6.71\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$	$9.92\ 10^{-5}$
^{147}Pm	$3.92\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$	$4.53\ 10^{-6}$
^{152}Eu	$9.05\ 10^{-5}$	$9.87\ 10^{-4}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$	$1.01\ 10^{-3}$
^{154}Eu	$7.64\ 10^{-5}$	$6.37\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$	$6.40\ 10^{-4}$
^{155}Eu	$5.33\ 10^{-6}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$	$2.17\ 10^{-5}$
^{234}U	$8.76\ 10^{-6}$	$2.54\ 10^{-5}$	$2.54\ 10^{-5}$	$2.56\ 10^{-5}$	$2.56\ 10^{-5}$	$2.59\ 10^{-5}$	$2.64\ 10^{-5}$	$2.84\ 10^{-5}$	$3.06\ 10^{-5}$
^{238}U	$8.06\ 10^{-6}$	$2.35\ 10^{-5}$	$2.36\ 10^{-5}$	$2.38\ 10^{-5}$	$2.38\ 10^{-5}$	$2.41\ 10^{-5}$	$2.45\ 10^{-5}$	$2.66\ 10^{-5}$	$2.91\ 10^{-5}$
^{237}Np	$1.98\ 10^{-3}$	$5.56\ 10^{-3}$	$5.60\ 10^{-3}$	$5.63\ 10^{-3}$	$5.64\ 10^{-3}$	$5.69\ 10^{-3}$	$5.75\ 10^{-3}$	$6.08\ 10^{-3}$	$6.40\ 10^{-3}$
^{239}Pu	$1.78\ 10^{-2}$	$4.21\ 10^{-2}$	$5.31\ 10^{-2}$	$6.87\ 10^{-2}$	$6.92\ 10^{-2}$	$6.93\ 10^{-2}$	$6.94\ 10^{-2}$	$6.96\ 10^{-2}$	$6.97\ 10^{-2}$
^{241}Pu	$9.61\ 10^{-3}$	$1.62\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$	$1.64\ 10^{-2}$
^{241}Am	$9.05\ 10^{-4}$	$5.07\ 10^{-3}$	$8.87\ 10^{-3}$	$1.81\ 10^{-2}$	$1.89\ 10^{-2}$	$1.90\ 10^{-2}$	$1.90\ 10^{-2}$	$1.90\ 10^{-2}$	$1.90\ 10^{-2}$
^{242}Cm	$1.53\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$	$1.59\ 10^{-5}$
^{243}Cm	$8.22\ 10^{-5}$	$1.42\ 10^{-4}$	$1.51\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$	$1.54\ 10^{-4}$
Total	**$4.42\ 10^{-1}$**	**$2.17\ 10^{0}$**	**$2.22\ 10^{0}$**	**$2.28\ 10^{0}$**	**$2.29\ 10^{0}$**	**$2.32\ 10^{0}$**	**$2.36\ 10^{0}$**	**$2.39\ 10^{0}$**	**$2.41\ 10^{0}$**

TABLE D18 Collective doses (man Sv) to the UK population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (global circulation only)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	$1.10\ 10^{-5}$	$5.50\ 10^{-4}$	$5.50\ 10^{-4}$	$5.50\ 10^{-4}$	$5.50\ 10^{-4}$	$5.50\ 10^{-4}$	$5.50\ 10^{-4}$	$5.50\ 10^{-4}$	$5.50\ 10^{-4}$
^{14}C	$1.30\ 10^{-4}$	$1.10\ 10^{-1}$	$1.90\ 10^{-1}$	$6.00\ 10^{-1}$	$9.40\ 10^{-1}$	$2.90\ 10^{0}$	$4.20\ 10^{0}$	$5.80\ 10^{0}$	$5.80\ 10^{0}$
^{129}I	$2.00\ 10^{-5}$	$4.10\ 10^{-4}$	$4.70\ 10^{-4}$	$9.70\ 10^{-4}$	$1.70\ 10^{-3}$	$8.60\ 10^{-3}$	$2.00\ 10^{-2}$	$1.10\ 10^{-1}$	$2.10\ 10^{-1}$
Total	**$1.60\ 10^{-4}$**	**$1.10\ 10^{-1}$**	**$1.90\ 10^{-1}$**	**$6.00\ 10^{-1}$**	**$9.40\ 10^{-1}$**	**$2.90\ 10^{0}$**	**$4.20\ 10^{0}$**	**$5.90\ 10^{0}$**	**$6.00\ 10^{0}$**

TABLE D19 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (first-pass plus global circulation)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	3.77 10^{-4}	5.44 10^{-3}	5.44 10^{-3}	5.44 10^{-3}	5.44 10^{-3}	5.44 10^{-3}	5.44 10^{-3}	5.44 10^{-3}	5.44 10^{-3}
^{14}C	5.99 10^{-1}	4.92 10^{0}	5.56 10^{0}	8.27 10^{0}	1.05 10^{1}	2.26 10^{1}	3.17 10^{1}	4.18 10^{1}	4.18 10^{1}
^{35}S	1.52 10^{-6}	2.12 10^{-6}	2.12 10^{-6}	2.12 10^{-6}	2.12 10^{-6}	2.12 10^{-6}	2.12 10^{-6}	2.12 10^{-6}	2.12 10^{-6}
^{54}Mn	9.87 10^{-5}	1.23 10^{-4}	1.23 10^{-4}	1.23 10^{-4}	1.23 10^{-4}	1.23 10^{-4}	1.23 10^{-4}	1.23 10^{-4}	1.23 10^{-4}
^{55}Fe	1.25 10^{-4}	1.69 10^{-4}	1.69 10^{-4}	1.69 10^{-4}	1.69 10^{-4}	1.69 10^{-4}	1.69 10^{-4}	1.69 10^{-4}	1.69 10^{-4}
^{60}Co	4.14 10^{-3}	1.45 10^{-2}	1.45 10^{-2}	1.45 10^{-2}	1.45 10^{-2}	1.45 10^{-2}	1.45 10^{-2}	1.45 10^{-2}	1.45 10^{-2}
^{63}Ni	4.62 10^{-5}	1.43 10^{-4}	1.89 10^{-4}	2.34 10^{-4}	2.34 10^{-4}	2.34 10^{-4}	2.34 10^{-4}	2.34 10^{-4}	2.34 10^{-4}
^{65}Zn	6.63 10^{-3}	8.65 10^{-3}	8.65 10^{-3}	8.65 10^{-3}	8.65 10^{-3}	8.65 10^{-3}	8.65 10^{-3}	8.65 10^{-3}	8.65 10^{-3}
^{89}Sr	4.72 10^{-6}	5.84 10^{-6}	5.84 10^{-6}	5.84 10^{-6}	5.84 10^{-6}	5.84 10^{-6}	5.84 10^{-6}	5.84 10^{-6}	5.84 10^{-6}
^{90}Sr	5.34 10^{-3}	4.01 10^{-2}	4.03 10^{-2}	4.03 10^{-2}	4.03 10^{-2}	4.03 10^{-2}	4.03 10^{-2}	4.03 10^{-2}	4.03 10^{-2}
^{95}Zr	3.04 10^{-5}	3.74 10^{-5}	3.74 10^{-5}	3.74 10^{-5}	3.74 10^{-5}	3.74 10^{-5}	3.74 10^{-5}	3.74 10^{-5}	3.74 10^{-5}
^{95}Nb	2.42 10^{-5}	3.15 10^{-5}	3.15 10^{-5}	3.15 10^{-5}	3.15 10^{-5}	3.15 10^{-5}	3.15 10^{-5}	3.15 10^{-5}	3.15 10^{-5}
^{99}Tc	1.37 10^{-1}	4.76 10^{-1}	4.78 10^{-1}	4.83 10^{-1}	4.86 10^{-1}	4.95 10^{-1}	5.05 10^{-1}	5.77 10^{-1}	6.45 10^{-1}
^{103}Ru	1.65 10^{-4}	1.91 10^{-4}	1.91 10^{-4}	1.91 10^{-4}	1.91 10^{-4}	1.91 10^{-4}	1.91 10^{-4}	1.91 10^{-4}	1.91 10^{-4}
^{106}Ru	1.57 10^{-1}	2.89 10^{-1}	2.89 10^{-1}	2.89 10^{-1}	2.89 10^{-1}	2.89 10^{-1}	2.89 10^{-1}	2.89 10^{-1}	2.89 10^{-1}
^{110m}Ag	5.89 10^{-3}	9.98 10^{-3}	9.98 10^{-3}	9.98 10^{-3}	9.98 10^{-3}	9.98 10^{-3}	9.98 10^{-3}	9.98 10^{-3}	9.98 10^{-3}
^{125}Sb	1.15 10^{-2}	7.24 10^{-2}	7.24 10^{-2}	7.24 10^{-2}	7.24 10^{-2}	7.24 10^{-2}	7.24 10^{-2}	7.24 10^{-2}	7.24 10^{-2}
^{129}I	3.85 10^{-3}	2.98 10^{-2}	3.05 10^{-2}	3.45 10^{-2}	3.84 10^{-2}	8.56 10^{-2}	1.61 10^{-1}	7.83 10^{-1}	1.36 10^{0}
^{134}Cs	2.35 10^{-3}	1.18 10^{-2}	1.18 10^{-2}	1.18 10^{-2}	1.18 10^{-2}	1.18 10^{-2}	1.18 10^{-2}	1.18 10^{-2}	1.18 10^{-2}
^{137}Cs	3.60 10^{-2}	3.31 10^{-1}	3.32 10^{-1}	3.32 10^{-1}	3.32 10^{-1}	3.32 10^{-1}	3.32 10^{-1}	3.32 10^{-1}	3.32 10^{-1}
^{144}Ce	1.08 10^{-4}	1.43 10^{-4}	1.43 10^{-4}	1.43 10^{-4}	1.43 10^{-4}	1.43 10^{-4}	1.43 10^{-4}	1.43 10^{-4}	1.43 10^{-4}
^{147}Pm	7.05 10^{-6}	8.44 10^{-6}	8.44 10^{-6}	8.44 10^{-6}	8.44 10^{-6}	8.44 10^{-6}	8.44 10^{-6}	8.44 10^{-6}	8.44 10^{-6}
^{152}Eu	1.13 10^{-4}	1.03 10^{-3}	1.05 10^{-3}	1.05 10^{-3}	1.05 10^{-3}	1.05 10^{-3}	1.05 10^{-3}	1.05 10^{-3}	1.05 10^{-3}
^{154}Eu	9.96 10^{-5}	6.77 10^{-4}	6.79 10^{-4}	6.79 10^{-4}	6.79 10^{-4}	6.79 10^{-4}	6.79 10^{-4}	6.79 10^{-4}	6.79 10^{-4}
^{155}Eu	8.34 10^{-6}	2.60 10^{-5}	2.60 10^{-5}	2.60 10^{-5}	2.60 10^{-5}	2.60 10^{-5}	2.60 10^{-5}	2.60 10^{-5}	2.60 10^{-5}
^{234}U	2.15 10^{-5}	7.31 10^{-5}	7.38 10^{-5}	7.46 10^{-5}	7.51 10^{-5}	7.66 10^{-5}	7.84 10^{-5}	8.97 10^{-5}	1.01 10^{-4}
^{238}U	1.98 10^{-5}	6.76 10^{-5}	6.83 10^{-5}	6.88 10^{-5}	6.91 10^{-5}	7.06 10^{-5}	7.23 10^{-5}	8.36 10^{-5}	9.67 10^{-5}
^{237}Np	4.85 10^{-3}	1.61 10^{-2}	1.63 10^{-2}	1.64 10^{-2}	1.65 10^{-2}	1.67 10^{-2}	1.70 10^{-2}	1.89 10^{-2}	2.06 10^{-2}
^{239}Pu	3.80 10^{-2}	9.94 10^{-2}	1.29 10^{-1}	1.81 10^{-1}	1.84 10^{-1}	1.85 10^{-1}	1.85 10^{-1}	1.86 10^{-1}	1.86 10^{-1}
^{241}Pu	2.05 10^{-2}	3.68 10^{-2}	3.74 10^{-2}	3.75 10^{-2}	3.75 10^{-2}	3.75 10^{-2}	3.75 10^{-2}	3.75 10^{-2}	3.75 10^{-2}
^{241}Am	1.64 10^{-3}	1.20 10^{-2}	2.17 10^{-2}	4.57 10^{-2}	4.81 10^{-2}	4.84 10^{-2}	4.84 10^{-2}	4.84 10^{-2}	4.84 10^{-2}
^{242}Cm	2.72 10^{-5}	2.85 10^{-5}	2.85 10^{-5}	2.85 10^{-5}	2.85 10^{-5}	2.85 10^{-5}	2.85 10^{-5}	2.85 10^{-5}	2.85 10^{-5}
^{243}Cm	1.48 10^{-4}	2.86 10^{-4}	3.08 10^{-4}	3.15 10^{-4}	3.15 10^{-4}	3.15 10^{-4}	3.15 10^{-4}	3.15 10^{-4}	3.15 10^{-4}
Total	**1.03 10^{0}**	**6.38 10^{0}**	**7.06 10^{0}**	**9.86 10^{0}**	**1.21 10^{1}**	**2.43 10^{1}**	**3.35 10^{1}**	**4.43 10^{1}**	**4.49 10^{1}**

