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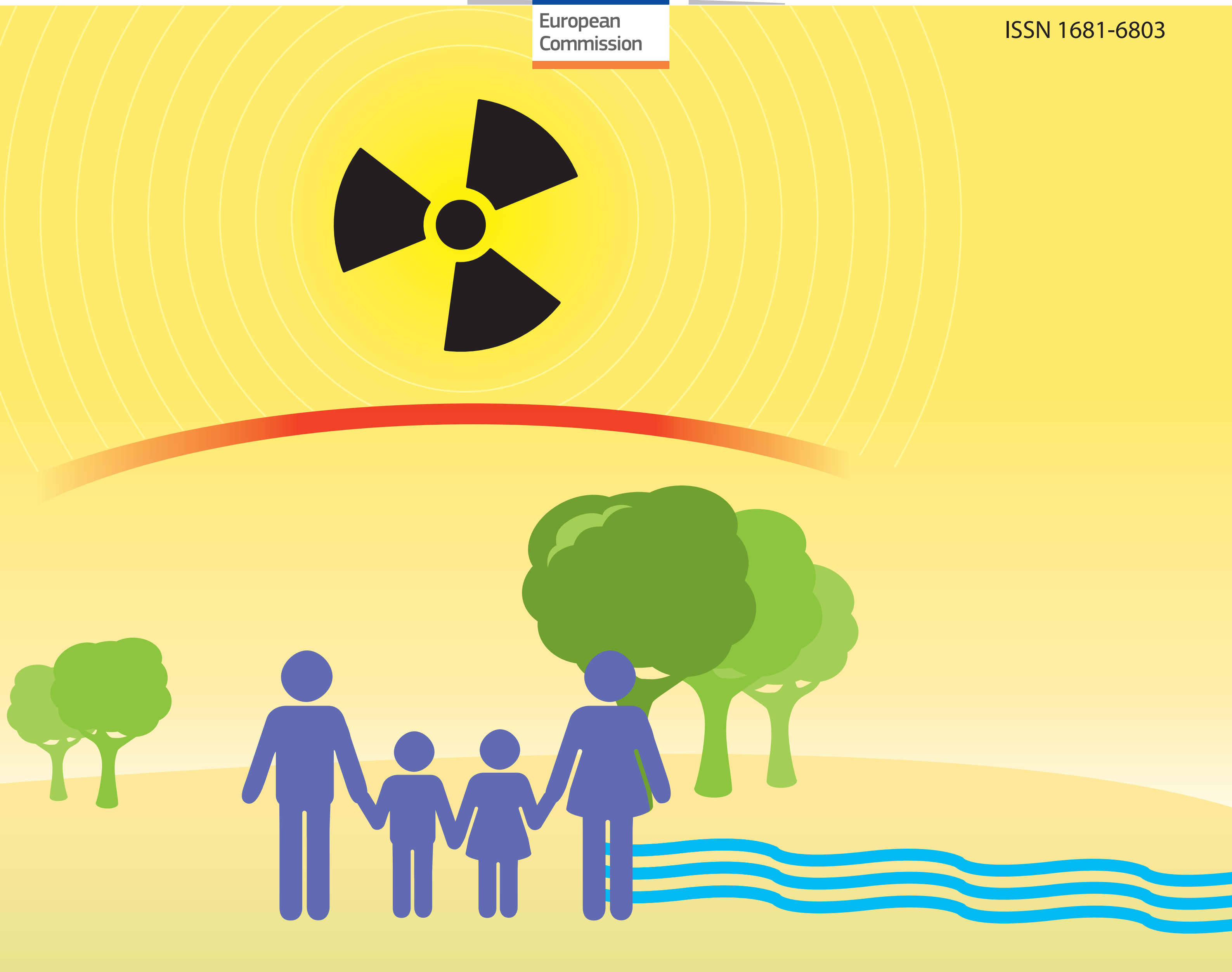

Radiation Protection

No 176

Implied doses to the population of the EU arising from reported discharges from EU nuclear power stations and reprocessing sites in the years 2004 to 2008

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RADIATION PROTECTION N° 176

Implied doses to the population of the EU arising from reported discharges from EU nuclear power stations and reprocessing sites in the years 2004 to 2008

Directorate-General for Energy

Directorate D — Nuclear Safety and Fuel Cycle

Unit D3— Radiation Protection

2013

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Authors: K A Jones, J G Smith, T Anderson, M P Harvey, I K Brown, S J Field, A L Jones

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ABSTRACT

The aim of this study was to assess implied doses to the population of the European Union (EU) based on reported discharges of radioactive material from EU nuclear power stations and reprocessing sites for the period 2004 to 2008. The twenty five countries that were Member States of the European Union in 2004 were included in the study. The dose calculations were performed using the software program PC-CREAM 08®, which is an updated implementation of European Commission methodology for assessing the radiological impact of routine releases of radionuclides to the environment. For selected years, estimates of both individual and collective doses were made for each site. These dose estimates take account of reported discharges to the atmosphere, to rivers and to the sea. The report gives details of the assessment methodologies and data used and discusses the estimated doses and compares them with those calculated for previous years.

EXECUTIVE SUMMARY

The aim of this study was to assess implied doses to the population of the European Union (EU) based on reported discharges of radioactive material from EU nuclear power stations and reprocessing sites for the period 2004 to 2008. Twenty five countries, which were Member States in 2004, were included in the study. Estimates of both individual and collective doses were made for each site and selected years namely 2004 and 2008. The report gives details of the assessment methodologies and data used and discusses the estimated doses and compares them with those calculated for previous years.

The dose calculations were performed using the software program PC-CREAM 08® which is an updated implementation of the European Commission methodology for assessing the radiological impact of routine releases of radionuclides to the environment. The individual doses assessed were indicative of those likely to be received by the more highly exposed individuals in the population, but are not intended for the purpose of determining compliance with the annual dose limit or dose constraint for members of the public. For this study, population, agricultural production and seafood catch data used in the calculation of collective doses and intake rates for calculation of individual doses were updated using the latest information from EUROSTAT, the European Environment Agency and the Food and Agriculture Organization.

The dose calculations were based solely on the discharge data that Member States had reported to the European Commission. Although the radionuclides that contribute most significantly to the dose are required to be reported, the reported discharges are not the full discharge inventory in some cases; consequently the doses calculated were those implied by the reported discharges. The implied total collective dose (integrated to 500 years) arising from reported discharges in 2004 and 2008 was estimated to be approximately 110 and 90 man Sv respectively. This reduction in doses mainly reflecting a decrease in the discharges from the reprocessing sites Cap de la Hague and Sellafield.

The atmospheric discharges from all the sites contributed between 80% and 90% of the estimated total collective dose to the EU population. Power production sites only were responsible for slightly less than 70% of this dose, with Cap de la Hague and Sellafield accounting for the rest. For power production sites, there was a decrease in the maximum dose to the representative person at 500 m from around 40 μSv y^{-1} in 2004 to around 20 μSv y^{-1} due to the closure of three sites with gas-cooled reactors.

The total collective dose integrated to 500 years for liquid discharges from all sites was about 25 man Sv in 2004 and about 15 man Sv in 2008. About 95% of this dose was as a result of the discharges from Sellafield and Cap de la Hague. The decrease in the collective dose from 2004 to 2008 reflected the general decrease in discharges from Sellafield and Cap de la Hague. This decrease was also seen in the doses calculated for the representative person for these sites.

There are differences between the data and methodology used in this assessment and the previous study. Generally the collective doses in this study are lower than the previous one because of decreases in the population, agricultural production and seafood catch data which are now more appropriate for the Member States being considered. In addition, significant efforts have been made to ensure that only food that is used for human consumption is included.

This study has shown that it is necessary to harmonise the reporting of radionuclide discharges among EU Member States if valid conclusions about dose trends are to be drawn from the assessment. Consistency of reporting by the operators would be needed to show trends in dose as a function of time and to allow comparisons between sites to be made. To

promote such consistency throughout the EU the European Commission issued Commission Recommendation 2004/2/Euratom on standardised information on radioactive airborne and liquid discharges from nuclear power reactors and reprocessing plants in normal operation, but inconsistencies still remain and need to be addressed. As an example, the recommendation identifies ^{14}C as a radionuclide for which the activity should be reported for airborne and liquid discharges from nuclear fuel reprocessing sites and airborne discharges from nuclear power reactors. However, the recommendation does not require Member States to report liquid discharges of ^{14}C from nuclear power reactors and yet assessments carried out in this study suggest this radionuclide makes a significant contribution to the dose.

A number of facilities were in a state of final shut down during the period considered in this study and attempts were made to determine the impact of these closures. The impact of the closure of three sites with gas-cooled reactors (Chapelcross, Dungeness A and Sizewell A) is discussed.