TABLE D20 Collective doses (man Sv) to the European population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (first-pass only)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	$3.05\ 10^{-4}$	$1.94\ 10^{-3}$	$1.94\ 10^{-3}$	$1.94\ 10^{-3}$	$1.94\ 10^{-3}$	$1.94\ 10^{-3}$	$1.94\ 10^{-3}$	$1.94\ 10^{-3}$	$1.94\ 10^{-3}$
^{14}C	$5.98\ 10^{-1}$	$4.22\ 10^{0}$	$4.36\ 10^{0}$	$4.47\ 10^{0}$	$4.50\ 10^{0}$	$4.64\ 10^{0}$	$4.73\ 10^{0}$	$4.83\ 10^{0}$	$4.83\ 10^{0}$
^{35}S	$1.52\ 10^{-6}$	$2.12\ 10^{-6}$	$2.12\ 10^{-6}$	$2.12\ 10^{-6}$	$2.12\ 10^{-6}$	$2.12\ 10^{-6}$	$2.12\ 10^{-6}$	$2.12\ 10^{-6}$	$2.12\ 10^{-6}$
^{54}Mn	$9.87\ 10^{-5}$	$1.23\ 10^{-4}$	$1.23\ 10^{-4}$	$1.23\ 10^{-4}$	$1.23\ 10^{-4}$	$1.23\ 10^{-4}$	$1.23\ 10^{-4}$	$1.23\ 10^{-4}$	$1.23\ 10^{-4}$
^{55}Fe	$1.25\ 10^{-4}$	$1.69\ 10^{-4}$	$1.69\ 10^{-4}$	$1.69\ 10^{-4}$	$1.69\ 10^{-4}$	$1.69\ 10^{-4}$	$1.69\ 10^{-4}$	$1.69\ 10^{-4}$	$1.69\ 10^{-4}$
^{60}Co	$4.14\ 10^{-3}$	$1.45\ 10^{-2}$	$1.45\ 10^{-2}$	$1.45\ 10^{-2}$	$1.45\ 10^{-2}$	$1.45\ 10^{-2}$	$1.45\ 10^{-2}$	$1.45\ 10^{-2}$	$1.45\ 10^{-2}$
^{63}Ni	$4.62\ 10^{-5}$	$1.43\ 10^{-4}$	$1.89\ 10^{-4}$	$2.34\ 10^{-4}$	$2.34\ 10^{-4}$	$2.34\ 10^{-4}$	$2.34\ 10^{-4}$	$2.34\ 10^{-4}$	$2.34\ 10^{-4}$
^{65}Zn	$6.63\ 10^{-3}$	$8.65\ 10^{-3}$	$8.65\ 10^{-3}$	$8.65\ 10^{-3}$	$8.65\ 10^{-3}$	$8.65\ 10^{-3}$	$8.65\ 10^{-3}$	$8.65\ 10^{-3}$	$8.65\ 10^{-3}$
^{89}Sr	$4.72\ 10^{-6}$	$5.84\ 10^{-6}$	$5.84\ 10^{-6}$	$5.84\ 10^{-6}$	$5.84\ 10^{-6}$	$5.84\ 10^{-6}$	$5.84\ 10^{-6}$	$5.84\ 10^{-6}$	$5.84\ 10^{-6}$
^{90}Sr	$5.34\ 10^{-3}$	$4.01\ 10^{-2}$	$4.03\ 10^{-2}$	$4.03\ 10^{-2}$	$4.03\ 10^{-2}$	$4.03\ 10^{-2}$	$4.03\ 10^{-2}$	$4.03\ 10^{-2}$	$4.03\ 10^{-2}$
^{95}Zr	$3.04\ 10^{-5}$	$3.74\ 10^{-5}$	$3.74\ 10^{-5}$	$3.74\ 10^{-5}$	$3.74\ 10^{-5}$	$3.74\ 10^{-5}$	$3.74\ 10^{-5}$	$3.74\ 10^{-5}$	$3.74\ 10^{-5}$
^{95}Nb	$2.42\ 10^{-5}$	$3.15\ 10^{-5}$	$3.15\ 10^{-5}$	$3.15\ 10^{-5}$	$3.15\ 10^{-5}$	$3.15\ 10^{-5}$	$3.15\ 10^{-5}$	$3.15\ 10^{-5}$	$3.15\ 10^{-5}$
^{99}Tc	$1.37\ 10^{-1}$	$4.76\ 10^{-1}$	$4.78\ 10^{-1}$	$4.83\ 10^{-1}$	$4.86\ 10^{-1}$	$4.95\ 10^{-1}$	$5.05\ 10^{-1}$	$5.77\ 10^{-1}$	$6.45\ 10^{-1}$
^{103}Ru	$1.65\ 10^{-4}$	$1.91\ 10^{-4}$	$1.91\ 10^{-4}$	$1.91\ 10^{-4}$	$1.91\ 10^{-4}$	$1.91\ 10^{-4}$	$1.91\ 10^{-4}$	$1.91\ 10^{-4}$	$1.91\ 10^{-4}$
^{106}Ru	$1.57\ 10^{-1}$	$2.89\ 10^{-1}$	$2.89\ 10^{-1}$	$2.89\ 10^{-1}$	$2.89\ 10^{-1}$	$2.89\ 10^{-1}$	$2.89\ 10^{-1}$	$2.89\ 10^{-1}$	$2.89\ 10^{-1}$
^{110m}Ag	$5.89\ 10^{-3}$	$9.98\ 10^{-3}$	$9.98\ 10^{-3}$	$9.98\ 10^{-3}$	$9.98\ 10^{-3}$	$9.98\ 10^{-3}$	$9.98\ 10^{-3}$	$9.98\ 10^{-3}$	$9.98\ 10^{-3}$
^{125}Sb	$1.15\ 10^{-2}$	$7.24\ 10^{-2}$	$7.24\ 10^{-2}$	$7.24\ 10^{-2}$	$7.24\ 10^{-2}$	$7.24\ 10^{-2}$	$7.24\ 10^{-2}$	$7.24\ 10^{-2}$	$7.24\ 10^{-2}$
^{129}I	$3.72\ 10^{-3}$	$2.72\ 10^{-2}$	$2.75\ 10^{-2}$	$2.82\ 10^{-2}$	$2.84\ 10^{-2}$	$2.96\ 10^{-2}$	$3.11\ 10^{-2}$	$4.26\ 10^{-2}$	$5.61\ 10^{-2}$
^{134}Cs	$2.35\ 10^{-3}$	$1.18\ 10^{-2}$	$1.18\ 10^{-2}$	$1.18\ 10^{-2}$	$1.18\ 10^{-2}$	$1.18\ 10^{-2}$	$1.18\ 10^{-2}$	$1.18\ 10^{-2}$	$1.18\ 10^{-2}$
^{137}Cs	$3.60\ 10^{-2}$	$3.31\ 10^{-1}$	$3.32\ 10^{-1}$	$3.32\ 10^{-1}$	$3.32\ 10^{-1}$	$3.32\ 10^{-1}$	$3.32\ 10^{-1}$	$3.32\ 10^{-1}$	$3.32\ 10^{-1}$
^{144}Ce	$1.08\ 10^{-4}$	$1.43\ 10^{-4}$	$1.43\ 10^{-4}$	$1.43\ 10^{-4}$	$1.43\ 10^{-4}$	$1.43\ 10^{-4}$	$1.43\ 10^{-4}$	$1.43\ 10^{-4}$	$1.43\ 10^{-4}$
^{147}Pm	$7.05\ 10^{-6}$	$8.44\ 10^{-6}$	$8.44\ 10^{-6}$	$8.44\ 10^{-6}$	$8.44\ 10^{-6}$	$8.44\ 10^{-6}$	$8.44\ 10^{-6}$	$8.44\ 10^{-6}$	$8.44\ 10^{-6}$
^{152}Eu	$1.13\ 10^{-4}$	$1.03\ 10^{-3}$	$1.05\ 10^{-3}$	$1.05\ 10^{-3}$	$1.05\ 10^{-3}$	$1.05\ 10^{-3}$	$1.05\ 10^{-3}$	$1.05\ 10^{-3}$	$1.05\ 10^{-3}$
^{154}Eu	$9.96\ 10^{-5}$	$6.77\ 10^{-4}$	$6.79\ 10^{-4}$	$6.79\ 10^{-4}$	$6.79\ 10^{-4}$	$6.79\ 10^{-4}$	$6.79\ 10^{-4}$	$6.79\ 10^{-4}$	$6.79\ 10^{-4}$
^{155}Eu	$8.34\ 10^{-6}$	$2.60\ 10^{-5}$	$2.60\ 10^{-5}$	$2.60\ 10^{-5}$	$2.60\ 10^{-5}$	$2.60\ 10^{-5}$	$2.60\ 10^{-5}$	$2.60\ 10^{-5}$	$2.60\ 10^{-5}$
^{234}U	$2.15\ 10^{-5}$	$7.31\ 10^{-5}$	$7.38\ 10^{-5}$	$7.46\ 10^{-5}$	$7.51\ 10^{-5}$	$7.66\ 10^{-5}$	$7.84\ 10^{-5}$	$8.97\ 10^{-5}$	$1.01\ 10^{-4}$
^{238}U	$1.98\ 10^{-5}$	$6.76\ 10^{-5}$	$6.83\ 10^{-5}$	$6.88\ 10^{-5}$	$6.91\ 10^{-5}$	$7.06\ 10^{-5}$	$7.23\ 10^{-5}$	$8.36\ 10^{-5}$	$9.67\ 10^{-5}$
^{237}Np	$4.85\ 10^{-3}$	$1.61\ 10^{-2}$	$1.63\ 10^{-2}$	$1.64\ 10^{-2}$	$1.65\ 10^{-2}$	$1.67\ 10^{-2}$	$1.70\ 10^{-2}$	$1.89\ 10^{-2}$	$2.06\ 10^{-2}$
^{239}Pu	$3.80\ 10^{-2}$	$9.94\ 10^{-2}$	$1.29\ 10^{-1}$	$1.81\ 10^{-1}$	$1.84\ 10^{-1}$	$1.85\ 10^{-1}$	$1.85\ 10^{-1}$	$1.86\ 10^{-1}$	$1.86\ 10^{-1}$
^{241}Pu	$2.05\ 10^{-2}$	$3.68\ 10^{-2}$	$3.74\ 10^{-2}$	$3.75\ 10^{-2}$	$3.75\ 10^{-2}$	$3.75\ 10^{-2}$	$3.75\ 10^{-2}$	$3.75\ 10^{-2}$	$3.75\ 10^{-2}$
^{241}Am	$1.64\ 10^{-3}$	$1.20\ 10^{-2}$	$2.17\ 10^{-2}$	$4.57\ 10^{-2}$	$4.81\ 10^{-2}$	$4.84\ 10^{-2}$	$4.84\ 10^{-2}$	$4.84\ 10^{-2}$	$4.84\ 10^{-2}$
^{242}Cm	$2.72\ 10^{-5}$	$2.85\ 10^{-5}$	$2.85\ 10^{-5}$	$2.85\ 10^{-5}$	$2.85\ 10^{-5}$	$2.85\ 10^{-5}$	$2.85\ 10^{-5}$	$2.85\ 10^{-5}$	$2.85\ 10^{-5}$
^{243}Cm	$1.48\ 10^{-4}$	$2.86\ 10^{-4}$	$3.08\ 10^{-4}$	$3.15\ 10^{-4}$	$3.15\ 10^{-4}$	$3.15\ 10^{-4}$	$3.15\ 10^{-4}$	$3.15\ 10^{-4}$	$3.15\ 10^{-4}$
Total	**$1.03\ 10^{0}$**	**$5.67\ 10^{0}$**	**$5.85\ 10^{0}$**	**$6.05\ 10^{0}$**	**$6.08\ 10^{0}$**	**$6.24\ 10^{0}$**	**$6.34\ 10^{0}$**	**$6.52\ 10^{0}$**	**$6.61\ 10^{0}$**

TABLE D21 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (global circulation only)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	$7.20\ 10^{-5}$	$3.50\ 10^{-3}$	$3.50\ 10^{-3}$	$3.50\ 10^{-3}$	$3.50\ 10^{-3}$	$3.50\ 10^{-3}$	$3.50\ 10^{-3}$	$3.50\ 10^{-3}$	$3.50\ 10^{-3}$
^{14}C	$8.20\ 10^{-4}$	$7.00\ 10^{-1}$	$1.20\ 10^{0}$	$3.80\ 10^{0}$	$6.00\ 10^{0}$	$1.80\ 10^{1}$	$2.70\ 10^{1}$	$3.70\ 10^{1}$	$3.70\ 10^{1}$
^{129}I	$1.30\ 10^{-4}$	$2.60\ 10^{-3}$	$3.00\ 10^{-3}$	$6.30\ 10^{-3}$	$1.00\ 10^{-2}$	$5.60\ 10^{-2}$	$1.30\ 10^{-1}$	$7.40\ 10^{-1}$	$1.30\ 10^{0}$
Total	**$1.00\ 10^{-3}$**	**$7.10\ 10^{-1}$**	**$1.20\ 10^{0}$**	**$3.80\ 10^{0}$**	**$6.00\ 10^{0}$**	**$1.80\ 10^{1}$**	**$2.70\ 10^{1}$**	**$3.80\ 10^{1}$**	**$3.80\ 10^{1}$**

World

TABLE D22 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (first-pass plus global circulation)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	$2.38\ 10^{-3}$	$1.02\ 10^{-1}$	$1.02\ 10^{-1}$	$1.02\ 10^{-1}$	$1.02\ 10^{-1}$	$1.02\ 10^{-1}$	$1.02\ 10^{-1}$	$1.02\ 10^{-1}$	$1.02\ 10^{-1}$
^{14}C	$7.50\ 10^{-1}$	$2.68\ 10^{1}$	$4.31\ 10^{1}$	$1.17\ 10^{2}$	$1.77\ 10^{2}$	$5.38\ 10^{2}$	$7.98\ 10^{2}$	$1.11\ 10^{3}$	$1.11\ 10^{3}$
^{35}S	$1.77\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$
^{54}Mn	$1.05\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$
^{55}Fe	$1.37\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$
^{60}Co	$4.61\ 10^{-3}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$
^{63}Ni	$5.38\ 10^{-5}$	$1.82\ 10^{-4}$	$2.47\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$
^{65}Zn	$7.63\ 10^{-3}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$
^{89}Sr	$5.85\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$
^{90}Sr	$6.86\ 10^{-3}$	$6.48\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$
^{95}Zr	$3.11\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$
^{95}Nb	$2.44\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$
^{99}Tc	$1.55\ 10^{-1}$	$5.79\ 10^{-1}$	$5.83\ 10^{-1}$	$5.92\ 10^{-1}$	$5.96\ 10^{-1}$	$6.10\ 10^{-1}$	$6.28\ 10^{-1}$	$7.47\ 10^{-1}$	$8.60\ 10^{-1}$
^{103}Ru	$1.79\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$
^{106}Ru	$1.71\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$
^{110m}Ag	$6.59\ 10^{-3}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$
^{125}Sb	$1.57\ 10^{-2}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$
^{129}I	$7.12\ 10^{-3}$	$9.58\ 10^{-2}$	$1.02\ 10^{-1}$	$1.66\ 10^{-1}$	$2.57\ 10^{-1}$	$1.15\ 10^{0}$	$2.55\ 10^{0}$	$1.41\ 10^{1}$	$2.61\ 10^{1}$
^{134}Cs	$3.07\ 10^{-3}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$
^{137}Cs	$4.74\ 10^{-2}$	$5.51\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$
^{144}Ce	$1.15\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$
^{147}Pm	$7.64\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$
^{152}Eu	$1.17\ 10^{-4}$	$1.04\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$
^{154}Eu	$1.03\ 10^{-4}$	$6.83\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$
^{155}Eu	$8.85\ 10^{-6}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$
^{234}U	$2.39\ 10^{-5}$	$8.76\ 10^{-5}$	$8.89\ 10^{-5}$	$9.02\ 10^{-5}$	$9.07\ 10^{-5}$	$9.32\ 10^{-5}$	$9.59\ 10^{-5}$	$1.15\ 10^{-4}$	$1.34\ 10^{-4}$
^{238}U	$2.19\ 10^{-5}$	$8.06\ 10^{-5}$	$8.19\ 10^{-5}$	$8.31\ 10^{-5}$	$8.36\ 10^{-5}$	$8.59\ 10^{-5}$	$8.84\ 10^{-5}$	$1.07\ 10^{-4}$	$1.29\ 10^{-4}$
^{237}Np	$5.35\ 10^{-3}$	$1.89\ 10^{-2}$	$1.92\ 10^{-2}$	$1.94\ 10^{-2}$	$1.95\ 10^{-2}$	$1.99\ 10^{-2}$	$2.04\ 10^{-2}$	$2.34\ 10^{-2}$	$2.62\ 10^{-2}$
^{239}Pu	$4.13\ 10^{-2}$	$1.10\ 10^{-1}$	$1.45\ 10^{-1}$	$2.13\ 10^{-1}$	$2.17\ 10^{-1}$	$2.19\ 10^{-1}$	$2.19\ 10^{-1}$	$2.21\ 10^{-1}$	$2.21\ 10^{-1}$
^{241}Pu	$2.23\ 10^{-2}$	$4.05\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$
^{241}Am	$1.74\ 10^{-3}$	$1.30\ 10^{-2}$	$2.36\ 10^{-2}$	$5.01\ 10^{-2}$	$5.30\ 10^{-2}$	$5.33\ 10^{-2}$	$5.33\ 10^{-2}$	$5.33\ 10^{-2}$	$5.33\ 10^{-2}$
^{242}Cm	$2.89\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$
^{243}Cm	$1.57\ 10^{-4}$	$3.06\ 10^{-4}$	$3.31\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$
Total	**$1.25\ 10^{0}$**	**$2.88\ 10^{1}$**	**$4.52\ 10^{1}$**	**$1.20\ 10^{2}$**	**$1.80\ 10^{2}$**	**$5.41\ 10^{2}$**	**$8.03\ 10^{2}$**	**$1.12\ 10^{3}$**	**$1.14\ 10^{3}$**

TABLE D23 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (first-pass only)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	$3.78\ 10^{-4}$	$2.99\ 10^{-3}$	$2.99\ 10^{-3}$	$2.99\ 10^{-3}$	$2.99\ 10^{-3}$	$2.99\ 10^{-3}$	$2.99\ 10^{-3}$	$2.99\ 10^{-3}$	$2.99\ 10^{-3}$
^{14}C	$7.43\ 10^{-1}$	$6.75\ 10^{0}$	$7.06\ 10^{0}$	$7.31\ 10^{0}$	$7.38\ 10^{0}$	$7.66\ 10^{0}$	$7.85\ 10^{0}$	$8.07\ 10^{0}$	$8.07\ 10^{0}$
^{35}S	$1.77\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$	$2.53\ 10^{-6}$
^{54}Mn	$1.05\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$	$1.31\ 10^{-4}$
^{55}Fe	$1.37\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$	$1.85\ 10^{-4}$
^{60}Co	$4.61\ 10^{-3}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$	$1.52\ 10^{-2}$
^{63}Ni	$5.38\ 10^{-5}$	$1.82\ 10^{-4}$	$2.47\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$	$3.17\ 10^{-4}$
^{65}Zn	$7.63\ 10^{-3}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$
^{89}Sr	$5.85\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$	$7.31\ 10^{-6}$
^{90}Sr	$6.86\ 10^{-3}$	$6.48\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$	$6.53\ 10^{-2}$
^{95}Zr	$3.11\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$	$3.81\ 10^{-5}$
^{95}Nb	$2.44\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$	$3.17\ 10^{-5}$
^{99}Tc	$1.55\ 10^{-1}$	$5.79\ 10^{-1}$	$5.83\ 10^{-1}$	$5.92\ 10^{-1}$	$5.96\ 10^{-1}$	$6.10\ 10^{-1}$	$6.28\ 10^{-1}$	$7.47\ 10^{-1}$	$8.60\ 10^{-1}$
^{103}Ru	$1.79\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$	$2.07\ 10^{-4}$
^{106}Ru	$1.71\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$	$3.14\ 10^{-1}$
^{110m}Ag	$6.59\ 10^{-3}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$	$1.14\ 10^{-2}$
^{125}Sb	$1.57\ 10^{-2}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$	$1.13\ 10^{-1}$
^{129}I	$4.62\ 10^{-3}$	$4.38\ 10^{-2}$	$4.46\ 10^{-2}$	$4.62\ 10^{-2}$	$4.67\ 10^{-2}$	$4.93\ 10^{-2}$	$5.25\ 10^{-2}$	$7.70\ 10^{-2}$	$1.06\ 10^{-1}$
^{134}Cs	$3.07\ 10^{-3}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$	$1.79\ 10^{-2}$
^{137}Cs	$4.74\ 10^{-2}$	$5.51\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$	$5.54\ 10^{-1}$
^{144}Ce	$1.15\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$	$1.52\ 10^{-4}$
^{147}Pm	$7.64\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$	$9.17\ 10^{-6}$
^{152}Eu	$1.17\ 10^{-4}$	$1.04\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$	$1.06\ 10^{-3}$
^{154}Eu	$1.03\ 10^{-4}$	$6.83\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$	$6.86\ 10^{-4}$
^{155}Eu	$8.85\ 10^{-6}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$	$2.67\ 10^{-5}$
^{234}U	$2.39\ 10^{-5}$	$8.76\ 10^{-5}$	$8.89\ 10^{-5}$	$9.02\ 10^{-5}$	$9.07\ 10^{-5}$	$9.32\ 10^{-5}$	$9.59\ 10^{-5}$	$1.15\ 10^{-4}$	$1.34\ 10^{-4}$
^{238}U	$2.19\ 10^{-5}$	$8.06\ 10^{-5}$	$8.19\ 10^{-5}$	$8.31\ 10^{-5}$	$8.36\ 10^{-5}$	$8.59\ 10^{-5}$	$8.84\ 10^{-5}$	$1.07\ 10^{-4}$	$1.29\ 10^{-4}$
^{237}Np	$5.35\ 10^{-3}$	$1.89\ 10^{-2}$	$1.92\ 10^{-2}$	$1.94\ 10^{-2}$	$1.95\ 10^{-2}$	$1.99\ 10^{-2}$	$2.04\ 10^{-2}$	$2.34\ 10^{-2}$	$2.62\ 10^{-2}$
^{239}Pu	$4.13\ 10^{-2}$	$1.10\ 10^{-1}$	$1.45\ 10^{-1}$	$2.13\ 10^{-1}$	$2.17\ 10^{-1}$	$2.19\ 10^{-1}$	$2.19\ 10^{-1}$	$2.21\ 10^{-1}$	$2.21\ 10^{-1}$
^{241}Pu	$2.23\ 10^{-2}$	$4.05\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$	$4.12\ 10^{-2}$
^{241}Am	$1.74\ 10^{-3}$	$1.30\ 10^{-2}$	$2.36\ 10^{-2}$	$5.01\ 10^{-2}$	$5.30\ 10^{-2}$	$5.33\ 10^{-2}$	$5.33\ 10^{-2}$	$5.33\ 10^{-2}$	$5.33\ 10^{-2}$
^{242}Cm	$2.89\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$	$3.03\ 10^{-5}$
^{243}Cm	$1.57\ 10^{-4}$	$3.06\ 10^{-4}$	$3.31\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$	$3.38\ 10^{-4}$
Total	**$1.24\ 10^{0}$**	**$8.66\ 10^{0}$**	**$9.02\ 10^{0}$**	**$9.38\ 10^{0}$**	**$9.46\ 10^{0}$**	**$9.76\ 10^{0}$**	**$9.97\ 10^{0}$**	**$1.03\ 10^{1}$**	**$1.05\ 10^{1}$**

TABLE D24 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to the marine environment from Sellafield between 1999 and 2003 (global circulation only)

Radio-nuclide	Truncation time (y)								
	1	50	100	500	1000	5000	10000	50000	100000
^{3}H	$2.00\ 10^{-3}$	$9.90\ 10^{-2}$	$9.90\ 10^{-2}$	$9.90\ 10^{-2}$	$9.90\ 10^{-2}$	$9.90\ 10^{-2}$	$9.90\ 10^{-2}$	$9.90\ 10^{-2}$	$9.90\ 10^{-2}$
^{14}C	$6.70\ 10^{-3}$	$2.00\ 10^{1}$	$3.60\ 10^{1}$	$1.10\ 10^{2}$	$1.70\ 10^{2}$	$5.30\ 10^{2}$	$7.90\ 10^{2}$	$1.10\ 10^{3}$	$1.10\ 10^{3}$
^{129}I	$2.50\ 10^{-3}$	$5.20\ 10^{-2}$	$5.70\ 10^{-2}$	$1.20\ 10^{-1}$	$2.10\ 10^{-1}$	$1.10\ 10^{0}$	$2.50\ 10^{0}$	$1.40\ 10^{1}$	$2.60\ 10^{1}$
Total	**$1.10\ 10^{-2}$**	**$2.00\ 10^{1}$**	**$3.60\ 10^{1}$**	**$1.10\ 10^{2}$**	**$1.70\ 10^{2}$**	**$5.30\ 10^{2}$**	**$7.90\ 10^{2}$**	**$1.10\ 10^{3}$**	**$1.10\ 10^{3}$**

La Hague

France

TABLE D25 Collective doses (man Sv) to the French population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (first-pass and global circulation)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$1.48\ 10^{-3}$	$4.90\ 10^{-3}$	$5.10\ 10^{-3}$	$5.10\ 10^{-3}$	$5.10\ 10^{-3}$
^{14}C	$6.60\ 10^{-1}$	$1.19\ 10^{0}$	$1.81\ 10^{0}$	$6.50\ 10^{0}$	$8.40\ 10^{0}$
^{60}Co	$1.30\ 10^{-2}$	$1.80\ 10^{-2}$	$1.80\ 10^{-2}$	$1.80\ 10^{-2}$	$1.80\ 10^{-2}$
^{65}Zn	$5.30\ 10^{-5}$	$6.60\ 10^{-5}$	$6.60\ 10^{-5}$	$6.60\ 10^{-5}$	$6.60\ 10^{-5}$
^{89}Sr	$2.70\ 10^{-15}$	$3.00\ 10^{-15}$	$3.00\ 10^{-15}$	$3.00\ 10^{-15}$	$3.00\ 10^{-15}$
^{90}Sr	$3.20\ 10^{-4}$	$5.60\ 10^{-4}$	$5.60\ 10^{-4}$	$5.60\ 10^{-4}$	$5.60\ 10^{-4}$
^{99}Tc	$6.00\ 10^{-4}$	$8.50\ 10^{-4}$	$9.20\ 10^{-4}$	$1.70\ 10^{-3}$	$1.90\ 10^{-3}$
^{103}Ru	$8.20\ 10^{-11}$	$8.70\ 10^{-11}$	$8.70\ 10^{-11}$	$8.70\ 10^{-11}$	$8.70\ 10^{-11}$
^{106}Ru	$5.80\ 10^{-1}$	$7.20\ 10^{-1}$	$7.20\ 10^{-1}$	$7.20\ 10^{-1}$	$7.20\ 10^{-1}$
^{125}Sb	$9.40\ 10^{-4}$	$1.50\ 10^{-3}$	$1.50\ 10^{-3}$	$1.50\ 10^{-3}$	$1.50\ 10^{-3}$
^{129}I	$1.00\ 10^{-2}$	$1.90\ 10^{-2}$	$2.24\ 10^{-2}$	$1.09\ 10^{-1}$	$5.40\ 10^{0}$
^{134}Cs	$1.40\ 10^{-3}$	$2.30\ 10^{-3}$	$2.30\ 10^{-3}$	$2.30\ 10^{-3}$	$2.30\ 10^{-3}$
^{137}Cs	$1.10\ 10^{-2}$	$2.00\ 10^{-2}$	$2.00\ 10^{-2}$	$2.00\ 10^{-2}$	$2.00\ 10^{-2}$
^{144}Ce	$1.10\ 10^{-5}$	$1.30\ 10^{-5}$	$1.30\ 10^{-5}$	$1.30\ 10^{-5}$	$1.30\ 10^{-5}$
^{234}U	$1.70\ 10^{-5}$	$2.40\ 10^{-5}$	$2.60\ 10^{-5}$	$5.50\ 10^{-5}$	$1.30\ 10^{-4}$
^{235}U	$3.40\ 10^{-17}$	$5.50\ 10^{-16}$	$5.00\ 10^{-15}$	$4.10\ 10^{-13}$	$2.00\ 10^{-12}$
^{238}U	$5.00\ 10^{-6}$	$6.90\ 10^{-6}$	$7.40\ 10^{-6}$	$1.60\ 10^{-5}$	$3.70\ 10^{-5}$
^{239}Pu	$2.70\ 10^{-3}$	$3.80\ 10^{-3}$	$4.00\ 10^{-3}$	$4.30\ 10^{-3}$	$4.30\ 10^{-3}$
^{241}Pu	$1.20\ 10^{-2}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$
^{241}Am	$3.10\ 10^{-6}$	$2.00\ 10^{-5}$	$4.40\ 10^{-5}$	$4.40\ 10^{-5}$	$4.40\ 10^{-5}$
Total	**$1.29\ 10^{0}$**	**$2.00\ 10^{0}$**	**$2.62\ 10^{0}$**	**$7.40\ 10^{0}$**	**$1.46\ 10^{1}$**

TABLE D26 Collective doses (man Sv) to the French population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (first-pass only)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$1.40\ 10^{-3}$	$2.20\ 10^{-3}$	$2.20\ 10^{-3}$	$2.20\ 10^{-3}$	$2.20\ 10^{-3}$
^{14}C	$6.60\ 10^{-1}$	$1.10\ 10^{0}$	$1.30\ 10^{0}$	$2.90\ 10^{0}$	$3.40\ 10^{0}$
^{60}Co	$1.30\ 10^{-2}$	$1.80\ 10^{-2}$	$1.80\ 10^{-2}$	$1.80\ 10^{-2}$	$1.80\ 10^{-2}$
^{65}Zn	$5.30\ 10^{-5}$	$6.60\ 10^{-5}$	$6.60\ 10^{-5}$	$6.60\ 10^{-5}$	$6.60\ 10^{-5}$
^{89}Sr	$2.70\ 10^{-15}$	$3.00\ 10^{-15}$	$3.00\ 10^{-15}$	$3.00\ 10^{-15}$	$3.00\ 10^{-15}$
^{90}Sr	$3.20\ 10^{-4}$	$5.60\ 10^{-4}$	$5.60\ 10^{-4}$	$5.60\ 10^{-4}$	$5.60\ 10^{-4}$
^{99}Tc	$6.00\ 10^{-4}$	$8.50\ 10^{-4}$	$9.20\ 10^{-4}$	$1.70\ 10^{-3}$	$1.90\ 10^{-3}$
^{103}Ru	$8.20\ 10^{-11}$	$8.70\ 10^{-11}$	$8.70\ 10^{-11}$	$8.70\ 10^{-11}$	$8.70\ 10^{-11}$
^{106}Ru	$5.80\ 10^{-1}$	$7.20\ 10^{-1}$	$7.20\ 10^{-1}$	$7.20\ 10^{-1}$	$7.20\ 10^{-1}$
^{125}Sb	$9.40\ 10^{-4}$	$1.50\ 10^{-3}$	$1.50\ 10^{-3}$	$1.50\ 10^{-3}$	$1.50\ 10^{-3}$
^{129}I	$1.00\ 10^{-2}$	$1.80\ 10^{-2}$	$2.00\ 10^{-2}$	$5.90\ 10^{-2}$	$9.90\ 10^{-2}$
^{134}Cs	$1.40\ 10^{-3}$	$2.30\ 10^{-3}$	$2.30\ 10^{-3}$	$2.30\ 10^{-3}$	$2.30\ 10^{-3}$
^{137}Cs	$1.10\ 10^{-2}$	$2.00\ 10^{-2}$	$2.00\ 10^{-2}$	$2.00\ 10^{-2}$	$2.00\ 10^{-2}$
^{144}Ce	$1.10\ 10^{-5}$	$1.30\ 10^{-5}$	$1.30\ 10^{-5}$	$1.30\ 10^{-5}$	$1.30\ 10^{-5}$
^{234}U	$1.70\ 10^{-5}$	$2.40\ 10^{-5}$	$2.60\ 10^{-5}$	$5.50\ 10^{-5}$	$1.30\ 10^{-4}$
^{235}U	$3.40\ 10^{-17}$	$5.50\ 10^{-16}$	$5.00\ 10^{-15}$	$4.10\ 10^{-13}$	$2.00\ 10^{-12}$
^{238}U	$5.00\ 10^{-6}$	$6.90\ 10^{-6}$	$7.40\ 10^{-6}$	$1.60\ 10^{-5}$	$3.70\ 10^{-5}$
^{239}Pu	$2.70\ 10^{-3}$	$3.80\ 10^{-3}$	$4.00\ 10^{-3}$	$4.30\ 10^{-3}$	$4.30\ 10^{-3}$
^{241}Pu	$1.20\ 10^{-2}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$
^{241}Am	$3.10\ 10^{-6}$	$2.00\ 10^{-5}$	$4.40\ 10^{-5}$	$4.40\ 10^{-5}$	$4.40\ 10^{-5}$
Total	**$1.29\ 10^{0}$**	**$1.90\ 10^{0}$**	**$2.11\ 10^{0}$**	**$3.75\ 10^{0}$**	**$4.29\ 10^{0}$**

TABLE D27 Collective doses (man Sv) to the French population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (global circulation only)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$7.90\ 10^{-5}$	$2.70\ 10^{-3}$	$2.90\ 10^{-3}$	$2.90\ 10^{-3}$	$2.90\ 10^{-3}$
^{14}C	$1.10\ 10^{-4}$	$9.30\ 10^{-2}$	$5.10\ 10^{-1}$	$3.60\ 10^{0}$	$5.00\ 10^{0}$
^{129}I	$4.90\ 10^{-5}$	$1.00\ 10^{-3}$	$2.40\ 10^{-3}$	$5.00\ 10^{-2}$	$5.30\ 10^{0}$
Total	**$2.38\ 10^{-4}$**	**$9.67\ 10^{-2}$**	**$5.15\ 10^{-1}$**	**$3.65\ 10^{0}$**	**$1.03\ 10^{1}$**