To put all of these doses in context, the annual collective dose to the EU population from natural radioactivity, based on UK data, is estimated to be several hundred thousand man Sv.

Contents

1. INTRODUCTION

The assessment of doses to a population is an important part of the system of radiological protection (EC, 1996). The European Commission (EC) periodically initiates a programme of work to assess collective and individual doses to the population of the European Union (EU) resulting from discharges from EU nuclear facilities. This current report describes the assessment carried out by the Centre for Radiation, Chemicals and Environment Hazards of the UK Health Protection Agency (HPA), under contract to the EC, for radioactive discharges occurring between the years 2004 to 2008. Twenty five countries, which were Member States of the EU in 2004, were included. It is important to note that only discharges reported to the EC by Member States were included in this study. Consequently, the doses calculated for this study are those implied by the levels of reported discharges and not necessarily those actually received by members of the EU population.

2. DOSIMETIC QUANTITIES CALCULATED IN THE ASSESSMENT

The term dose used in this report refers to the effective dose and represents the sum of the annual dose from external irradiation and the committed effective dose following the intake of radioactivity in a year. The intake of radioactivity includes the inhalation of radionuclides in the air and the ingestion of radionuclides that have been incorporated into foods. Doses from the intake of radioactivity into the body were determined in accordance with recommendations from the International Commission on Radiological Protection (ICRP) (ICRP, 2007), using the dose coefficients from ICRP Publication 72 (ICRP, 1996). Radiological impact assessments usually involved two aspects. The first is the calculation of individual doses and the second is the calculation of radiation dose received by an exposed population otherwise referred to as the collective dose.

For each nuclear facility, individual doses were calculated for hypothetical individuals whose habits and behaviours were likely to be indicative of the more highly exposed individuals in the population (a *representative person* as defined by ICRP (ICRP, 2006)) and collective doses were estimated for the population of the European Union. Detailed assessments of doses to representative persons are generally carried out by operators and national authorities for the purpose of authorising discharges to demonstrate compliance with the annual dose limit or dose constraint for members of the public. However, the purpose of this study was to obtain an indication of doses received by the more highly exposed members of the public in the EU, who were identified using a standardised approach and generic assumptions about the location where they live and their habits. Therefore, doses calculated in this study are likely to differ from those calculated in the individual Member States for each site as part of its licensing or authorisation procedures. For discharges to rivers and the marine environment, although individual doses were calculated for each site, the results presented in this study are for locations where the more highly exposed individuals were likely to live. For example, an estuary where the doses may result from sites discharging into the river as well as those discharging into the sea.

The indicative individual doses to the representative person were based on an assessment which assumed that the annual discharge for a given year continued for a further 50 years. This took into account the build-up of long-lived radionuclides in the environment.

The collective dose is the sum of doses received by members of an exposed population from all significant pathways and over many generations. Long-lived radionuclides can give rises to doses over extended times, long after a release has stopped. The assessment considered exposure to the population over a period of 500 years from the single year of discharge and is referred to as the collective dose integrated to 500 years. To simplify the calculation it was assumed that all members of the population were adults. The exposed population considered was the population of the European Member States in 2004.

3. NUCLEAR SITES AND DISCHARGES CONSIDERED IN THE ASSESSMENT

3.1 Nuclear sites

The sites included in this study are nuclear reactors nominally generating more than 50 MW(e) and nuclear fuel reprocessing plants discharging under authorisation within the EU between 2004 and 2008. For the sites in the Member States which acceded to the EU in 2004 (Czech Republic, Hungary, Lithuania, Slovakia and Slovenia), appropriate discharge stack heights, meteorological data, agricultural production and population distribution data were obtained. For the other sites, data previously obtained was used (EC, 2008). A full list of the sites considered is given in Appendix A and Figure 1 shows the EU Member States in 2004. Italy reported discharges from four nuclear reactors which were shut down several decades ago. Given that the discharges were low, and therefore also the resulting doses, these sites were not considered in the study.

In this report Cap de la Hague and Sellafield are referred to as nuclear fuel reprocessing sites but it is important to note that many other processes occur at these sites and reported discharges represent the whole of the site and not just the reprocessing operations.

3.2 Discharge data

In 2004 the EC issued Commission Recommendation 2004/2/Euratom on standardised information on radioactive airborne and liquid discharges from nuclear reactors nominally generating more than 50 MW(e) and nuclear reprocessing plants in normal operation (EC, 2004). This recommendation provides guidance with respect to the reporting of radioactive discharges and defines the categories and individual radionuclides that should be reported because of their relevance in terms of radiological protection.

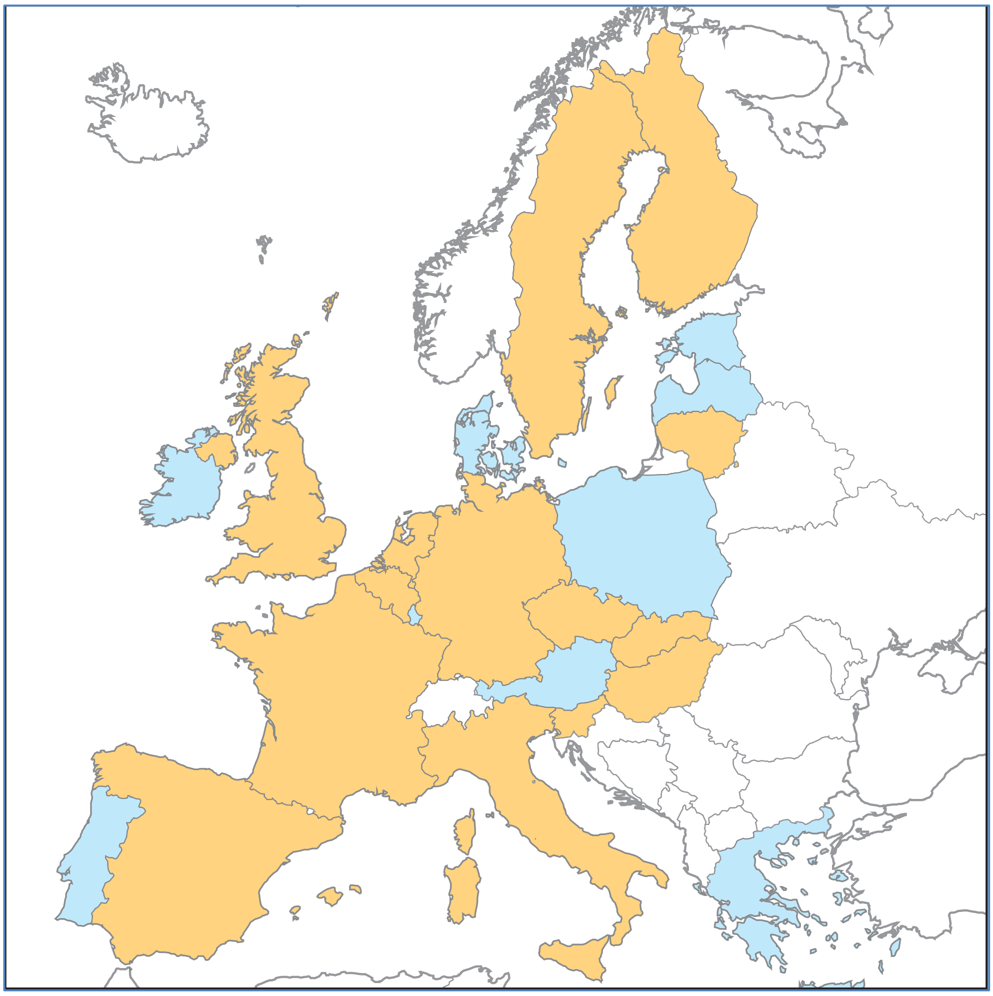

Figure 1: European Union Members States in 2004. Orange indicates those with operational and/or shutdown nuclear power stations (Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Lithuania, Slovakia, Slovenia, Spain, Sweden, the Netherlands and United Kingdom). Blue indicates those without nuclear sites or sites no longer reporting discharges (Austria, Cyprus (not shown), Denmark, Estonia, Greece, Ireland, Latvia, Luxembourg, Malta (not shown), Poland and Portugal) Copyright © Esri 2012. All rights reserved

The Radiation Protection Unit of the EC Directorate-General for Energy maintains a database containing information on radioactive discharges for all nuclear power stations and spent fuel reprocessing plants within the EU (both operational and shutdown). Member States are requested to report this information to the EC in line with the recommendations made in the Commission Recommendation 2004/2/Euratom (EC, 2004). This study used the information contained in this database to obtain both atmospheric and aquatic discharge data for each site of interest and for each year between 2004 and 2008. ^{14}C is of particular importance as it is a long lived emitter of beta radiation and is readily transferred throughout the environment, both locally and on a global scale. As a consequence it can make a significant contribution to both individual and collective doses in the short and long term. The Commission Recommendation 2004/2/Euratom (EC, 2004) requires Member States to report atmospheric discharges of ^{14}C from nuclear power reactors but there is no requirement for liquid discharges.