EU

TABLE D28 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (first-pass and global circulation)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$3.29\ 10^{-3}$	$2.35\ 10^{-2}$	$2.35\ 10^{-2}$	$2.35\ 10^{-2}$	$2.35\ 10^{-2}$
^{14}C	$1.40\ 10^{0}$	$3.99\ 10^{0}$	$7.60\ 10^{0}$	$3.80\ 10^{1}$	$4.90\ 10^{1}$
^{60}Co	$2.00\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$
^{65}Zn	$7.80\ 10^{-5}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$
^{89}Sr	$4.70\ 10^{-15}$	$5.50\ 10^{-15}$	$5.50\ 10^{-15}$	$5.50\ 10^{-15}$	$5.50\ 10^{-15}$
^{90}Sr	$7.10\ 10^{-4}$	$1.80\ 10^{-3}$	$1.90\ 10^{-3}$	$1.90\ 10^{-3}$	$1.90\ 10^{-3}$
^{99}Tc	$9.20\ 10^{-4}$	$1.60\ 10^{-3}$	$1.80\ 10^{-3}$	$3.80\ 10^{-3}$	$4.50\ 10^{-3}$
^{103}Ru	$9.40\ 10^{-11}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$
^{106}Ru	$7.80\ 10^{-1}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$
^{125}Sb	$2.00\ 10^{-3}$	$4.30\ 10^{-3}$	$4.30\ 10^{-3}$	$4.30\ 10^{-3}$	$4.30\ 10^{-3}$
^{129}I	$2.13\ 10^{-2}$	$6.04\ 10^{-2}$	$8.60\ 10^{-2}$	$6.30\ 10^{-1}$	$3.36\ 10^{1}$
^{134}Cs	$3.20\ 10^{-3}$	$6.70\ 10^{-3}$	$6.70\ 10^{-3}$	$6.70\ 10^{-3}$	$6.70\ 10^{-3}$
^{137}Cs	$2.60\ 10^{-2}$	$6.90\ 10^{-2}$	$7.00\ 10^{-2}$	$7.00\ 10^{-2}$	$7.00\ 10^{-2}$
^{144}Ce	$1.30\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$
^{234}U	$2.50\ 10^{-5}$	$4.30\ 10^{-5}$	$4.80\ 10^{-5}$	$1.30\ 10^{-4}$	$3.30\ 10^{-4}$
^{235}U	$7.00\ 10^{-17}$	$1.50\ 10^{-15}$	$1.40\ 10^{-14}$	$1.10\ 10^{-12}$	$5.50\ 10^{-12}$
^{238}U	$7.30\ 10^{-6}$	$1.30\ 10^{-5}$	$1.40\ 10^{-5}$	$3.80\ 10^{-5}$	$9.60\ 10^{-5}$
^{239}Pu	$3.70\ 10^{-3}$	$6.10\ 10^{-3}$	$6.50\ 10^{-3}$	$7.10\ 10^{-3}$	$7.10\ 10^{-3}$
^{241}Pu	$1.60\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$
^{241}Am	$4.30\ 10^{-6}$	$3.20\ 10^{-5}$	$6.90\ 10^{-5}$	$6.90\ 10^{-5}$	$6.90\ 10^{-5}$
Total	**$2.28\ 10^{0}$**	**$5.32\ 10^{0}$**	**$8.96\ 10^{0}$**	**$3.99\ 10^{1}$**	**$8.39\ 10^{1}$**

TABLE D29 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (first-pass only)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$2.80\ 10^{-3}$	$6.50\ 10^{-3}$	$6.50\ 10^{-3}$	$6.50\ 10^{-3}$	$6.50\ 10^{-3}$
^{14}C	$1.40\ 10^{0}$	$3.40\ 10^{0}$	$4.40\ 10^{0}$	$1.50\ 10^{1}$	$1.80\ 10^{1}$
^{60}Co	$2.00\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$
^{65}Zn	$7.80\ 10^{-5}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$
^{89}Sr	$4.70\ 10^{-15}$	$5.50\ 10^{-15}$	$5.50\ 10^{-15}$	$5.50\ 10^{-15}$	$5.50\ 10^{-15}$
^{90}Sr	$7.10\ 10^{-4}$	$1.80\ 10^{-3}$	$1.90\ 10^{-3}$	$1.90\ 10^{-3}$	$1.90\ 10^{-3}$
^{99}Tc	$9.20\ 10^{-4}$	$1.60\ 10^{-3}$	$1.80\ 10^{-3}$	$3.80\ 10^{-3}$	$4.50\ 10^{-3}$
^{103}Ru	$9.40\ 10^{-11}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$
^{106}Ru	$7.80\ 10^{-1}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$
^{125}Sb	$2.00\ 10^{-3}$	$4.30\ 10^{-3}$	$4.30\ 10^{-3}$	$4.30\ 10^{-3}$	$4.30\ 10^{-3}$
^{129}I	$2.10\ 10^{-2}$	$5.40\ 10^{-2}$	$7.10\ 10^{-2}$	$3.20\ 10^{-1}$	$5.80\ 10^{-1}$
^{134}Cs	$3.20\ 10^{-3}$	$6.70\ 10^{-3}$	$6.70\ 10^{-3}$	$6.70\ 10^{-3}$	$6.70\ 10^{-3}$
^{137}Cs	$2.60\ 10^{-2}$	$6.90\ 10^{-2}$	$7.00\ 10^{-2}$	$7.00\ 10^{-2}$	$7.00\ 10^{-2}$
^{144}Ce	$1.30\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$
^{234}U	$2.50\ 10^{-5}$	$4.30\ 10^{-5}$	$4.80\ 10^{-5}$	$1.30\ 10^{-4}$	$3.30\ 10^{-4}$
^{235}U	$7.00\ 10^{-17}$	$1.50\ 10^{-15}$	$1.40\ 10^{-14}$	$1.10\ 10^{-12}$	$5.50\ 10^{-12}$
^{238}U	$7.30\ 10^{-6}$	$1.30\ 10^{-5}$	$1.40\ 10^{-5}$	$3.80\ 10^{-5}$	$9.60\ 10^{-5}$
^{239}Pu	$3.70\ 10^{-3}$	$6.10\ 10^{-3}$	$6.50\ 10^{-3}$	$7.10\ 10^{-3}$	$7.10\ 10^{-3}$
^{241}Pu	$1.60\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$
^{241}Am	$4.30\ 10^{-6}$	$3.20\ 10^{-5}$	$6.90\ 10^{-5}$	$6.90\ 10^{-5}$	$6.90\ 10^{-5}$
Total	$\mathbf{2.28\ 10^{0}}$	$\mathbf{4.71\ 10^{0}}$	$\mathbf{5.73\ 10^{0}}$	$\mathbf{1.66\ 10^{1}}$	$\mathbf{1.98\ 10^{1}}$

TABLE D30 Collective doses (man Sv) to the European Union population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (global circulation only)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$4.90\ 10^{-4}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$	$1.70\ 10^{-2}$
^{14}C	$6.90\ 10^{-4}$	$5.90\ 10^{-1}$	$3.20\ 10^{0}$	$2.30\ 10^{1}$	$3.10\ 10^{1}$
^{129}I	$3.10\ 10^{-4}$	$6.40\ 10^{-3}$	$1.50\ 10^{-2}$	$3.10\ 10^{-1}$	$3.30\ 10^{1}$
Total	$\mathbf{1.49\ 10^{-3}}$	$\mathbf{6.13\ 10^{-1}}$	$\mathbf{3.23\ 10^{0}}$	$\mathbf{2.33\ 10^{1}}$	$\mathbf{6.40\ 10^{1}}$

World

TABLE D31 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (first-pass and global circulation)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	$1.69\ 10^{-2}$	$4.87\ 10^{-1}$	$4.97\ 10^{-1}$	$4.97\ 10^{-1}$	$4.97\ 10^{-1}$
^{14}C	$1.41\ 10^{0}$	$1.99\ 10^{1}$	$9.87\ 10^{1}$	$6.54\ 10^{2}$	$8.70\ 10^{2}$
^{60}Co	$2.00\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$
^{65}Zn	$7.90\ 10^{-5}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$	$1.10\ 10^{-4}$
^{89}Sr	$4.70\ 10^{-15}$	$5.60\ 10^{-15}$	$5.60\ 10^{-15}$	$5.60\ 10^{-15}$	$5.60\ 10^{-15}$
^{90}Sr	$7.20\ 10^{-4}$	$2.10\ 10^{-3}$	$2.10\ 10^{-3}$	$2.10\ 10^{-3}$	$2.10\ 10^{-3}$
^{99}Tc	$9.20\ 10^{-4}$	$1.70\ 10^{-3}$	$1.90\ 10^{-3}$	$4.60\ 10^{-3}$	$5.60\ 10^{-3}$
^{103}Ru	$9.50\ 10^{-11}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$	$1.00\ 10^{-10}$
^{106}Ru	$7.80\ 10^{-1}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$	$1.10\ 10^{0}$
^{125}Sb	$2.10\ 10^{-3}$	$4.60\ 10^{-3}$	$4.60\ 10^{-3}$	$4.60\ 10^{-3}$	$4.60\ 10^{-3}$
^{129}I	$2.80\ 10^{-2}$	$1.92\ 10^{-1}$	$3.82\ 10^{-1}$	$6.64\ 10^{0}$	$6.51\ 10^{2}$
^{134}Cs	$3.30\ 10^{-3}$	$7.10\ 10^{-3}$	$7.10\ 10^{-3}$	$7.10\ 10^{-3}$	$7.10\ 10^{-3}$
^{137}Cs	$2.70\ 10^{-2}$	$7.80\ 10^{-2}$	$8.00\ 10^{-2}$	$8.00\ 10^{-2}$	$8.00\ 10^{-2}$
^{144}Ce	$1.30\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$
^{234}U	$2.50\ 10^{-5}$	$4.50\ 10^{-5}$	$5.10\ 10^{-5}$	$1.60\ 10^{-4}$	$4.40\ 10^{-4}$
^{235}U	$7.10\ 10^{-17}$	$1.70\ 10^{-15}$	$1.90\ 10^{-14}$	$1.60\ 10^{-12}$	$7.60\ 10^{-12}$
^{238}U	$7.30\ 10^{-6}$	$1.30\ 10^{-5}$	$1.50\ 10^{-5}$	$4.80\ 10^{-5}$	$1.30\ 10^{-4}$
^{239}Pu	$3.70\ 10^{-3}$	$6.10\ 10^{-3}$	$6.70\ 10^{-3}$	$7.30\ 10^{-3}$	$7.30\ 10^{-3}$
^{241}Pu	$1.70\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$	$2.60\ 10^{-2}$
^{241}Am	$4.30\ 10^{-6}$	$3.30\ 10^{-5}$	$7.20\ 10^{-5}$	$7.20\ 10^{-5}$	$7.20\ 10^{-5}$
Total	**$2.31\ 10^{0}$**	**$2.18\ 10^{1}$**	**$1.01\ 10^{2}$**	**$6.62\ 10^{2}$**	**$1.52\ 10^{3}$**

TABLE D32 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (first-pass only)

Radionuclide	Truncation time (y)				
	1	50	500	10000	100000
^{3}H	2.90 10^{-3}	7.10 10^{-3}	7.10 10^{-3}	7.10 10^{-3}	7.10 10^{-3}
^{14}C	1.40 10^{0}	3.90 10^{0}	5.70 10^{0}	2.40 10^{1}	3.00 10^{1}
^{60}Co	2.00 10^{-2}	3.30 10^{-2}	3.30 10^{-2}	3.30 10^{-2}	3.30 10^{-2}
^{65}Zn	7.90 10^{-5}	1.10 10^{-4}	1.10 10^{-4}	1.10 10^{-4}	1.10 10^{-4}
^{89}Sr	4.70 10^{-15}	5.60 10^{-15}	5.60 10^{-15}	5.60 10^{-15}	5.60 10^{-15}
^{90}Sr	7.20 10^{-4}	2.10 10^{-3}	2.10 10^{-3}	2.10 10^{-3}	2.10 10^{-3}
^{99}Tc	9.20 10^{-4}	1.70 10^{-3}	1.90 10^{-3}	4.60 10^{-3}	5.60 10^{-3}
^{103}Ru	9.50 10^{-11}	1.00 10^{-10}	1.00 10^{-10}	1.00 10^{-10}	1.00 10^{-10}
^{106}Ru	7.80 10^{-1}	1.10 10^{0}	1.10 10^{0}	1.10 10^{0}	1.10 10^{0}
^{125}Sb	2.10 10^{-3}	4.60 10^{-3}	4.60 10^{-3}	4.60 10^{-3}	4.60 10^{-3}
^{129}I	2.20 10^{-2}	6.20 10^{-2}	9.20 10^{-2}	5.40 10^{-1}	9.90 10^{-1}
^{134}Cs	3.30 10^{-3}	7.10 10^{-3}	7.10 10^{-3}	7.10 10^{-3}	7.10 10^{-3}
^{137}Cs	2.70 10^{-2}	7.80 10^{-2}	8.00 10^{-2}	8.00 10^{-2}	8.00 10^{-2}
^{144}Ce	1.30 10^{-5}	1.60 10^{-5}	1.60 10^{-5}	1.60 10^{-5}	1.60 10^{-5}
^{234}U	2.50 10^{-5}	4.50 10^{-5}	5.10 10^{-5}	1.60 10^{-4}	4.40 10^{-4}
^{235}U	7.10 10^{-17}	1.70 10^{-15}	1.90 10^{-14}	1.60 10^{-12}	7.60 10^{-12}
^{238}U	7.30 10^{-6}	1.30 10^{-5}	1.50 10^{-5}	4.80 10^{-5}	1.30 10^{-4}
^{239}Pu	3.70 10^{-3}	6.10 10^{-3}	6.70 10^{-3}	7.30 10^{-3}	7.30 10^{-3}
^{241}Pu	1.70 10^{-2}	2.60 10^{-2}	2.60 10^{-2}	2.60 10^{-2}	2.60 10^{-2}
^{241}Am	4.30 10^{-6}	3.30 10^{-5}	7.20 10^{-5}	7.20 10^{-5}	7.20 10^{-5}
Total	**2.28 10^{0}**	**5.23 10^{0}**	**7.06 10^{0}**	**2.58 10^{1}**	**3.23 10^{1}**

TABLE D33 Collective doses (man Sv) to the World population truncated at selected times due to annual average discharges to the marine environment from La Hague between 1999 and 2003 (global circulation only)

	Truncation time (y)				
Radionuclide	1	50	500	10000	100000
^{3}H	1.40 10^{-2}	4.80 10^{-1}	4.90 10^{-1}	4.90 10^{-1}	4.90 10^{-1}
^{14}C	8.30 10^{-3}	1.60 10^{1}	9.30 10^{1}	6.30 10^{2}	8.40 10^{2}
^{129}I	6.00 10^{-3}	1.30 10^{-1}	2.90 10^{-1}	6.10 10^{0}	6.50 10^{2}
Total	**2.83 10^{-2}**	**1.66 10^{1}**	**9.38 10^{1}**	**6.37 10^{2}**	**1.49 10^{3}**

D2 PER-CAPUT DOSES

D2.1 Atmosphere

Sellafield

TABLE D34 Maximum annual per-caput doses (Sv) assuming continuous discharge to atmosphere from Sellafield (discharges are at an annual rate obtained as an average value of the discharges between 1999 and 2003)