3.3 Analysis of discharge data

In general, the database of the Directorate-General for Energy of the EC included the magnitude of the discharge in terms of radioactivity released per year for each radionuclide. This information could be used directly to assess the doses from both atmospheric and liquid discharges. However, there were also a significant number of discharges reported as aggregated totals, such as total alpha or total iodine, which had to be broken down into radionuclide specific discharges. If disaggregated discharge data were available in another year for that same site then these were used to estimate the percentage contribution that various radionuclides made to the aggregated total. This method assumed that the amount of each radionuclide discharged relative to the total would not change between years. For example, if iodine discharges were reported as 'total iodine' for some years and as 30% ^{131}I and 70% ^{129}I in another year, then the same fractions are assumed to apply to all years where 'total iodine' was reported. If such data were not available then data provided by Gesellschaft für Anlagen-und-Reaktorsicherheit (GRS) for different reactor/types of facility in terms of the percentage contribution of different radionuclides to aggregated groups from a previous study (EC, 2002a) were used.

Some radionuclides, which were outside the scope of the Recommendation (EC, 2004), but were nevertheless reported in the discharge database, were not included within the PC-CREAM 08 system. The radionuclides not included are those for which transfer rates were not available and were also not considered important in terms of their potential contribution to the total dose. Table 1 provides a list of those radionuclides not included in this study for this reason.

Table 1: Radionuclides discharged but not included in the dose assessment

Discharge to	Radionuclides
Atmosphere	Environmental transfer data for the isotopes of As, Be, Gd, Hf, In, Hg, K, Re, Sc, Na and W were not available
River	All are included
Lake	^{54}Mn, ^{55}Fe, ^{65}Ni, ^{90}Sr, ^{90}Y, ^{95}Nb, ^{238}Pu, ^{239}Pu, ^{241}Pu and ^{241}Am
Sea	^{7}Be, ^{42}K, ^{76}As, ^{83}Rb, ^{99}Mo, ^{106}Ru and ^{109}Cd

4. METHODOLOGY FOR THE ASSESSMENT OF DOSES TO THE EU POPULATION

4.1 General methodology and assessment data

The release of radioactivity into the environment can lead to the exposure of the local and wider populations via a number of exposure pathways. These pathways depend on the form of the discharge. For example, liquid discharges may result in radionuclides being taken up by fish which are subsequently ingested whilst an atmospheric release may lead to the direct inhalation of radionuclides as the dispersing plume passes over populated areas.

In order to carry out this assessment the software tool PC-CREAM 08 was used (Smith et al, 2009). PC-CREAM 08 was developed by the Centre for Radiation, Chemicals and Environment Hazard of the UK Health Protection Agency with permission from the European Commission (EC), and is an implementation of the methodology described in Smith and Simmonds, 2009. It is an updated version of the EC code PC-CREAM 98 (Mayall et al, 1997). With PC-CREAM 08 it is possible to calculate collective doses to population groups and individual doses. Differences between the two codes are discussed in Section 4.4.

For modelling purposes the collective doses from atmospheric and liquid discharges to the sea were split into two components: the non-global component which arises from the initial discharge, which is commonly known as the first pass of the radioactive material; and the global component which arises only from radionuclides that have become globally dispersed.

Doses were calculated for all the pathways included in PC-CREAM 08. A review of these pathways in light of the recommendations made concerning realistic dose assessments (EC, 2002b, Jones et al, 2006) demonstrated that no significant pathways were being omitted. The pathways included in this assessment are detailed in Tables 2 and 3.

Input data, such as habit and meteorological data and population and agricultural production distributions, that supported the calculation of doses for the previous assessment (EC, 2008), were reviewed to ensure that were still relevant. Since the previous study, the population, agricultural production and seafood catch data have been updated and are discussed in more detail in Sections 4.2 and 4.3.4.

Table 2: Pathways included in the assessment of doses from atmospheric discharges

Inhalation of radionuclides in the plume	
Beta and gamma external irradiation from radionuclides in the plume	
Beta and gamma external irradiation from deposited radionuclides	
Inhalation from resuspended radionuclides	
Ingestion of radionuclides incorporated in food *	Cow meat
	Cow liver
	Milk
	Milk products
	Offal
	Sheep meat
	Sheep liver
	Green vegetables
	Root vegetables
	Grain (collective dose only)
	Fruit (individual dose only)

*: Foods shown in bold were those considered to be ingested at a high rate for assessing individual doses. All others foods were considered to be ingested at an average rate for that particular country.

Table 3: Pathways included in the assessment of doses from liquid discharges

Individual doses	Collective doses
Discharges to the marine environment	
Beta and gamma external irradiation from radionuclides deposited in sediments	Beta and gamma external irradiation from radionuclides deposited in sediments
Beta and gamma external irradiation from radionuclides from marine sediments in fishing gear	Ingestion of radionuclides incorporated into marine fish
Ingestion of radionuclides incorporated into marine fish	Ingestion of radionuclides incorporated into crustaceans
Ingestion of radionuclides incorporated into crustaceans	Ingestion of radionuclides incorporated into molluscs
Ingestion of radionuclides incorporated into molluscs	
Inhalation of sea spray	
Discharges to lakes	
Ingestion of radionuclides incorporated into freshwater fish	Ingestion of radionuclides incorporated into freshwater fish
Ingestion of radionuclides in drinking water (not included for Trawsfynydd)	Ingestion of radionuclides in drinking water (not included for Trawsfynydd)
Ingestion of radionuclides incorporated into food following irrigation by water from lake	Ingestion of radionuclides incorporated into food following irrigation by water from lake
Discharges to rivers*	
Ingestion of radionuclides in drinking water	Ingestion of radionuclides in drinking water
Beta and gamma external irradiation from radionuclides deposited in sediments	
Ingestion of radionuclides incorporated into freshwater fish	

*: Doses were also calculated for the pathways associated with discharges to the marine environment once the radionuclides discharged reached the sea

4.2 Methodology for the assessment of doses from atmospheric discharges

The methodology used in this study to assess doses arising from atmospheric discharges was similar to that adopted in the previous study (EC, 2008). The study used PC-CREAM 08 (Smith et al, 2009), which comprises a series of mathematical models used to represent the transfer of a wide range of radionuclides through various parts of the environment.

Agricultural data for Europe used in the calculation of collective doses were taken from the EUROSTAT database (Eurostat, 2012a). EUROSTAT geographically breaks down all member countries into smaller units for the collection of statistics according to the Nomenclature of Territorial Units for Statistics (NUTS). Data for the years 2001 to 2010 were manipulated to obtain food production data at a regional level, according to the NUTS 2006 classification (Eurostat, 2007) for the food groups considered in the assessment (see Table 2) The data on food production were then combined with data on land use published by the European Environment Agency (European Environment Agency, 2011) to improve their spatial resolution.

The meteorological data and stack heights collated under the previous study were used for this assessment and supplemented with information provided by the Member States that acceded to the European Union in 2004. If this information was not provided for a site, a uniform wind rose was assumed and a stack height representative of the reactor type at the site was chosen. Ingestion rates for terrestrial foods used in the calculation of individual dose were updated using country specific intake rates based on more recent data from the Food and Agriculture Organization of the United Nations (FAO) for 2007 (FAOSTAT, 2007) (Table 4). These ingestion rates were averaged over the entire population of the country and were assumed to be representative of the ingestion rates of adults for all the years covered in this study. Ingestion rates for cow milk and green vegetables given in Table 4 were typical of high rate consumers. These data were derived by scaling average rates using factors derived from UK data (Byrom et al, 1995).

Ingestion rates were only needed for those countries where the representative person for a particular release resides. For atmospheric discharges the representative person for ingestion of terrestrial foods was assumed to be located within the country in which the discharge originated. Consequently, no terrestrial ingestion rates were needed for Austria, Cyprus, Denmark, Estonia, Greece, Ireland, Italy, Latvia, Luxembourg, Malta, Poland or Portugal because none of the nuclear sites considered in this study are located within these Member States.

For the calculation of individual doses to the representative person, it was assumed that individuals were located at 0.5 km and 5 km from the discharge point and that they obtained all their terrestrial food from these locations. It was also assumed that the wind blew towards them for 20% of the time. Habit data in the form of inhalation rates and occupancy times were reviewed in line with the recommendations made concerning realistic dose assessments (EC, 2002b, Jones et al, 2006) and PC-CREAM 08 default values were considered fit for purpose.