Radio-nuclide	Years of discharge								
	UK			European Union			World		
	1	50	100	1	50	100	1	50	100
^{3}H	$2.11\ 10^{-9}$	$2.12\ 10^{-9}$	$2.12\ 10^{-9}$	$4.10\ 10^{-10}$	$4.15\ 10^{-10}$	$4.15\ 10^{-10}$	$3.17\ 10^{-11}$	$3.72\ 10^{-11}$	$3.72\ 10^{-11}$
^{14}C	$2.29\ 10^{-9}$	$3.39\ 10^{-9}$	$3.77\ 10^{-9}$	$1.21\ 10^{-9}$	$2.30\ 10^{-9}$	$2.68\ 10^{-9}$	$9.23\ 10^{-11}$	$1.19\ 10^{-9}$	$1.57\ 10^{-9}$
^{35}S	$3.49\ 10^{-10}$	$3.60\ 10^{-10}$	$3.60\ 10^{-10}$	$8.30\ 10^{-11}$	$8.56\ 10^{-11}$	$8.56\ 10^{-11}$	$5.81\ 10^{-12}$	$5.99\ 10^{-12}$	$5.99\ 10^{-12}$
^{41}Ar	$1.84\ 10^{-9}$	$1.84\ 10^{-9}$	$1.84\ 10^{-9}$	$1.38\ 10^{-10}$	$1.38\ 10^{-10}$	$1.38\ 10^{-10}$	$9.67\ 10^{-12}$	$9.67\ 10^{-12}$	$9.67\ 10^{-12}$
^{60}Co	$1.81\ 10^{-13}$	$1.54\ 10^{-12}$	$1.54\ 10^{-12}$	$3.11\ 10^{-14}$	$1.95\ 10^{-13}$	$1.95\ 10^{-13}$	$2.18\ 10^{-15}$	$1.37\ 10^{-14}$	$1.37\ 10^{-14}$
^{85}Kr	$3.85\ 10^{-9}$	$6.14\ 10^{-9}$	$6.24\ 10^{-9}$	$9.64\ 10^{-10}$	$3.26\ 10^{-9}$	$3.35\ 10^{-9}$	$1.71\ 10^{-10}$	$2.46\ 10^{-9}$	$2.56\ 10^{-9}$
^{90}Sr	$4.61\ 10^{-13}$	$1.70\ 10^{-12}$	$1.84\ 10^{-12}$	$1.98\ 10^{-13}$	$7.08\ 10^{-13}$	$7.41\ 10^{-13}$	$1.38\ 10^{-14}$	$4.95\ 10^{-14}$	$5.18\ 10^{-14}$
^{106}Ru	$3.26\ 10^{-12}$	$4.57\ 10^{-12}$	$4.57\ 10^{-12}$	$4.62\ 10^{-13}$	$6.03\ 10^{-13}$	$6.03\ 10^{-13}$	$3.23\ 10^{-14}$	$4.22\ 10^{-14}$	$4.22\ 10^{-14}$
^{125}Sb	$6.94\ 10^{-13}$	$3.70\ 10^{-12}$	$3.70\ 10^{-12}$	$9.27\ 10^{-14}$	$4.54\ 10^{-13}$	$4.54\ 10^{-13}$	$6.49\ 10^{-15}$	$3.18\ 10^{-14}$	$3.18\ 10^{-14}$
^{129}I	$8.60\ 10^{-9}$	$1.38\ 10^{-8}$	$1.48\ 10^{-8}$	$3.23\ 10^{-9}$	$5.64\ 10^{-9}$	$6.00\ 10^{-9}$	$3.61\ 10^{-10}$	$5.62\ 10^{-10}$	$5.90\ 10^{-10}$
^{131}I	$2.87\ 10^{-11}$	$2.87\ 10^{-11}$	$2.87\ 10^{-11}$	$1.35\ 10^{-12}$	$1.35\ 10^{-12}$	$1.35\ 10^{-12}$	$9.46\ 10^{-14}$	$9.46\ 10^{-14}$	$9.46\ 10^{-14}$
^{137}Cs	$9.61\ 10^{-12}$	$2.86\ 10^{-11}$	$2.86\ 10^{-11}$	$3.37\ 10^{-12}$	$5.94\ 10^{-12}$	$6.10\ 10^{-12}$	$2.36\ 10^{-13}$	$4.16\ 10^{-13}$	$4.27\ 10^{-13}$
^{239}Pu	$8.47\ 10^{-11}$	$8.47\ 10^{-11}$	$8.47\ 10^{-11}$	$1.49\ 10^{-11}$	$1.49\ 10^{-11}$	$1.49\ 10^{-11}$	$1.04\ 10^{-12}$	$1.04\ 10^{-12}$	$1.04\ 10^{-12}$
^{241}Pu	$1.05\ 10^{-11}$	$1.05\ 10^{-11}$	$1.05\ 10^{-11}$	$1.81\ 10^{-12}$	$1.81\ 10^{-12}$	$1.81\ 10^{-12}$	$1.27\ 10^{-13}$	$1.27\ 10^{-13}$	$1.27\ 10^{-13}$
^{241}Am	$5.88\ 10^{-11}$	$5.88\ 10^{-11}$	$5.88\ 10^{-11}$	$1.02\ 10^{-11}$	$1.02\ 10^{-11}$	$1.02\ 10^{-11}$	$7.11\ 10^{-13}$	$7.11\ 10^{-13}$	$7.11\ 10^{-13}$
Total	**$1.92\ 10^{-8}$**	**$2.78\ 10^{-8}$**	**$2.94\ 10^{-8}$**	**$6.06\ 10^{-9}$**	**$1.19\ 10^{-8}$**	**$1.27\ 10^{-8}$**	**$6.73\ 10^{-10}$**	**$4.26\ 10^{-9}$**	**$4.78\ 10^{-9}$**

La Hague

TABLE D35 Maximum annual per-caput doses (Sv) assuming continuous discharge to atmosphere from La Hague (discharges are at an annual rate obtained as an average value of the discharges between 1999 and 2003)

	Years of discharge			
	EU		World	
Radionuclide	1	50	1	50
^{3}H	$1.41\ 10^{-10}$	$1.42\ 10^{-10}$	$1.06\ 10^{-11}$	$1.20\ 10^{-11}$
^{14}C	$1.87\ 10^{-8}$	$2.98\ 10^{-8}$	$1.39\ 10^{-9}$	$1.25\ 10^{-8}$
^{60}Co	$1.57\ 10^{-17}$	$1.03\ 10^{-16}$	$1.10\ 10^{-18}$	$7.20\ 10^{-18}$
^{85}Kr	$3.43\ 10^{-9}$	$9.39\ 10^{-9}$	$5.10\ 10^{-10}$	$6.47\ 10^{-9}$
^{106}Ru	$7.14\ 10^{-14}$	$9.29\ 10^{-14}$	$5.00\ 10^{-15}$	$6.50\ 10^{-15}$
^{125}Sb	$1.71\ 10^{-15}$	$7.71\ 10^{-15}$	$1.20\ 10^{-16}$	$5.40\ 10^{-16}$
^{131}I	$1.86\ 10^{-13}$	$1.86\ 10^{-13}$	$1.30\ 10^{-14}$	$1.30\ 10^{-14}$
^{133}I	$6.57\ 10^{-15}$	$6.71\ 10^{-15}$	$4.60\ 10^{-16}$	$4.70\ 10^{-16}$
^{134}Cs	$1.16\ 10^{-14}$	$1.43\ 10^{-14}$	$8.10\ 10^{-16}$	$1.00\ 10^{-15}$
^{137}Cs	$2.29\ 10^{-14}$	$4.14\ 10^{-14}$	$1.60\ 10^{-15}$	$2.90\ 10^{-15}$
^{239}Pu	$1.26\ 10^{-15}$	$1.26\ 10^{-15}$	$8.80\ 10^{-17}$	$8.80\ 10^{-17}$
^{241}Pu	$5.00\ 10^{-15}$	$5.00\ 10^{-15}$	$3.50\ 10^{-16}$	$3.50\ 10^{-16}$
^{241}Am	$4.00\ 10^{-15}$	$4.00\ 10^{-15}$	$2.80\ 10^{-16}$	$2.80\ 10^{-16}$
Total	$\mathbf{2.22\ 10^{-8}}$	$\mathbf{3.93\ 10^{-8}}$	$\mathbf{1.91\ 10^{-9}}$	$\mathbf{1.90\ 10^{-8}}$

D2.2 Marine

Sellafield

TABLE D36 Maximum annual per-caput doses (Sv) assuming continuous discharge to the marine environment from Sellafield (discharges are at an annual rate obtained as an average value of the discharges between 1999 and 2003)

Radio-nuclide	Years of discharge								
	UK			European Union			World		
	1	50	100	1	50	100	1	50	100
^{3}H	$2.58\ 10^{-12}$	$2.36\ 10^{-11}$	$2.36\ 10^{-11}$	$1.05\ 10^{-12}$	$1.52\ 10^{-11}$	$1.52\ 10^{-11}$	$2.38\ 10^{-13}$	$1.02\ 10^{-11}$	$1.02\ 10^{-11}$
^{14}C	$4.68\ 10^{-9}$	$3.13\ 10^{-8}$	$3.35\ 10^{-8}$	$1.67\ 10^{-9}$	$1.37\ 10^{-8}$	$1.55\ 10^{-8}$	$7.50\ 10^{-11}$	$2.68\ 10^{-9}$	$4.31\ 10^{-9}$
^{35}S	$1.21\ 10^{-14}$	$1.67\ 10^{-14}$	$1.67\ 10^{-14}$	$4.23\ 10^{-15}$	$5.91\ 10^{-15}$	$5.91\ 10^{-15}$	$1.77\ 10^{-16}$	$2.53\ 10^{-16}$	$2.53\ 10^{-16}$
^{54}Mn	$9.65\ 10^{-13}$	$1.31\ 10^{-12}$	$1.31\ 10^{-12}$	$2.75\ 10^{-13}$	$3.43\ 10^{-13}$	$3.43\ 10^{-13}$	$1.05\ 10^{-14}$	$1.31\ 10^{-14}$	$1.31\ 10^{-14}$
^{55}Fe	$1.01\ 10^{-12}$	$1.32\ 10^{-12}$	$1.32\ 10^{-12}$	$3.48\ 10^{-13}$	$4.71\ 10^{-13}$	$4.71\ 10^{-13}$	$1.37\ 10^{-14}$	$1.85\ 10^{-14}$	$1.85\ 10^{-14}$
^{60}Co	$4.60\ 10^{-11}$	$2.20\ 10^{-10}$	$2.20\ 10^{-10}$	$1.15\ 10^{-11}$	$4.04\ 10^{-11}$	$4.04\ 10^{-11}$	$4.61\ 10^{-13}$	$1.52\ 10^{-12}$	$1.52\ 10^{-12}$
^{63}Ni	$3.98\ 10^{-13}$	$1.13\ 10^{-12}$	$1.47\ 10^{-12}$	$1.29\ 10^{-13}$	$3.98\ 10^{-13}$	$5.26\ 10^{-13}$	$5.38\ 10^{-15}$	$1.82\ 10^{-14}$	$2.47\ 10^{-14}$
^{65}Zn	$4.98\ 10^{-11}$	$6.35\ 10^{-11}$	$6.35\ 10^{-11}$	$1.85\ 10^{-11}$	$2.41\ 10^{-11}$	$2.41\ 10^{-11}$	$7.63\ 10^{-13}$	$1.00\ 10^{-12}$	$1.00\ 10^{-12}$
^{89}Sr	$3.93\ 10^{-14}$	$4.78\ 10^{-14}$	$4.78\ 10^{-14}$	$1.31\ 10^{-14}$	$1.63\ 10^{-14}$	$1.63\ 10^{-14}$	$5.85\ 10^{-16}$	$7.31\ 10^{-16}$	$7.31\ 10^{-16}$
^{90}Sr	$4.22\ 10^{-11}$	$2.82\ 10^{-10}$	$2.84\ 10^{-10}$	$1.49\ 10^{-11}$	$1.12\ 10^{-10}$	$1.12\ 10^{-10}$	$6.86\ 10^{-13}$	$6.48\ 10^{-12}$	$6.53\ 10^{-12}$
^{95}Zr	$4.65\ 10^{-13}$	$5.87\ 10^{-13}$	$5.87\ 10^{-13}$	$8.47\ 10^{-14}$	$1.04\ 10^{-13}$	$1.04\ 10^{-13}$	$3.11\ 10^{-15}$	$3.81\ 10^{-15}$	$3.81\ 10^{-15}$
^{95}Nb	$4.16\ 10^{-13}$	$5.49\ 10^{-13}$	$5.49\ 10^{-13}$	$6.74\ 10^{-14}$	$8.77\ 10^{-14}$	$8.77\ 10^{-14}$	$2.44\ 10^{-15}$	$3.17\ 10^{-15}$	$3.17\ 10^{-15}$
^{99}Tc	$9.89\ 10^{-10}$	$2.93\ 10^{-9}$	$2.93\ 10^{-9}$	$3.82\ 10^{-10}$	$1.33\ 10^{-9}$	$1.33\ 10^{-9}$	$1.55\ 10^{-11}$	$5.79\ 10^{-11}$	$5.83\ 10^{-11}$
^{103}Ru	$1.30\ 10^{-12}$	$1.49\ 10^{-12}$	$1.49\ 10^{-12}$	$4.60\ 10^{-13}$	$5.32\ 10^{-13}$	$5.32\ 10^{-13}$	$1.79\ 10^{-14}$	$2.07\ 10^{-14}$	$2.07\ 10^{-14}$
^{106}Ru	$1.18\ 10^{-9}$	$2.05\ 10^{-9}$	$2.05\ 10^{-9}$	$4.37\ 10^{-10}$	$8.05\ 10^{-10}$	$8.05\ 10^{-10}$	$1.71\ 10^{-11}$	$3.14\ 10^{-11}$	$3.14\ 10^{-11}$
^{110m}Ag	$4.38\ 10^{-11}$	$7.20\ 10^{-11}$	$7.20\ 10^{-11}$	$1.64\ 10^{-11}$	$2.78\ 10^{-11}$	$2.78\ 10^{-11}$	$6.59\ 10^{-13}$	$1.14\ 10^{-12}$	$1.14\ 10^{-12}$
^{125}Sb	$9.93\ 10^{-11}$	$5.65\ 10^{-10}$	$5.65\ 10^{-10}$	$3.20\ 10^{-11}$	$2.02\ 10^{-10}$	$2.02\ 10^{-10}$	$1.57\ 10^{-12}$	$1.13\ 10^{-11}$	$1.13\ 10^{-11}$
^{129}I	$2.93\ 10^{-11}$	$1.95\ 10^{-10}$	$1.98\ 10^{-10}$	$1.07\ 10^{-11}$	$8.30\ 10^{-11}$	$8.50\ 10^{-11}$	$7.12\ 10^{-13}$	$9.58\ 10^{-12}$	$1.02\ 10^{-11}$
^{134}Cs	$1.93\ 10^{-11}$	$8.98\ 10^{-11}$	$8.98\ 10^{-11}$	$6.55\ 10^{-12}$	$3.29\ 10^{-11}$	$3.29\ 10^{-11}$	$3.07\ 10^{-13}$	$1.79\ 10^{-12}$	$1.79\ 10^{-12}$
^{137}Cs	$2.96\ 10^{-10}$	$2.38\ 10^{-9}$	$2.38\ 10^{-9}$	$1.00\ 10^{-10}$	$9.22\ 10^{-10}$	$9.25\ 10^{-10}$	$4.74\ 10^{-12}$	$5.51\ 10^{-11}$	$5.54\ 10^{-11}$
^{144}Ce	$1.22\ 10^{-12}$	$1.80\ 10^{-12}$	$1.80\ 10^{-12}$	$3.01\ 10^{-13}$	$3.98\ 10^{-13}$	$3.98\ 10^{-13}$	$1.15\ 10^{-14}$	$1.52\ 10^{-14}$	$1.52\ 10^{-14}$
^{147}Pm	$7.13\ 10^{-14}$	$8.24\ 10^{-14}$	$8.24\ 10^{-14}$	$1.96\ 10^{-14}$	$2.35\ 10^{-14}$	$2.35\ 10^{-14}$	$7.64\ 10^{-16}$	$9.17\ 10^{-16}$	$9.17\ 10^{-16}$
^{152}Eu	$1.65\ 10^{-12}$	$1.79\ 10^{-11}$	$1.84\ 10^{-11}$	$3.15\ 10^{-13}$	$2.87\ 10^{-12}$	$2.92\ 10^{-12}$	$1.17\ 10^{-14}$	$1.04\ 10^{-13}$	$1.06\ 10^{-13}$
^{154}Eu	$1.39\ 10^{-12}$	$1.16\ 10^{-11}$	$1.16\ 10^{-11}$	$2.77\ 10^{-13}$	$1.89\ 10^{-12}$	$1.89\ 10^{-12}$	$1.03\ 10^{-14}$	$6.83\ 10^{-14}$	$6.86\ 10^{-14}$
^{155}Eu	$9.69\ 10^{-14}$	$3.95\ 10^{-13}$	$3.95\ 10^{-13}$	$2.32\ 10^{-14}$	$7.24\ 10^{-14}$	$7.24\ 10^{-14}$	$8.85\ 10^{-16}$	$2.67\ 10^{-15}$	$2.67\ 10^{-15}$
^{234}U	$1.59\ 10^{-13}$	$4.61\ 10^{-13}$	$4.61\ 10^{-13}$	$6.00\ 10^{-14}$	$2.04\ 10^{-13}$	$2.06\ 10^{-13}$	$2.39\ 10^{-15}$	$8.76\ 10^{-15}$	$8.89\ 10^{-15}$
^{238}U	$1.47\ 10^{-13}$	$4.26\ 10^{-13}$	$4.30\ 10^{-13}$	$5.51\ 10^{-14}$	$1.88\ 10^{-13}$	$1.90\ 10^{-13}$	$2.19\ 10^{-15}$	$8.06\ 10^{-15}$	$8.19\ 10^{-15}$
^{237}Np	$3.60\ 10^{-11}$	$1.01\ 10^{-10}$	$1.02\ 10^{-10}$	$1.35\ 10^{-11}$	$4.48\ 10^{-11}$	$4.54\ 10^{-11}$	$5.35\ 10^{-13}$	$1.89\ 10^{-12}$	$1.92\ 10^{-12}$
^{239}Pu	$3.24\ 10^{-10}$	$7.65\ 10^{-10}$	$9.65\ 10^{-10}$	$1.06\ 10^{-10}$	$2.77\ 10^{-10}$	$3.59\ 10^{-10}$	$4.13\ 10^{-12}$	$1.10\ 10^{-11}$	$1.45\ 10^{-11}$
^{241}Pu	$1.75\ 10^{-10}$	$2.95\ 10^{-10}$	$2.98\ 10^{-10}$	$5.71\ 10^{-11}$	$1.03\ 10^{-10}$	$1.04\ 10^{-10}$	$2.23\ 10^{-12}$	$4.05\ 10^{-12}$	$4.12\ 10^{-12}$
^{241}Am	$1.65\ 10^{-11}$	$9.22\ 10^{-11}$	$1.61\ 10^{-10}$	$4.57\ 10^{-12}$	$3.34\ 10^{-11}$	$6.04\ 10^{-11}$	$1.74\ 10^{-13}$	$1.30\ 10^{-12}$	$2.36\ 10^{-12}$
^{242}Cm	$2.78\ 10^{-13}$	$2.89\ 10^{-13}$	$2.89\ 10^{-13}$	$7.58\ 10^{-14}$	$7.94\ 10^{-14}$	$7.94\ 10^{-14}$	$2.89\ 10^{-15}$	$3.03\ 10^{-15}$	$3.03\ 10^{-15}$
^{243}Cm	$1.49\ 10^{-12}$	$2.58\ 10^{-12}$	$2.75\ 10^{-12}$	$4.12\ 10^{-13}$	$7.97\ 10^{-13}$	$8.58\ 10^{-13}$	$1.57\ 10^{-14}$	$3.06\ 10^{-14}$	$3.31\ 10^{-14}$
Total	**$8.03\ 10^{-9}$**	**$4.14\ 10^{-8}$**	**$4.39\ 10^{-8}$**	**$2.88\ 10^{-9}$**	**$1.78\ 10^{-8}$**	**$1.97\ 10^{-8}$**	**$1.25\ 10^{-10}$**	**$2.88\ 10^{-9}$**	**$4.52\ 10^{-9}$**