Table 4: Food ingestion rates* for adults used in the calculation of doses typical of the representative person arising from atmospheric discharges (kg y^{-1})

Country	Cow meat	Cow milk#	Milk products	Cow liver
Belgium	13	240	99	0.6
Czech Republic	6	190	44	1.5
Finland	13	360	69	0.5
France	18	260	93	2.6
Germany	9	250	83	0.3
Hungary	3	170	72	0.9
Lithuania	16	250	39	2.0
Slovakia	5	270	12	0.6
Slovenia	4	130	23	2.0
Spain	15	240	68	0.7
Sweden	10	180	16	0.5
The Netherlands	16	350	83	0.6
United Kingdom	13	320	32	1.0

	Sheep meat	Sheep liver	Green vegetables#	Root vegetables	Fruit
Belgium	0.8	0.6	100	42	12
Czech Republic	0.1	1.5	65	39	8
Finland	0.2	0.5	69	39	11
France	1.6	2.6	86	37	12
Germany	0.3	0.3	82	39	12
Hungary	0.05	0.9	96	29	14
Lithuania	0.7	1.1	130	22	17
Slovakia	0.1	2.0	84	54	14
Slovenia	0.05	0.6	78	35	8
Spain	0.5	2.0	67	36	20
Sweden	2.3	0.7	140	41	10
The Netherlands	0.6	0.5	77	34	12
United Kingdom	0.4	0.6	90	52	16

4.3 Methodology for the assessment of doses from aquatic discharges

4.3.1 Calculation of doses from discharges to rivers

It was not possible to collect detailed data for some of these rivers as the information was not readily available. Information was available for different sections of the Loire, the Rhine, and the Rhône (EC, 1995), the Vltava (Czech Republic State Office for Nuclear Safety, 2012), and the Danube (Maringer, 2010) on the dimensions, sedimentation rates and flow rates. However, for the other rivers, detailed data were not readily available and therefore it was decided that other rivers would adopt the characteristics of one or more sections of the Rhine, Loire and Rhône in the same way as it was done in the previous study (EC, 2008). A schematic of the model structures used for the Danube, the Loire, the Rhine and the Rhône is given in

Figure 2. Details of the river sections used to model the discharges from each site are presented in Table A2 of Appendix A. When calculating individual doses it was assumed that a representative person was located in each river section into which discharges occurred.

For discharges to rivers, the dose to the representative person was calculated for ingestion of radionuclides in drinking water and freshwater fish, and from external exposure to radionuclides in riverbank sediments using the PC-CREAM dynamic river model. This included modelling the adsorption of radionuclides onto river bed sediments over the whole length of the river. The dose to the representative person arising from the ingestion of foods from irrigated land was found to be small in comparison and therefore was not included in the assessment. The doses were only calculated for the EU Member States through which the rivers passed.

The annual consumption of drinking water by adult members of the population was assumed to be 600 litres per year (Smith and Jones, 2003) for all countries and this value was used in both individual and collective dose calculations. It should be noted that the individual doses are likely to be an overestimate as it was assumed that the annual individual intake of 600 litres of water was taken entirely from the river or lake.

The total collective dose for liquid discharges from inland sites included the collective dose from both river and marine pathways, i.e. account was taken of the exposures arising after radionuclides discharged into rivers reached the sea (see Section 4.3.3). The desorption of radionuclides from river sediments as they enter an estuary was modelled so that account of discharges into the sea from inland sites was made. For the river exposure pathways, ingestion of drinking water was the only one considered as it makes the most significant contribution to collective doses for the majority of sites. The marine exposure pathways considered in the collective dose calculation are discussed in Section 4.3.3.

To estimate the collective dose from ingestion of drinking water the numbers of inhabitants in the major population centres along each river (see Table A3 in Appendix A) were multiplied by the average individual doses calculated at the corresponding locations and the fraction of drinking water sourced from the river. As large quantities of drinking water are obtained from boreholes, for all rivers, except the Danube which is discussed below, it was assumed that only 50% of drinking water was abstracted from the river. This assumption was supported by data on typical extraction rates from the Rhine (Dieperink, 1997). However, for the Danube, information on abstraction rates was taken from the International Association of Water Supply Companies in the Danube River Catchment Area (IAWD) (IAWD, 2012) for Austria, Czech Republic, Germany, Hungary, Slovakia and Slovenia. The total collective dose for a river was then calculated as the sum of the collective doses from all sites on that river.

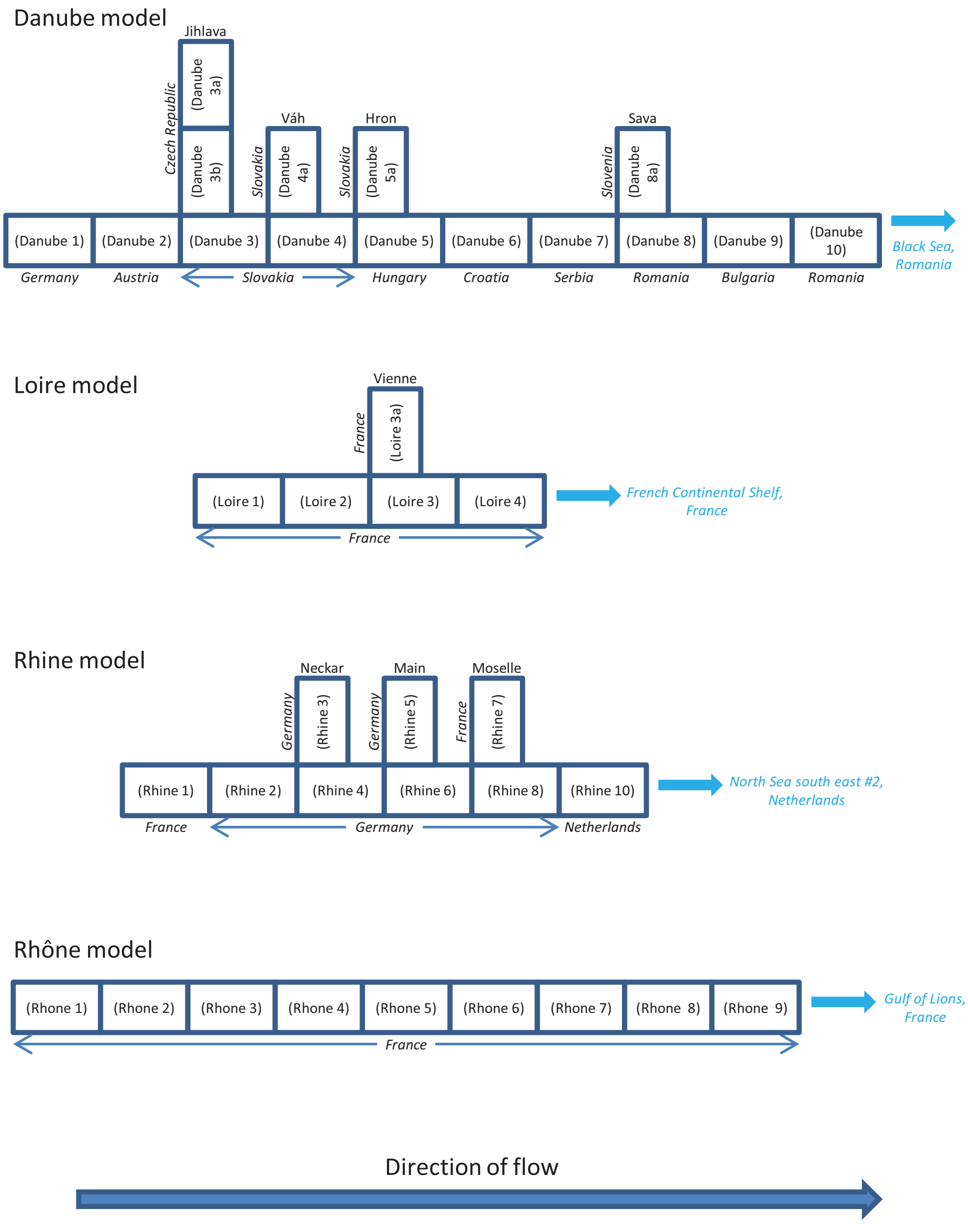

Figure 2: Layout of rivers modelled (section 9 of the Rhine river system, i.e. the river Lippe, was not considered as no discharges into this section of the river were reported)

4.3.2 Calculation of doses from discharges to lakes

Liquid discharges from three nuclear sites included in the study are released to lakes: Ignalina (Lithuania) which discharges into the Lake Druksiai, Rheinsberg (Germany) which discharges into Lake Stechlin and Trawsfynydd (United Kingdom) which discharges into Lake Trawsfynydd. It should be noted these nuclear reactor sites have been shut down. Individual and collective doses from the ingestion of radionuclides in freshwater fish, drinking water (for Lake Stechlin and Druksiai only) and foods following irrigation by water from the lake were considered were estimated using the model BIOS (Martin et al, 1991).

The dimensions and flow rate of Lake Druksiai were obtained from Nedveckaite et al (2011). The lake, which is situated on the border between Lithuania and Belarus, was assumed to flow into a number of rivers; Prova, Dysna and Daugava, before entering the sea at the Gulf Of Riga, about 550 km west of the lake. It was assumed that the local population of 45,000 people abstract all their drinking water from the lake and consume an annual catch of 41 tonnes of freshwater fish (Worlds Lake Database, 2010). The fish consumption rate for the representative person was the consumption rate for Lithuania given in Table 5. About 80% of the land around the lake was assumed to be given over to agriculture with about half being pasture land and the other half being arable land used for growing crops (Worlds Lake Database, 2010).

In the previous study (EC, 2008) it was assumed that discharges from the Rheinsberg nuclear power plant in Germany went into the River Elbe, which flows into the North Sea East compartment. However, it was found that the Rheinsberg nuclear power plant actually discharges into Lake Stechlin in Germany. Lake Stechlin is a self-contained lake with no outlet to the marine environment. Data on the dimensions and flow rate of the lake and on the population living nearby were obtained from the Worlds Lake Database (2010). The population living close to the lake varies considerably over the year, from 1,095 to 415,000 (Worlds Lake Database, 2010). It was assumed that the average population living close to the lake and drinking abstracted water is around 50,000 and that they consume 1 tonne of freshwater fish per year (Worlds Lake Database, 2010). The consumption rate for freshwater fish for the representative person was the consumption rate for Germany given in Table 5. It was also assumed that some irrigation of the surrounding farmland takes place (Worlds Lake Database, 2010).

For the Trawsfynydd nuclear reactor site, individual and collective doses were calculated for the ingestion of fish only, since water from the lake is not consumed by people or used for irrigation in any significant way (Carey et al, 1996).

4.3.3 Calculations of doses from discharges to sea

Doses arising from the exposure to radionuclides in the marine environment were calculated based on discharges from both inland and coastal sites (see Table A4 in Appendix A for the sites discharging into a particular region of the sea). Most coastal sites are sufficiently far apart that it was reasonable to assume that they have separate representative persons. However, in some limited cases, more than one nuclear site discharges into the same coastal area. For example, the representative person for coastal sites at Borssele and Doel reside on the Rhine and Meuse estuary and therefore also receive doses from discharges of a number of nuclear sites into those rivers. These doses were added. Doses to the representative person located within the country, or countries, adjacent to the local marine environment into which the discharge occurred were considered. Romania was included because, although it was not an EU member state in 2004, the representative person for discharges to the river Danube to the marine environment was likely to be located in Romania.

For the calculation of doses from discharges to sea the exposure pathways considered were ingestion of sea fish, crustaceans and molluscs, external exposure to radionuclides in beach sediment and on fishing gear and inhalation of sea spray (these last two only for individual doses) (see Table 3).

4.3.4 Marine catch data and intake rates of aquatic foods

Catches of marine fish, molluscs and crustaceans, for use in collective dose calculations, were updated using information published by FAO (FAO, 2010) and derived from statistics gathered by the regional fishery bodies, International Council for the Exploration of the Sea and General Fisheries Commission for the Mediterranean (FAO, 2010; ICES, 2011). The basic catch data were derived from the landings of seafood reported by each nation. Significant manipulation of these data was required to obtain an estimate of the amount of seafood caught in each sub-region of the sea and subsequently consumed in each EU Member State, using additional information on wastage, uses other than food consumption and imports and exports. The main sources for these data were FAOSTAT (FAOSTAT, 2010) and the EUROSTAT ComExt database (Eurostat, 2012b). The fraction of the catch used for domestic consumption was taken from FAOSTAT food balance sheets, while statistics on trade between EU Member States were derived from the ComExt database. Detailed matrices of catch data for each sea region and country were developed, taking into account the impact of imports, exports and uses other than food consumption. Finally, these results were transposed from the sea regions of the ICES database to those regions defined in the marine dispersion model used by PC-CREAM 08. Comparisons with the data used in the previous study, which were based on the MARINA II project (EC, 2003), indicated that in general, changes in catches of marine biota were less than a factor of two in most cases.

Ingestion rates for the various aquatic foods used in the calculation of individual doses to the representative person were derived using the methodology described in the guidance on the assessment of radiation doses to members of the public due to the operation of nuclear installations under normal conditions (Jones et al, 2006) and using data from FAOSTAT (FAOSTAT, 2007). They are given in Tables 5 and 6 for freshwater fish and marine food respectively.

Table 5: Freshwater food ingestion rates for adults used in the calculation of doses to the representative person arising from aquatic discharges (kg y^{-1})

Country	Freshwater fish
Austria	27
Belgium	34
Czech Republic	16
France	29
Germany	26
Hungary	6
Lithuania	17
Portugal	9
Slovakia	6
Slovenia	8
Spain	23
The Netherlands	10
United Kingdom	23

Table 6: Marine food ingestion rates for adults used in the calculation of doses to the representative person arising from aquatic discharges (kg y^{-1})

Country	Marine fish	Molluscs	Crustaceans
Finland	64	0.9	27
France	67	31	61
Germany	34	1.9	14
Latvia	30	1.1	19
Portugal	160	26	35
Romania	16	0.1	0.1
Spain	83	37	73
Sweden	54	1.9	110
The Netherlands	60	1.6	3.1
United Kingdom	47	4.0	52

4.4 Differences in methodology and data used for previous study

This assessment of doses to individuals and the population of the EU uses the radiological impact assessment software PC-CREAM (Smith et al, 2009) whereas the previous study of this type (EC, 2008) used PC-CREAM 98 (Mayall A et al, 1997). One of the aims of this type of assessment was to identify trends in the doses received over time and therefore it was important to identify whether changes in exposures are due to changes in discharges, modelling approaches or the behaviour of individuals and populations. The main changes are summarised below.

- Some refinements to the methodology of the calculation of doses were introduced. The impact of these changes depends on the radionuclide and pathway being considered.
- The population, seafood catch and agricultural production data were updated.
- The region defined as Europe was refined to cover EU Member States only

The following sections identify in more detail some of the main differences between new and old versions of PC-CREAM that have an impact on the calculation of dose.

4.4.1 Assessment of doses from liquid discharges

4.4.1.1 Differences in the methodology

Updates to the marine dispersion model implemented in PC CREAM 08, which is based on the findings of the MARINA II study (EC, 2003), increased the extent of the region modelled in the previous version of PC CREAM and better represents the process by which radionuclides are remobilised from marine sediments. In addition, sediment distribution coefficients were reviewed. Activity concentrations in water and sediments are determined by the complex interaction of processes affecting sedimentation, remobilisation and the movement of water. Some of these processes are radionuclide dependent and it is not possible to draw a general conclusion about the impact of modelling changes.

The river model has been revised to include the transfer of radionuclides from water to bed sediment. Particularly where a site discharges far upstream, this has the effect of reducing the activity discharged that reaches the sea. In addition, concentration factors for freshwater fish, sediment distribution coefficients have been reviewed. The impact on dose is very dependent on radionuclide. One of the significant changes was an increase in the concentration factor for freshwater fish for ^{14}C from a value of $5\ 10^{3}$ in PC-CREAM 98 to $5\ 10^{4}$ Bq t^{-1} per Bq m^{-3} in PC-CREAM 08 based on a review of more recently published data (IAEA, 2001). This means that the doses calculated for individuals resulting from the ingestion of

4.4.1.2 Differences in the data used in the calculation of collective doses from discharges to sea

PC-CREAM 08 used new seafood catch data in the calculation of first pass collective doses from marine discharges. Overall there has been a general reduction in annual catches of seafood from about $12\ 10^{6}$ t (live weight) in 1994 to about $10\ 10^{6}$ t (live weight) in 2009 (FAOSTAT, 2010). This reduction in catches has the effect of reducing the collective dose. However, doses cannot simply be scaled by the total catch because the activity concentration in sea water in the different regions varies. The effect of changes in the catch data is a slight decrease in the doses.