TABLE D37 Maximum annual per-caput doses (Sv) assuming continuous discharge to the marine environment from La Hague (discharges are at an annual rate obtained as an average value of the discharges between 1999 and 2003)

	Years of discharge					
	France		European Union		World	
Radionuclide	1	50	1	50	1	50
^{3}H	$2.59\ 10^{-11}$	$8.57\ 10^{-11}$	$9.16\ 10^{-12}$	$6.55\ 10^{-11}$	$1.69\ 10^{-12}$	$4.87\ 10^{-11}$
^{14}C	$1.15\ 10^{-8}$	$2.09\ 10^{-8}$	$3.90\ 10^{-9}$	$1.11\ 10^{-8}$	$1.41\ 10^{-10}$	$1.99\ 10^{-9}$
^{60}Co	$2.27\ 10^{-10}$	$3.15\ 10^{-10}$	$5.57\ 10^{-11}$	$9.19\ 10^{-11}$	$2.00\ 10^{-12}$	$3.30\ 10^{-12}$
^{65}Zn	$9.27\ 10^{-13}$	$1.15\ 10^{-12}$	$2.17\ 10^{-13}$	$3.06\ 10^{-13}$	$7.90\ 10^{-15}$	$1.10\ 10^{-14}$
^{89}Sr	$4.72\ 10^{-23}$	$5.24\ 10^{-23}$	$1.31\ 10^{-23}$	$1.53\ 10^{-23}$	$4.70\ 10^{-25}$	$5.60\ 10^{-25}$
^{90}Sr	$5.59\ 10^{-12}$	$9.79\ 10^{-12}$	$1.98\ 10^{-12}$	$5.01\ 10^{-12}$	$7.20\ 10^{-14}$	$2.10\ 10^{-13}$
^{99}Tc	$1.05\ 10^{-11}$	$1.49\ 10^{-11}$	$2.56\ 10^{-12}$	$4.46\ 10^{-12}$	$9.20\ 10^{-14}$	$1.70\ 10^{-13}$
^{103}Ru	$1.43\ 10^{-18}$	$1.52\ 10^{-18}$	$2.62\ 10^{-19}$	$2.79\ 10^{-19}$	$9.50\ 10^{-21}$	$1.00\ 10^{-20}$
^{106}Ru	$1.01\ 10^{-8}$	$1.26\ 10^{-8}$	$2.17\ 10^{-9}$	$3.06\ 10^{-9}$	$7.80\ 10^{-11}$	$1.10\ 10^{-10}$
^{125}Sb	$1.64\ 10^{-11}$	$2.62\ 10^{-11}$	$5.57\ 10^{-12}$	$1.20\ 10^{-11}$	$2.10\ 10^{-13}$	$4.60\ 10^{-13}$
^{129}I	$1.76\ 10^{-10}$	$3.32\ 10^{-10}$	$5.94\ 10^{-11}$	$1.68\ 10^{-10}$	$2.80\ 10^{-12}$	$1.92\ 10^{-11}$
^{134}Cs	$2.45\ 10^{-11}$	$4.02\ 10^{-11}$	$8.91\ 10^{-12}$	$1.87\ 10^{-11}$	$3.30\ 10^{-13}$	$7.10\ 10^{-13}$
^{137}Cs	$1.92\ 10^{-10}$	$3.50\ 10^{-10}$	$7.24\ 10^{-11}$	$1.92\ 10^{-10}$	$2.70\ 10^{-12}$	$7.80\ 10^{-12}$
^{144}Ce	$1.92\ 10^{-13}$	$2.27\ 10^{-13}$	$3.62\ 10^{-14}$	$4.46\ 10^{-14}$	$1.30\ 10^{-15}$	$1.60\ 10^{-15}$
^{234}U	$2.97\ 10^{-13}$	$4.20\ 10^{-13}$	$6.96\ 10^{-14}$	$1.20\ 10^{-13}$	$2.50\ 10^{-15}$	$4.50\ 10^{-15}$
^{235}U	$5.94\ 10^{-25}$	$9.62\ 10^{-24}$	$1.95\ 10^{-25}$	$4.18\ 10^{-24}$	$7.10\ 10^{-27}$	$1.70\ 10^{-25}$
^{238}U	$8.74\ 10^{-14}$	$1.21\ 10^{-13}$	$2.03\ 10^{-14}$	$3.62\ 10^{-14}$	$7.30\ 10^{-16}$	$1.30\ 10^{-15}$
^{239}Pu	$4.72\ 10^{-11}$	$6.64\ 10^{-11}$	$1.03\ 10^{-11}$	$1.70\ 10^{-11}$	$3.70\ 10^{-13}$	$6.10\ 10^{-13}$
^{241}Pu	$2.10\ 10^{-10}$	$2.97\ 10^{-10}$	$4.46\ 10^{-11}$	$7.24\ 10^{-11}$	$1.70\ 10^{-12}$	$2.60\ 10^{-12}$
^{241}Am	$5.42\ 10^{-14}$	$3.50\ 10^{-13}$	$1.20\ 10^{-14}$	$8.91\ 10^{-14}$	$4.30\ 10^{-16}$	$3.30\ 10^{-15}$
Total	**$2.26\ 10^{-8}$**	**$3.50\ 10^{-8}$**	**$6.35\ 10^{-9}$**	**$1.48\ 10^{-8}$**	**$2.31\ 10^{-10}$**	**$2.18\ 10^{-9}$**

D3 INDICATIVE PER-CAPUT ANNUAL DOSE RATES

D3.1 Atmosphere

Sellafield

TABLE D38 Indicative per-caput dose rates (Sv y^{-1}) at different time periods following one year's discharge to atmosphere from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

	Output time intervals (y)								
Radio-nuclide	1-50	50-100	100-500	500-1000	1000-5000	5000-10000	10000-50000	50000-100000	100000-1 10^{8}
a) UK									
^{3}H	1.12 10^{-13}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{14}C	2.23 10^{-11}	7.62 10^{-12}	3.56 10^{-12}	2.16 10^{-12}	1.48 10^{-12}	8.56 10^{-13}	1.29 10^{-13}	0.00 10^{0}	0.00 10^{0}
^{35}S	2.22 10^{-13}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{41}Ar	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{60}Co	2.78 10^{-14}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{85}Kr	4.67 10^{-11}	2.13 10^{-12}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{90}Sr	2.52 10^{-14}	2.93 10^{-15}	1.05 10^{-16}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{106}Ru	2.66 10^{-14}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{125}Sb	6.13 10^{-14}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{129}I	1.06 10^{-10}	2.12 10^{-11}	4.98 10^{-12}	6.04 10^{-14}	4.34 10^{-14}	1.84 10^{-14}	2.49 10^{-15}	9.06 10^{-16}	9.19 10^{-18}
^{131}I	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{137}Cs	3.88 10^{-13}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{239}Pu	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	9.97 10^{-16}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{241}Pu	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{241}Am	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
Total	**1.75 10^{-10}**	**3.10 10^{-11}**	**8.55 10^{-12}**	**2.22 10^{-12}**	**1.52 10^{-12}**	**8.76 10^{-13}**	**1.31 10^{-13}**	**9.06 10^{-16}**	**9.19 10^{-18}**
b) European Union									
^{3}H	1.12 10^{-13}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{14}C	2.23 10^{-11}	7.64 10^{-12}	3.56 10^{-12}	2.17 10^{-12}	1.48 10^{-12}	8.55 10^{-13}	1.29 10^{-13}	0.00 10^{0}	0.00 10^{0}
^{35}S	5.24 10^{-14}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{41}Ar	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{60}Co	3.35 10^{-15}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{85}Kr	4.68 10^{-11}	1.96 10^{-12}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{90}Sr	1.04 10^{-14}	6.58 10^{-16}	4.11 10^{-17}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{106}Ru	2.88 10^{-15}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{125}Sb	7.38 10^{-15}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{129}I	4.91 10^{-11}	7.19 10^{-12}	9.61 10^{-13}	6.17 10^{-14}	4.30 10^{-14}	1.88 10^{-14}	2.46 10^{-15}	9.26 10^{-16}	9.15 10^{-18}
^{131}I	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{137}Cs	5.25 10^{-14}	3.21 10^{-15}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{239}Pu	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{241}Pu	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
^{241}Am	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}	0.00 10^{0}
Total	**1.18 10^{-10}**	**1.68 10^{-11}**	**4.52 10^{-12}**	**2.23 10^{-12}**	**1.53 10^{-12}**	**8.74 10^{-13}**	**1.31 10^{-13}**	**9.26 10^{-16}**	**9.15 10^{-18}**

Radio-nuclide	Output time intervals (y) 1-50	50-100	100-500	500-1000	1000-5000	5000-10000	10000-50000	50000-100000	100000-1 10^8
c) World									
^{3}H	$1.12\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$2.23\ 10^{-11}$	$7.62\ 10^{-12}$	$3.58\ 10^{-12}$	$2.19\ 10^{-12}$	$1.48\ 10^{-12}$	$8.54\ 10^{-13}$	$1.29\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{35}S	$3.67\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{41}Ar	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{60}Co	$2.34\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{85}Kr	$4.66\ 10^{-11}$	$2.15\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{90}Sr	$7.29\ 10^{-16}$	$4.61\ 10^{-17}$	$2.88\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$2.02\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$5.16\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{129}I	$4.10\ 10^{-12}$	$5.65\ 10^{-13}$	$1.33\ 10^{-13}$	$6.15\ 10^{-14}$	$4.32\ 10^{-14}$	$1.86\ 10^{-14}$	$2.49\ 10^{-15}$	$8.97\ 10^{-16}$	$9.19\ 10^{-18}$
^{131}I	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$3.67\ 10^{-15}$	$2.25\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{239}Pu	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Pu	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	**$7.32\ 10^{-11}$**	**$1.03\ 10^{-11}$**	**$3.71\ 10^{-12}$**	**$2.26\ 10^{-12}$**	**$1.52\ 10^{-12}$**	**$8.73\ 10^{-13}$**	**$1.32\ 10^{-13}$**	**$8.97\ 10^{-16}$**	**$9.19\ 10^{-18}$**

La Hague

TABLE D39 Indicative per-caput dose rates (Sv y^{-1}) at different time periods following one year's discharge to atmosphere from La Hague (discharge is the average annual discharge between 1999 and 2003)

Radionuclide	Output time intervals (y) 1-50	50-500	500-10000	10000-100000
a) European Union				
^{3}H	$2.85\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$2.27\ 10^{-10}$	$4.08\ 10^{-11}$	$1.21\ 10^{-11}$	$5.87\ 10^{-13}$
^{60}Co	$1.78\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{85}Kr	$1.21\ 10^{-10}$	$5.71\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$4.37\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$1.22\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{131}I	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{133}I	$2.92\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{134}Cs	$5.54\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$3.79\ 10^{-16}$	$3.17\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{239}Pu	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Pu	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	**$3.48\ 10^{-10}$**	**$4.14\ 10^{-11}$**	**$1.21\ 10^{-11}$**	**$5.87\ 10^{-13}$**

	Output time intervals (y)			
Radionuclide	1-50	50-500	500-10000	10000-100000
b) World				
^{3}H	$2.84\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$2.27\ 10^{-10}$	$4.09\ 10^{-11}$	$1.20\ 10^{-11}$	$5.89\ 10^{-13}$
^{60}Co	$1.24\ 10^{-19}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{85}Kr	$1.22\ 10^{-10}$	$5.56\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$3.06\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$8.57\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{131}I	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{133}I	$2.04\ 10^{-19}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{134}Cs	$3.88\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$2.65\ 10^{-17}$	$2.22\ 10^{-19}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{239}Pu	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Pu	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	$\mathbf{3.48\ 10^{-10}}$	$\mathbf{4.14\ 10^{-11}}$	$\mathbf{1.20\ 10^{-11}}$	$\mathbf{5.89\ 10^{-13}}$

D3.2 Marine

Sellafield

TABLE D40 Indicative per-caput dose rates (Sv y^{-1}) at different time periods following one year's discharge to the marine environment from the Sellafield site (discharge is the average annual discharge between 1999 and 2003)