4.4.1.3 Differences in the data used in the calculation of collective doses from discharges to river

A review of the number of people living in the major population centres along each river was undertaken for this study. In comparison with the previous study (EC, 2008), in most cases the number of people has decreased. However, populations from the new Member States living along the river Danube and its tributaries (Slovakia, Hungary, Czech Republic and Slovenia) and the river Vltava, a tributary of the Elbe (Czech Republic) have been included. This means that the population assumed to live along the river Danube has increased from $1\ 10^{5}$ people in the previous study (EC, 2008) to $8\ 10^{5}$ people, while the population living along the river Elbe has increased from $9\ 10^{5}$ people to $2\ 10^{6}$ people.

4.4.2 Assessment of doses from atmospheric discharges

4.4.2.1 Difference in the methodology

PC-CREAM 98 does not include a reduction factor for external irradiation from deposited radionuclides for time spent indoors in the calculation of collective doses. However, in PC-CREAM 08 a reduction factor of 0.1 is used for 90% of the time spent at the location. This results in a reduction in dose from external exposure to gamma radiation on the ground by a factor of about five. This reduction has an impact on all gamma emitting radionuclides that are deposited on the ground.

4.4.2.2 Differences in the data used in the calculation of collective doses from atmospheric discharges

The population and agricultural production data used in PC-CREAM 98 covered a wide European population, including parts of Western Russia and Turkey. The population and agricultural production grids used in this study were refined to cover the current EU Member States only (see Section 4.2) resulting in a reduction in the collective dose.

5. RESULTS AND DISCUSSION

5.1 Results of the assessment of doses from atmospheric discharges

5.1.1 Collective doses

Figure 3 shows the estimated collective dose integrated to 500 years to the population of the EU from reported annual atmospheric discharges from nuclear power stations and the reprocessing sites at Sellafield and Cap de la Hague. The collective dose includes contributions from the first pass and global components (see Section 4.1). Dose estimates for selected years between 1987 and 2004 were taken from the previous studies (EC, 2002a, 2008) and those for 2004 and 2008 were calculated in the current assessment. Doses for 2004 from the previous study (EC, 2008) and the current assessment are both presented.

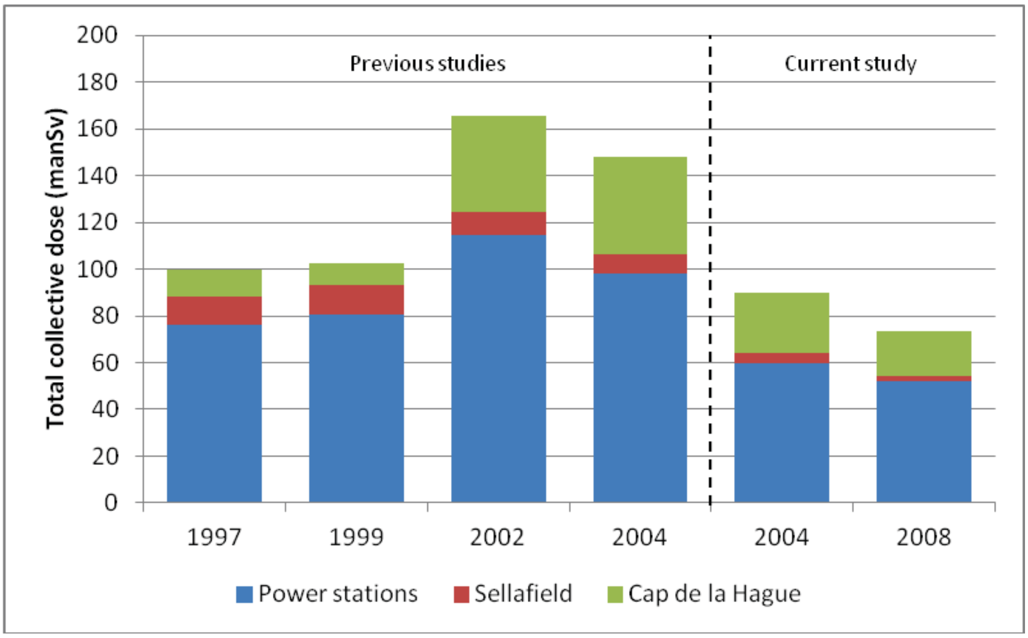

Figure 3: Implied collective doses to the EU population integrated to 500 y arising from reported atmospheric discharges from all nuclear power stations, Sellafield and Cap de la Hague (for Cap de la Hague and some nuclear power stations, reported discharges did not include ^{14}C in the years 1997 and 1999)

Doses for 1997 and 1999 do not include contributions from discharges of ^{14}C to atmosphere from Cap de la Hague and some nuclear power stations in France. For these sites ^{14}C discharges were only reported to the EC from 2002 onwards when it became a regulatory requirement to do so.

Figure 3 shows that the collective dose assessed for this study did not vary greatly from 2004 to 2008 remaining between about 90 and 70 man Sv. The decrease in collective dose in 2004 from the previous study (EC, 2008) to the current assessment reflects the decrease in population as discussed in Section 4.4.2.2.

In general, reported atmospheric releases from power production sites were responsible for slightly less than 70% of the estimated collective dose to the EU population. The collective dose calculated for power production sites was around 60 man Sv in 2004 and reduced to around 50 man Sv in 2008.

The largest contribution to the collective dose arose from the older generation gas-cooled reactors (GCRs) and advanced gas-cooled reactors (AGRs) still in operation which was around 20 man Sv in 2004 and reduced to 10 man Sv in 2008, mainly as a result of the closure of Dungeness A and Sizewell A in 2006, both of which are GCRs. Gas-cooled reactors and, to a lesser extent AGRs, release larger amounts of ^{14}C as gas than other reactor types as a result of the purification of the CO_2 circuits used to cool the reactor and from isotopic exchange between the moderator and the CO_2 circuit.

For some sites there was an increase in reported discharges, the most notable example being for the Spanish sites. In 2004 only Trillo reported discharges of ^{14}C to atmosphere, whereas in 2008 ^{14}C discharges were reported for all sites. The resulting collective dose from these sites changed from around 0.1 man Sv in 2004 to 6 man Sv in 2008 reflecting the addition of reported ^{14}C discharges.

Significant contributions to the implied collective dose also came from the reprocessing sites at Cap de la Hague and Sellafield, which contribute approximately 30% and 5% to the total, respectively.

Figures 4 and 5 show the reported atmospheric discharges of ^{14}C from Cap de la Hague and Sellafield and the total collective dose from all atmospheric discharges from these sites in the years 1997 to 2008 as this radionuclide is the most important contributor to dose.

Collective doses resulting from reported atmospheric discharges from each site are presented in Appendix B.

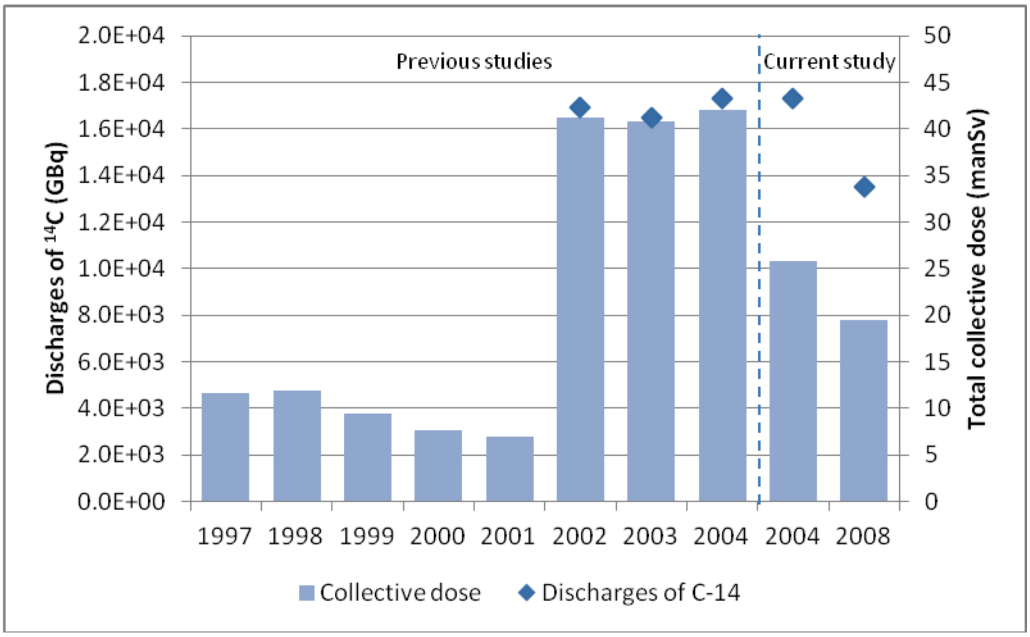

Figure 4: Reported atmospheric discharges of ^{14}C from Cap de la Hague and implied total collective dose to the EU population integrated to 500 y from exposure to all reported atmospheric discharges

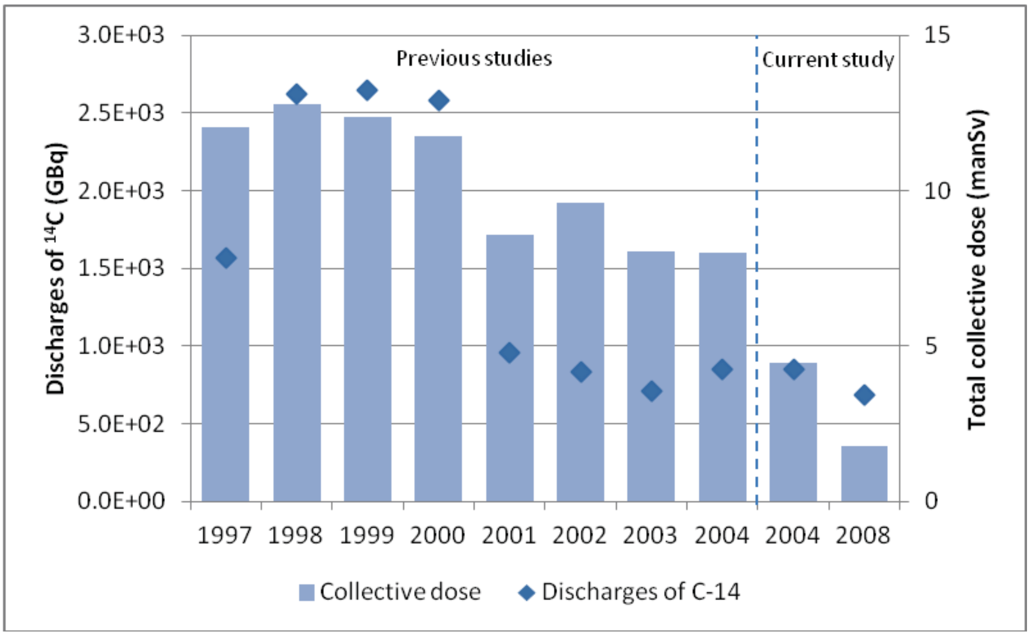

Figure 5: Reported atmospheric discharges of ^{14}C from Sellafield and implied total collective dose to the EU population integrated to 500 y from exposure to all reported atmospheric discharges

The collective doses given in this section can be put in context by considering the annual collective dose to the EU population from natural radioactivity which, based on UK data (Watson et al, 2005), is estimated to be several hundred thousand man Sieverts.

5.1.2 Individual doses

Figure 6 shows the numbers of sites for which the individual dose calculated was greater than 10 µSv y^{-1}. The figure illustrates the general reduction in the maximum dose over time. The highest maximum dose to the representative person from 1996 to 2002 was that estimated for the Chapelcross site (EC, 2008), which has four gas-cooled reactors (GCRs) and also produces tritium. The dose resulted predominantly from discharges of ^{3}H. In 2004 the maximum dose to the representative person of just over 40 µSv y^{-1} was estimated for discharges from the Dungeness A site. Just over 50% of the dose was estimated to result from discharges of ^{14}C and most of the remaining dose from ^{41}Ar. Argon-41 is a characteristic release from the UK GCRs (also known as Magnox reactors) produced by the neutron activation of natural ^{40}Ar in the shield cooling air. The dose to the representative person for another gas-cooled reactor, Sizewell A, was calculated to be just under 40 µSv y^{-1} with most of the dose being due to ^{41}Ar discharges. Chapelcross was shut down in 2004, while both Dungeness A and Sizewell A were shut down in 2006. As a result, the maximum dose to the representative person calculated for 2008 was 20 µSv y^{-1}, from discharges from Wylfa, the last remaining operating GCR in Europe.

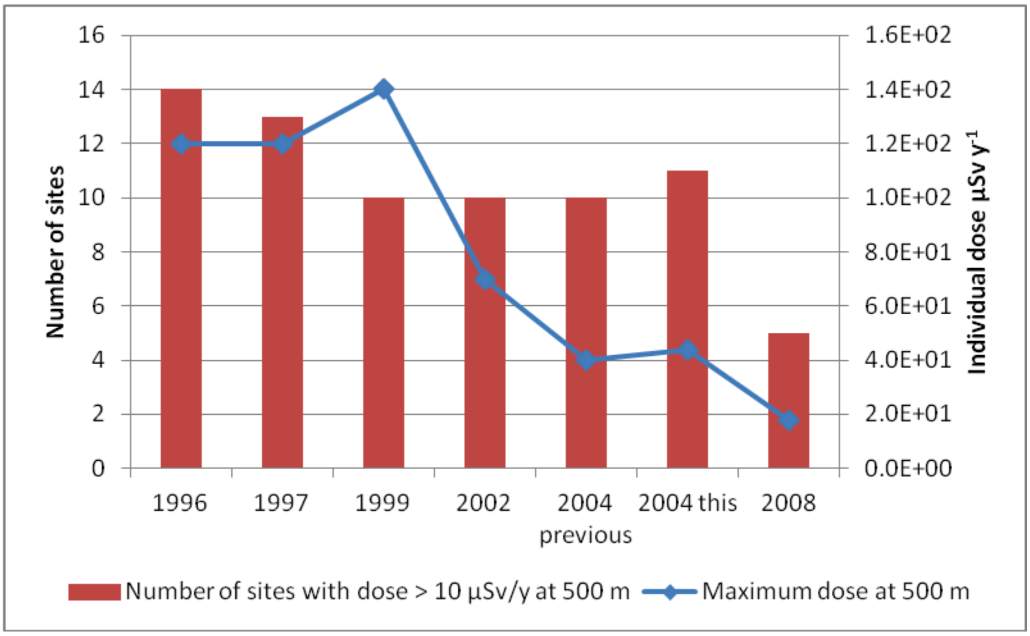

Figure 6: Maximum dose received by a representative person living 500 m from operating nuclear power stations (µSv y^{-1}) as a result of reported atmospheric discharges and the number of sites where the dose is greater than 10 µSv y^{-1}

The discharges from Sellafield and Cap de la Hague represent all activities on these sites and not just those related to the reprocessing of nuclear fuels. Figure 7 shows how the doses to a representative person at 500 m from each site due to reported atmospheric discharges have changed over the years. Doses for discharges occurring in the period 1987 to 2004 were taken from the previous studies (EC, 2002a, EC 2008), and doses for discharges occurring in 2004 and 2008 were calculated in this study. It should be noted once more that prior to 2002 atmospheric discharges of ^{14}C from Cap de la Hague were not part of the discharge inventory reported to the EC. Consequently, doses received by members of the public are likely to be underestimated for these years.

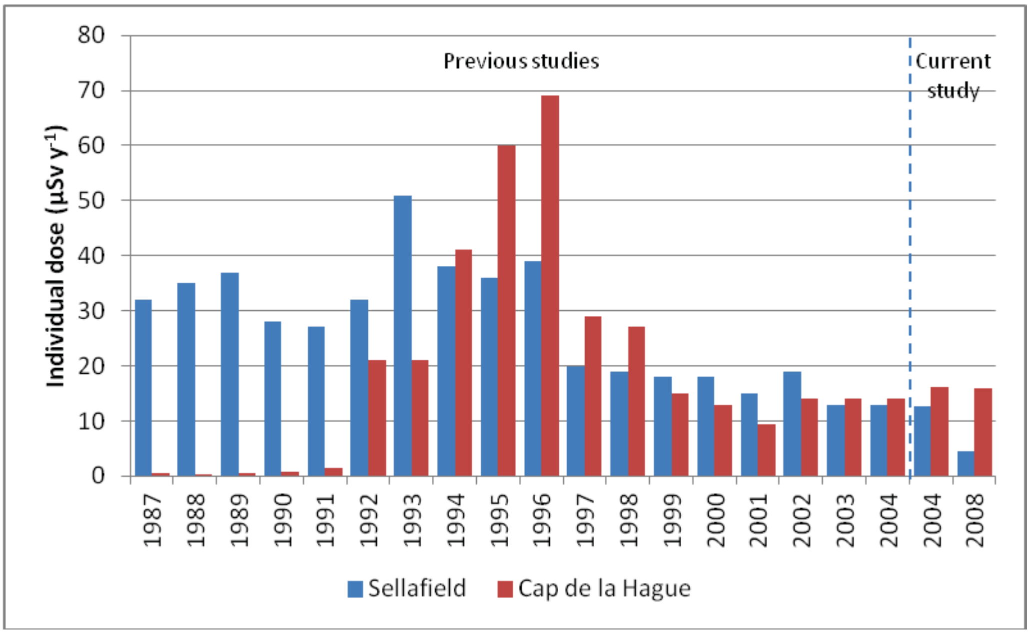

Figure 7: Doses to a representative person at the Sellafield and Cap de la Hague sites, based on reported atmospheric discharges, for a representative person living 500 m away from the point of release. For Cap de la Hague reported discharges did not include ^{14}C prior to 2002

From Figure 7 it can be seen that there is a slight increase in the dose to the representative person at the Cap de la Hague site in 2004 from the previous study (EC, 2008) to this one. This rise mainly reflects the slight increase in the consumption of milk products assumed for France from the previous study, from 74 kg y^{-1} to 93 kg y^{-1} based on more recent FAOSTAT data (FAOSTAT, 2007). A reduction in doses to the representative person at Sellafield from 2004 to 2008 mainly reflects the decrease in annual discharges of ^{129}I from 16 GBq to 6 GBq.