Radionuclide	Output time intervals (y)							
	1-50	50-100	100-500	500-1000	1000-5000	5000-10000	10000-50000	50000-100000
a) UK								
^{3}H	$4.28\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$5.43\ 10^{-10}$	$4.36\ 10^{-11}$	$2.00\ 10^{-11}$	$1.27\ 10^{-11}$	$9.05\ 10^{-12}$	$4.84\ 10^{-12}$	$7.36\ 10^{-13}$	$0.00\ 10^{0}$
^{35}S	$9.31\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{54}Mn	$7.09\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{55}Fe	$6.35\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{60}Co	$3.55\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{63}Ni	$1.50\ 10^{-14}$	$6.76\ 10^{-15}$	$7.91\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{65}Zn	$2.78\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{89}Sr	$1.74\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{90}Sr	$4.89\ 10^{-12}$	$3.64\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{95}Zr	$2.49\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{95}Nb	$2.71\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{99}Tc	$3.96\ 10^{-11}$	$0.00\ 10^{0}$	$9.09\ 10^{-14}$	$0.00\ 10^{0}$	$9.09\ 10^{-15}$	$7.27\ 10^{-15}$	$6.36\ 10^{-15}$	$5.09\ 10^{-15}$
^{103}Ru	$3.82\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$1.79\ 10^{-11}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{110m}Ag	$5.75\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$9.51\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{129}I	$3.38\ 10^{-12}$	$5.82\ 10^{-14}$	$3.18\ 10^{-14}$	$2.65\ 10^{-14}$	$3.27\ 10^{-14}$	$4.29\ 10^{-14}$	$4.21\ 10^{-14}$	$3.76\ 10^{-14}$
^{134}Cs	$1.44\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$4.26\ 10^{-11}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{144}Ce	$1.19\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{147}Pm	$2.26\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{152}Eu	$3.33\ 10^{-13}$	$8.36\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{154}Eu	$2.08\ 10^{-13}$	$1.09\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{155}Eu	$6.07\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{234}U	$6.16\ 10^{-15}$	$0.00\ 10^{0}$	$1.14\ 10^{-17}$	$0.00\ 10^{0}$	$1.14\ 10^{-18}$	$1.83\ 10^{-18}$	$9.13\ 10^{-19}$	$8.22\ 10^{-19}$
^{238}U	$5.71\ 10^{-15}$	$6.39\ 10^{-17}$	$6.85\ 10^{-18}$	$1.83\ 10^{-18}$	$1.37\ 10^{-18}$	$1.19\ 10^{-18}$	$9.82\ 10^{-19}$	$9.13\ 10^{-19}$
^{237}Np	$1.33\ 10^{-12}$	$1.45\ 10^{-14}$	$1.36\ 10^{-15}$	$3.64\ 10^{-16}$	$2.27\ 10^{-16}$	$2.18\ 10^{-16}$	$1.50\ 10^{-16}$	$1.16\ 10^{-16}$
^{239}Pu	$9.02\ 10^{-12}$	$4.00\ 10^{-12}$	$7.09\ 10^{-13}$	$1.82\ 10^{-14}$	$4.55\ 10^{-16}$	$3.64\ 10^{-16}$	$9.09\ 10^{-17}$	$3.64\ 10^{-17}$
^{241}Pu	$2.45\ 10^{-12}$	$7.27\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$1.55\ 10^{-12}$	$1.38\ 10^{-12}$	$4.20\ 10^{-13}$	$2.91\ 10^{-14}$	$4.55\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{242}Cm	$2.23\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{243}Cm	$2.22\ 10^{-14}$	$3.27\ 10^{-15}$	$1.36\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	**$6.82\ 10^{-10}$**	**$4.92\ 10^{-11}$**	**$2.13\ 10^{-11}$**	**$1.28\ 10^{-11}$**	**$9.09\ 10^{-12}$**	**$4.89\ 10^{-12}$**	**$7.85\ 10^{-13}$**	**$4.28\ 10^{-14}$**

Radionuclide	Output time intervals (y) 1-50	50-100	100-500	500-1000	1000-5000	5000-10000	10000-50000	50000-100000
b) European Union								
^{3}H	$2.88\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$2.46\ 10^{-10}$	$3.57\ 10^{-11}$	$1.89\ 10^{-11}$	$1.24\ 10^{-11}$	$8.45\ 10^{-12}$	$5.06\ 10^{-12}$	$7.03\ 10^{-13}$	$0.00\ 10^{0}$
^{35}S	$3.41\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{54}Mn	$1.38\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{55}Fe	$2.50\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{60}Co	$5.89\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{63}Ni	$5.50\ 10^{-15}$	$2.56\ 10^{-15}$	$3.13\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{65}Zn	$1.15\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{89}Sr	$6.37\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{90}Sr	$1.98\ 10^{-12}$	$1.11\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{95}Zr	$3.98\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{95}Nb	$4.15\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{99}Tc	$1.93\ 10^{-11}$	$1.11\ 10^{-13}$	$3.48\ 10^{-14}$	$1.67\ 10^{-14}$	$6.27\ 10^{-15}$	$5.57\ 10^{-15}$	$5.01\ 10^{-15}$	$3.79\ 10^{-15}$
^{103}Ru	$1.48\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$7.50\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{110m}Ag	$2.33\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$3.46\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{129}I	$1.48\ 10^{-12}$	$3.90\ 10^{-14}$	$2.79\ 10^{-14}$	$2.17\ 10^{-14}$	$3.29\ 10^{-14}$	$4.21\ 10^{-14}$	$4.33\ 10^{-14}$	$3.19\ 10^{-14}$
^{134}Cs	$5.37\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$1.68\ 10^{-11}$	$5.57\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{144}Ce	$1.99\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{147}Pm	$7.90\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{152}Eu	$5.21\ 10^{-14}$	$1.11\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{154}Eu	$3.28\ 10^{-14}$	$1.11\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{155}Eu	$1.00\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{234}U	$2.93\ 10^{-15}$	$4.20\ 10^{-17}$	$5.25\ 10^{-18}$	$2.80\ 10^{-18}$	$1.05\ 10^{-18}$	$9.79\ 10^{-19}$	$7.87\ 10^{-19}$	$6.44\ 10^{-19}$
^{238}U	$2.72\ 10^{-15}$	$4.20\ 10^{-17}$	$3.50\ 10^{-18}$	$1.40\ 10^{-18}$	$1.05\ 10^{-18}$	$9.79\ 10^{-19}$	$7.87\ 10^{-19}$	$7.28\ 10^{-19}$
^{237}Np	$6.40\ 10^{-13}$	$1.11\ 10^{-14}$	$6.96\ 10^{-16}$	$5.57\ 10^{-16}$	$1.39\ 10^{-16}$	$1.67\ 10^{-16}$	$1.32\ 10^{-16}$	$9.47\ 10^{-17}$
^{239}Pu	$3.49\ 10^{-12}$	$1.65\ 10^{-12}$	$3.62\ 10^{-13}$	$1.67\ 10^{-14}$	$6.96\ 10^{-16}$	$0.00\ 10^{0}$	$6.96\ 10^{-17}$	$0.00\ 10^{0}$
^{241}Pu	$9.27\ 10^{-13}$	$3.34\ 10^{-14}$	$6.96\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$5.89\ 10^{-13}$	$5.40\ 10^{-13}$	$1.67\ 10^{-13}$	$1.34\ 10^{-14}$	$2.09\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{242}Cm	$7.39\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{243}Cm	$7.84\ 10^{-15}$	$1.23\ 10^{-15}$	$4.87\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	**$3.04\ 10^{-10}$**	**$3.81\ 10^{-11}$**	**$1.95\ 10^{-11}$**	**$1.25\ 10^{-11}$**	**$8.49\ 10^{-12}$**	**$5.11\ 10^{-12}$**	**$7.52\ 10^{-13}$**	**$3.58\ 10^{-14}$**

Radionuclide	Output time intervals (y) 1-50	50-100	100-500	500-1000	1000-5000	5000-10000	10000-50000	50000-100000
c) World								
^{3}H	$2.03\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$5.31\ 10^{-11}$	$3.26\ 10^{-11}$	$1.86\ 10^{-11}$	$1.20\ 10^{-11}$	$9.01\ 10^{-12}$	$5.20\ 10^{-12}$	$7.76\ 10^{-13}$	$0.00\ 10^{0}$
^{35}S	$1.55\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{54}Mn	$5.31\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{55}Fe	$9.80\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{60}Co	$2.16\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{63}Ni	$2.62\ 10^{-16}$	$1.30\ 10^{-16}$	$1.75\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{65}Zn	$4.84\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{89}Sr	$2.98\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{90}Sr	$1.18\ 10^{-13}$	$1.00\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{95}Zr	$1.43\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{95}Nb	$1.49\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{99}Tc	$8.65\ 10^{-13}$	$8.00\ 10^{-15}$	$2.25\ 10^{-15}$	$8.00\ 10^{-16}$	$3.50\ 10^{-16}$	$3.60\ 10^{-16}$	$2.98\ 10^{-16}$	$2.26\ 10^{-16}$
^{103}Ru	$5.71\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$2.92\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{110m}Ag	$9.82\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$1.99\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{129}I	$1.81\ 10^{-13}$	$1.16\ 10^{-14}$	$1.62\ 10^{-14}$	$1.81\ 10^{-14}$	$2.23\ 10^{-14}$	$2.81\ 10^{-14}$	$2.88\ 10^{-14}$	$2.41\ 10^{-14}$
^{134}Cs	$3.03\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$1.03\ 10^{-12}$	$6.00\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{144}Ce	$7.55\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{147}Pm	$3.12\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{152}Eu	$1.88\ 10^{-15}$	$4.00\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{154}Eu	$1.18\ 10^{-15}$	$6.00\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{155}Eu	$3.64\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{234}U	$1.30\ 10^{-16}$	$2.51\ 10^{-18}$	$3.14\ 10^{-19}$	$1.00\ 10^{-19}$	$6.28\ 10^{-20}$	$5.53\ 10^{-20}$	$4.77\ 10^{-20}$	$3.77\ 10^{-20}$
^{238}U	$1.20\ 10^{-16}$	$2.51\ 10^{-18}$	$3.14\ 10^{-19}$	$1.00\ 10^{-19}$	$5.65\ 10^{-20}$	$5.02\ 10^{-20}$	$4.77\ 10^{-20}$	$4.32\ 10^{-20}$
^{237}Np	$2.77\ 10^{-14}$	$6.00\ 10^{-16}$	$5.00\ 10^{-17}$	$2.00\ 10^{-17}$	$1.00\ 10^{-17}$	$1.00\ 10^{-17}$	$7.50\ 10^{-18}$	$5.60\ 10^{-18}$
^{239}Pu	$1.40\ 10^{-13}$	$7.00\ 10^{-14}$	$1.70\ 10^{-14}$	$8.00\ 10^{-16}$	$5.00\ 10^{-17}$	$0.00\ 10^{0}$	$5.00\ 10^{-18}$	$0.00\ 10^{0}$
^{241}Pu	$3.71\ 10^{-14}$	$1.40\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$2.30\ 10^{-14}$	$2.12\ 10^{-14}$	$6.63\ 10^{-15}$	$5.80\ 10^{-16}$	$7.50\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{242}Cm	$2.86\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{243}Cm	$3.04\ 10^{-16}$	$5.00\ 10^{-17}$	$1.75\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	**$5.62\ 10^{-11}$**	**$3.27\ 10^{-11}$**	**$1.86\ 10^{-11}$**	**$1.20\ 10^{-11}$**	**$9.03\ 10^{-12}$**	**$5.23\ 10^{-12}$**	**$8.05\ 10^{-13}$**	**$2.43\ 10^{-14}$**

La Hague

TABLE D41 Indicative per-caput dose rates (Sv y-1) at different time periods following one year's discharge to the marine environment from La Hague (discharge is the average annual discharge between 1999 and 2003)

	Output time intervals (y)			
Radionuclide	1-50	50-500	500-10000	10000-100000
a) France				
^{3}H	$1.22\ 10^{-12}$	$7.77\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$1.90\ 10^{-10}$	$2.40\ 10^{-11}$	$8.63\ 10^{-12}$	$3.69\ 10^{-13}$
^{60}Co	$1.78\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{65}Zn	$4.64\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{89}Sr	$1.07\ 10^{-25}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{90}Sr	$8.56\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{99}Tc	$8.92\ 10^{-14}$	$2.72\ 10^{-15}$	$1.44\ 10^{-15}$	$3.89\ 10^{-17}$
^{103}Ru	$1.78\ 10^{-21}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$5.00\ 10^{-11}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$2.00\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{129}I	$3.19\ 10^{-12}$	$1.32\ 10^{-13}$	$1.59\ 10^{-13}$	$1.03\ 10^{-12}$
^{134}Cs	$3.21\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$3.21\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{144}Ce	$7.14\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{234}U	$2.50\ 10^{-15}$	$7.77\ 10^{-17}$	$5.34\ 10^{-17}$	$1.46\ 10^{-17}$
^{235}U	$1.84\ 10^{-25}$	$1.73\ 10^{-25}$	$7.45\ 10^{-25}$	$3.09\ 10^{-25}$
^{238}U	$6.78\ 10^{-16}$	$1.94\ 10^{-17}$	$1.58\ 10^{-17}$	$4.08\ 10^{-18}$
^{239}Pu	$3.92\ 10^{-13}$	$7.77\ 10^{-15}$	$5.52\ 10^{-16}$	$0.00\ 10^{0}$
^{241}Pu	$1.78\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$6.03\ 10^{-15}$	$9.32\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	**$2.52\ 10^{-10}$**	**$2.41\ 10^{-11}$**	**$8.79\ 10^{-12}$**	**$1.40\ 10^{-12}$**

	Output time intervals (y)			
Radionuclide	1-50	50-500	500-10000	10000-100000
b) European Union				
^{3}H	$1.15\ 10^{-12}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$1.47\ 10^{-10}$	$2.23\ 10^{-11}$	$8.91\ 10^{-12}$	$3.40\ 10^{-13}$
^{60}Co	$7.39\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{65}Zn	$1.82\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{89}Sr	$4.55\ 10^{-26}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{90}Sr	$6.20\ 10^{-14}$	$6.19\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{99}Tc	$3.87\ 10^{-14}$	$1.24\ 10^{-15}$	$5.86\ 10^{-16}$	$2.17\ 10^{-17}$
^{103}Ru	$3.41\ 10^{-22}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$1.82\ 10^{-11}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$1.31\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{129}I	$2.22\ 10^{-12}$	$1.58\ 10^{-13}$	$1.60\ 10^{-13}$	$1.02\ 10^{-12}$
^{134}Cs	$1.99\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$2.44\ 10^{-12}$	$6.19\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{144}Ce	$1.71\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{234}U	$1.02\ 10^{-15}$	$3.10\ 10^{-17}$	$2.40\ 10^{-17}$	$6.19\ 10^{-18}$
^{235}U	$8.13\ 10^{-26}$	$7.74\ 10^{-26}$	$3.18\ 10^{-25}$	$1.36\ 10^{-25}$
^{238}U	$3.24\ 10^{-16}$	$6.19\ 10^{-18}$	$7.04\ 10^{-18}$	$1.80\ 10^{-18}$
^{239}Pu	$1.36\ 10^{-13}$	$2.48\ 10^{-15}$	$1.76\ 10^{-16}$	$0.00\ 10^{0}$
^{241}Pu	$5.68\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$1.57\ 10^{-15}$	$2.29\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	**$1.73\ 10^{-10}$**	**$2.25\ 10^{-11}$**	**$9.07\ 10^{-12}$**	**$1.36\ 10^{-12}$**

Radionuclide	Output time intervals (y) 1-50	50-500	500-10000	10000-100000
c) World				
^{3}H	$9.60\ 10^{-13}$	$2.22\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{14}C	$3.77\ 10^{-11}$	$1.75\ 10^{-11}$	$5.85\ 10^{-12}$	$2.40\ 10^{-13}$
^{60}Co	$2.65\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{65}Zn	$6.33\ 10^{-17}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{89}Sr	$1.84\ 10^{-27}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{90}Sr	$2.82\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{99}Tc	$1.59\ 10^{-15}$	$4.44\ 10^{-17}$	$2.84\ 10^{-17}$	$1.11\ 10^{-18}$
^{103}Ru	$1.02\ 10^{-23}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{106}Ru	$6.53\ 10^{-13}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{125}Sb	$5.10\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{129}I	$3.35\ 10^{-13}$	$4.22\ 10^{-14}$	$6.59\ 10^{-14}$	$7.16\ 10^{-13}$
^{134}Cs	$7.76\ 10^{-15}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{137}Cs	$1.04\ 10^{-13}$	$4.44\ 10^{-16}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{144}Ce	$6.12\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{234}U	$4.08\ 10^{-17}$	$1.33\ 10^{-18}$	$1.15\ 10^{-18}$	$3.11\ 10^{-19}$
^{235}U	$3.32\ 10^{-27}$	$3.84\ 10^{-27}$	$1.66\ 10^{-26}$	$6.67\ 10^{-27}$
^{238}U	$1.16\ 10^{-17}$	$4.44\ 10^{-19}$	$3.47\ 10^{-19}$	$9.11\ 10^{-20}$
^{239}Pu	$4.90\ 10^{-15}$	$1.33\ 10^{-16}$	$6.32\ 10^{-18}$	$0.00\ 10^{0}$
^{241}Pu	$1.84\ 10^{-14}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
^{241}Am	$5.86\ 10^{-17}$	$8.67\ 10^{-18}$	$0.00\ 10^{0}$	$0.00\ 10^{0}$
Total	**$3.99\ 10^{-11}$**	**$1.76\ 10^{-11}$**	**$5.91\ 10^{-12}$**	**$9.56\ 10^{-13}$**

D4 COLLECTIVE AND PER-CAPUT DOSES BY DISTANCE FOR ATMOSPHERIC DISCHARGES FROM SELLAFIELD

D4.1 Collective doses by distance

TABLE D42 Collective doses (man Sv) by distance band to the UK population truncated at selected times due to annual average discharges to atmosphere from Sellafield between 1999 and 2003 (first-pass only)

	Truncation time (y)				
Pathway	1	50	500	10000	100000
a) 0-5 km					
Cloud gamma	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$	$1.00\ 10^{-2}$
Cloud beta	$1.10\ 10^{-3}$	$1.10\ 10^{-3}$	$1.10\ 10^{-3}$	$1.10\ 10^{-3}$	$1.10\ 10^{-3}$
Inhalation	$3.60\ 10^{-4}$	$3.60\ 10^{-4}$	$3.60\ 10^{-4}$	$3.60\ 10^{-4}$	$3.60\ 10^{-4}$
Dep gamma	$4.70\ 10^{-6}$	$5.00\ 10^{-5}$	$5.20\ 10^{-5}$	$5.20\ 10^{-5}$	$5.20\ 10^{-5}$
Dep beta	$2.10\ 10^{-6}$	$2.10\ 10^{-6}$	$2.10\ 10^{-6}$	$2.10\ 10^{-6}$	$2.10\ 10^{-6}$
Resuspension	$3.60\ 10^{-7}$	$5.90\ 10^{-7}$	$7.10\ 10^{-7}$	$8.40\ 10^{-7}$	$9.10\ 10^{-7}$
Sub-total	**$1.15\ 10^{-2}$**	**$1.15\ 10^{-2}$**	**$1.15\ 10^{-2}$**	**$1.15\ 10^{-2}$**	**$1.15\ 10^{-2}$**
Food (weighted)	$5.50\ 10^{-5}$	$7.76\ 10^{-5}$	$8.68\ 10^{-5}$	$8.83\ 10^{-5}$	$8.83\ 10^{-5}$
Total	**$1.15\ 10^{-2}$**	**$1.16\ 10^{-2}$**	**$1.16\ 10^{-2}$**	**$1.16\ 10^{-2}$**	**$1.16\ 10^{-2}$**
b) 5-20 km					
Cloud gamma	$2.10\ 10^{-2}$	$2.10\ 10^{-2}$	$2.10\ 10^{-2}$	$2.10\ 10^{-2}$	$2.10\ 10^{-2}$
Cloud beta	$3.30\ 10^{-3}$	$3.30\ 10^{-3}$	$3.30\ 10^{-3}$	$3.30\ 10^{-3}$	$3.30\ 10^{-3}$
Inhalation	$1.10\ 10^{-3}$	$1.10\ 10^{-3}$	$1.10\ 10^{-3}$	$1.10\ 10^{-3}$	$1.10\ 10^{-3}$
Dep gamma	$1.30\ 10^{-5}$	$1.40\ 10^{-4}$	$1.50\ 10^{-4}$	$1.50\ 10^{-4}$	$1.50\ 10^{-4}$
Dep beta	$5.90\ 10^{-6}$	$5.90\ 10^{-6}$	$5.90\ 10^{-6}$	$5.90\ 10^{-6}$	$5.90\ 10^{-6}$
Resuspension	$1.00\ 10^{-6}$	$1.70\ 10^{-6}$	$2.00\ 10^{-6}$	$2.40\ 10^{-6}$	$2.60\ 10^{-6}$
Sub-total	**$2.54\ 10^{-2}$**	**$2.55\ 10^{-2}$**	**$2.56\ 10^{-2}$**	**$2.56\ 10^{-2}$**	**$2.56\ 10^{-2}$**
Food (weighted)	$7.39\ 10^{-4}$	$1.04\ 10^{-3}$	$1.17\ 10^{-3}$	$1.19\ 10^{-3}$	$1.19\ 10^{-3}$
Total	**$2.62\ 10^{-2}$**	**$2.66\ 10^{-2}$**	**$2.67\ 10^{-2}$**	**$2.67\ 10^{-2}$**	**$2.67\ 10^{-2}$**
c) 20-100 km					
Cloud gamma	$3.40\ 10^{-2}$	$3.40\ 10^{-2}$	$3.40\ 10^{-2}$	$3.40\ 10^{-2}$	$3.40\ 10^{-2}$
Cloud beta	$1.10\ 10^{-2}$	$1.10\ 10^{-2}$	$1.10\ 10^{-2}$	$1.10\ 10^{-2}$	$1.10\ 10^{-2}$
Inhalation	$3.40\ 10^{-3}$	$3.40\ 10^{-3}$	$3.40\ 10^{-3}$	$3.40\ 10^{-3}$	$3.40\ 10^{-3}$
Dep gamma	$3.50\ 10^{-5}$	$3.80\ 10^{-4}$	$3.90\ 10^{-4}$	$3.90\ 10^{-4}$	$3.90\ 10^{-4}$
Dep beta	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$	$1.60\ 10^{-5}$
Resuspension	$2.70\ 10^{-6}$	$4.50\ 10^{-6}$	$5.40\ 10^{-6}$	$6.30\ 10^{-6}$	$6.80\ 10^{-6}$
Sub-total	**$4.85\ 10^{-2}$**	**$4.88\ 10^{-2}$**	**$4.88\ 10^{-2}$**	**$4.88\ 10^{-2}$**	**$4.88\ 10^{-2}$**
Food (weighted)	$2.01\ 10^{-2}$	$2.84\ 10^{-2}$	$3.18\ 10^{-2}$	$3.23\ 10^{-2}$	$3.23\ 10^{-2}$
Total	**$6.86\ 10^{-2}$**	**$7.72\ 10^{-2}$**	**$8.06\ 10^{-2}$**	**$8.12\ 10^{-2}$**	**$8.12\ 10^{-2}$**

Pathway	Truncation time (y) 1	50	500	10000	100000
d) 100-500 km					
Cloud gamma	$1.20\ 10^{-1}$	$1.20\ 10^{-1}$	$1.20\ 10^{-1}$	$1.20\ 10^{-1}$	$1.20\ 10^{-1}$
Cloud beta	$1.10\ 10^{-1}$	$1.10\ 10^{-1}$	$1.10\ 10^{-1}$	$1.10\ 10^{-1}$	$1.10\ 10^{-1}$
Inhalation	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$	$3.30\ 10^{-2}$
Dep gamma	$1.60\ 10^{-4}$	$1.70\ 10^{-3}$	$1.80\ 10^{-3}$	$1.80\ 10^{-3}$	$1.80\ 10^{-3}$
Dep beta	$7.00\ 10^{-5}$	$7.00\ 10^{-5}$	$7.00\ 10^{-5}$	$7.00\ 10^{-5}$	$7.00\ 10^{-5}$
Resuspension	$1.20\ 10^{-5}$	$2.00\ 10^{-5}$	$2.40\ 10^{-5}$	$2.80\ 10^{-5}$	$3.00\ 10^{-5}$
Sub-total	**$2.63\ 10^{-1}$**	**$2.65\ 10^{-1}$**	**$2.65\ 10^{-1}$**	**$2.65\ 10^{-1}$**	**$2.65\ 10^{-1}$**
Food (weighted)	$6.95\ 10^{-1}$	$9.79\ 10^{-1}$	$1.10\ 10^{0}$	$1.12\ 10^{0}$	$1.12\ 10^{0}$
Total	**$9.58\ 10^{-1}$**	**$1.24\ 10^{0}$**	**$1.36\ 10^{0}$**	**$1.38\ 10^{0}$**	**$1.38\ 10^{0}$**
e) 500-1500 km					
Cloud gamma	$1.90\ 10^{-5}$	$1.90\ 10^{-5}$	$1.90\ 10^{-5}$	$1.90\ 10^{-5}$	$1.90\ 10^{-5}$
Cloud beta	$2.90\ 10^{-5}$	$2.90\ 10^{-5}$	$2.90\ 10^{-5}$	$2.90\ 10^{-5}$	$2.90\ 10^{-5}$
Inhalation	$7.90\ 10^{-6}$	$7.90\ 10^{-6}$	$7.90\ 10^{-6}$	$7.90\ 10^{-6}$	$7.90\ 10^{-6}$
Dep gamma	$1.60\ 10^{-8}$	$1.70\ 10^{-7}$	$1.80\ 10^{-7}$	$1.80\ 10^{-7}$	$1.80\ 10^{-7}$
Dep beta	$7.20\ 10^{-9}$	$7.20\ 10^{-9}$	$7.20\ 10^{-9}$	$7.20\ 10^{-9}$	$7.20\ 10^{-9}$
Resuspension	$1.20\ 10^{-9}$	$2.00\ 10^{-9}$	$2.40\ 10^{-9}$	$2.90\ 10^{-9}$	$3.10\ 10^{-9}$
Sub-total	**$5.59\ 10^{-5}$**	**$5.61\ 10^{-5}$**	**$5.61\ 10^{-5}$**	**$5.61\ 10^{-5}$**	**$5.61\ 10^{-5}$**
Food (weighted)	$7.10\ 10^{-4}$	$1.00\ 10^{-3}$	$1.12\ 10^{-3}$	$1.14\ 10^{-3}$	$1.14\ 10^{-3}$
Total	**$7.66\ 10^{-4}$**	**$1.06\ 10^{-3}$**	**$1.18\ 10^{-3}$**	**$1.20\ 10^{-3}$**	**$1.20\ 10^{-3}$**

D4.2 Per-caput doses by distance

TABLE D43 Annual per-caput doses (Sv) by distance integrated to selected times to individuals within various populations due to continuous discharges to atmosphere from Sellafield. (Discharges are assumed to be at an annual rate obtained as the average of discharges between 1999 and 2003).

	Integration time (y)					
	0-5 km		5-20 km		20-100 km	
Pathway	1	50	1	50	1	50
Cloud gamma	$2.36\ 10^{-6}$	$2.36\ 10^{-6}$	$3.69\ 10^{-7}$	$3.69\ 10^{-7}$	$2.19\ 10^{-8}$	$2.19\ 10^{-8}$
Cloud beta	$2.60\ 10^{-7}$	$2.60\ 10^{-7}$	$5.80\ 10^{-8}$	$5.80\ 10^{-8}$	$7.09\ 10^{-9}$	$7.09\ 10^{-9}$
Inhalation	$8.50\ 10^{-8}$	$8.50\ 10^{-8}$	$1.93\ 10^{-8}$	$1.93\ 10^{-8}$	$2.19\ 10^{-9}$	$2.19\ 10^{-9}$
Dep gamma	$1.11\ 10^{-9}$	$1.18\ 10^{-8}$	$2.29\ 10^{-10}$	$2.46\ 10^{-9}$	$2.26\ 10^{-11}$	$2.45\ 10^{-10}$
Dep beta	$4.96\ 10^{-10}$	$4.96\ 10^{-10}$	$1.04\ 10^{-10}$	$1.04\ 10^{-10}$	$1.03\ 10^{-11}$	$1.03\ 10^{-11}$
Resuspension	$8.50\ 10^{-11}$	$1.39\ 10^{-10}$	$1.76\ 10^{-11}$	$2.99\ 10^{-11}$	$1.74\ 10^{-12}$	$2.90\ 10^{-12}$
Total	**$2.71\ 10^{-6}$**	**$2.72\ 10^{-6}$**	**$4.47\ 10^{-7}$**	**$4.49\ 10^{-7}$**	**$3.12\ 10^{-8}$**	**$3.15\ 10^{-8}$**

	100-500 km		500-1500 km	
	1	50	1	50
Cloud gamma	$2.24\ 10^{-9}$	$2.24\ 10^{-9}$	$3.48\ 10^{-10}$	$3.48\ 10^{-10}$
Cloud beta	$2.06\ 10^{-9}$	$2.06\ 10^{-9}$	$5.31\ 10^{-10}$	$5.31\ 10^{-10}$
Inhalation	$6.17\ 10^{-10}$	$6.17\ 10^{-10}$	$1.45\ 10^{-10}$	$1.45\ 10^{-10}$
Dep gamma	$2.99\ 10^{-12}$	$3.18\ 10^{-11}$	$2.93\ 10^{-13}$	$3.11\ 10^{-12}$
Dep beta	$1.31\ 10^{-12}$	$1.31\ 10^{-12}$	$1.32\ 10^{-13}$	$1.32\ 10^{-13}$
Resuspension	$2.24\ 10^{-13}$	$3.74\ 10^{-13}$	$2.20\ 10^{-14}$	$3.66\ 10^{-14}$
Total	**$4.92\ 10^{-9}$**	**$4.95\ 10^{-9}$**	**$1.02\ 10^{-9}$**	**$1.03\ 10^{-9}$**

Summary over all distances

	Breakdown by pathway							
	1 y integration time				50 y integration time			
	Non-food	Food	**Total**	% contribution of food	Non-food	Food	**Total**	% contribution of food
0-5 km	$2.71\ 10^{-6}$	$1.30\ 10^{-8}$	**$2.72\ 10^{-6}$**	0.5%	$2.72\ 10^{-6}$	$1.79\ 10^{-8}$	**$2.74\ 10^{-6}$**	0.7%
5-20 km	$4.47\ 10^{-7}$	$1.30\ 10^{-8}$	**$4.60\ 10^{-7}$**	2.8%	$4.49\ 10^{-7}$	$1.77\ 10^{-8}$	**$4.67\ 10^{-7}$**	3.9%
20-100 km	$3.12\ 10^{-8}$	$1.29\ 10^{-8}$	**$4.42\ 10^{-8}$**	29.4%	$3.15\ 10^{-8}$	$1.91\ 10^{-8}$	**$4.98\ 10^{-8}$**	36.8%
100-500 km	$4.92\ 10^{-9}$	$1.30\ 10^{-8}$	**$1.79\ 10^{-8}$**	72.5%	$4.95\ 10^{-9}$	$1.88\ 10^{-8}$	**$2.33\ 10^{-8}$**	78.7%
500-1500 km	$1.02\ 10^{-9}$	$1.31\ 10^{-8}$	**$1.40\ 10^{-8}$**	92.7%	$1.03\ 10^{-9}$	$1.81\ 10^{-8}$	**$1.93\ 10^{-8}$**	94.7%
Total	**$6.32\ 10^{-9}$**	**$1.30\ 10^{-8}$**	**$1.93\ 10^{-8}$**	**67.3%**	**$6.36\ 10^{-9}$**	**$1.83\ 10^{-8}$**	**$2.47\ 10^{-8}$**	**74.2%**