Figure 7 shows that the annual dose to the representative person for Sellafield at 500 m decreased from about 40 µSv in 1996 to about 5 µSv in 2008, while for Cap de la Hague it decreased from about 70 µSv to about 15 µSv over the same period.

Tables providing indicative individual doses to representative persons from discharges to the atmosphere for each site are presented in Appendix B.

5.2 Results of the assessment of doses from liquid discharges

5.2.1 Collective doses

5.2.1.1 Collective doses from discharges from inland sites to rivers and lakes

Collective doses to the EU population from discharges from inland sites to various European rivers and lakes are shown in Figure 8. Dose estimates were taken from the previous studies (EC, 2002a, 2008) and those for 2004 and 2008 were calculated in the current assessment. Doses for 2004 from the previous study (EC, 2008) and the current assessment are both presented. The collective doses were dominated by discharges of ^{3}H into the river systems. Consequently, the fact that discharges of ^{14}C were only reported after 2001 for some sites had only a small impact on estimates of collective dose. The decrease in doses for 2004 from the previous study (EC, 2008) reflects the decrease in population assumed to be living along river banks in this study. The highest collective doses were estimated for the river Rhine reflecting the large number of people living near this river. There is an increase in the collective dose calculated for the river Elbe in 2008 as a result of the increase in discharges of ^{3}H from the Temelín nuclear power plant (from 2 10^{12} Bq in 2004 to 5 10^{13} Bq in 2008).

A level of caution should be attached to these results due to the uncertainty associated with the amount of drinking water that is extracted from each of the rivers and lakes considered in the assessment.

The total collective dose for each inland site also includes the resulting doses from discharges to sea which is discussed in Section 5.2.1.2.

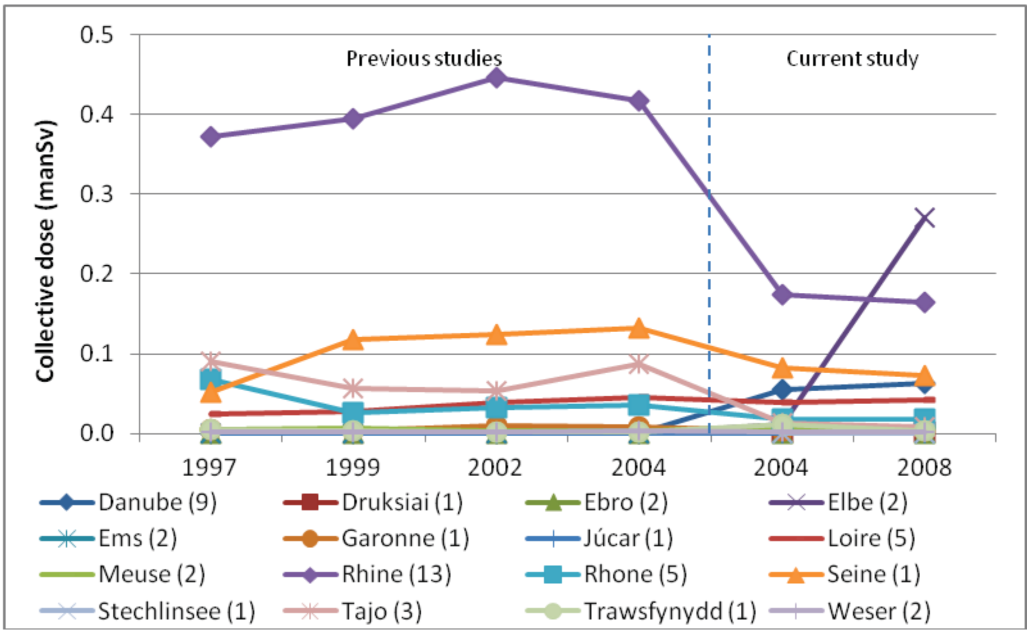

Figure 8: Implied collective doses integrated to 500 y to the EU population from drinking water as a result of reported discharges to rivers from inland sites. Legend includes number of sites in brackets

5.2.1.2 *Collective doses from discharges from inland and coastal sites to sea*

Collective doses from discharges into the marine environment may arise from both inland sites and coastal sites.

Figure 9 shows collective doses integrated to 500 years for nuclear power stations, Sellafield and Cap de la Hague based on reported discharges into the marine environment. The importance of liquid discharges from the coastal sites of Sellafield and Cap de la Hague can be seen.

Figure 10 shows the implied collective doses from inland and coastal nuclear power stations arising from marine discharges integrated to 500 years, while Figure 11 gives a breakdown by river of the collective dose resulting from discharges which reach the sea. As discussed previously, not all sites reported discharges of ^{14}C before 2002 and therefore collective doses for discharges before that year are generally lower as can be seen in Figures 10 and 11. These figures also highlight the changes in modelling approach used for rivers between this study and the previous one (EC, 2008), since the new approach tends to result in lower discharges into estuaries for inland sites and hence gives rise to lower doses.

Figure 12 shows the first pass and global contribution from all sites to implied collective doses from discharges to sea. The doses were greater from 2002 onwards because of the inclusion of ^{14}C in the discharges reported. There was a decrease in the doses in 2008 which reflect the general decrease in discharges from Sellafield and Cap de la Hague, and in particular the decrease of discharges of ^{14}C from Sellafield which fell from 16 10^{12} Bq in 2004 to 7 10^{12} Bq in 2008.

Figures 13 and 14 show the discharges and total marine collective dose integrated to 500 years for the Cap de la Hague and Sellafield sites for ^{14}C which is the most significant radionuclide in terms of contribution to dose.

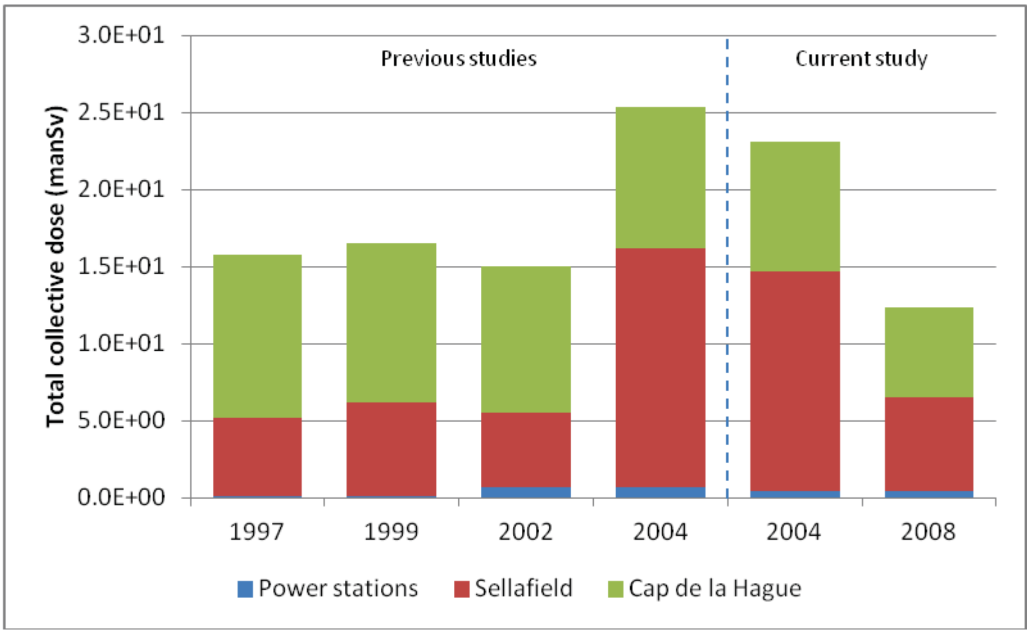

Figure 9: Implied collective doses integrated to 500 y to the EU population arising from reported marine discharges from all nuclear power stations, Sellafield and Cap de la Hague (for some sites reported discharges did not include ^{14}C prior to 2002)

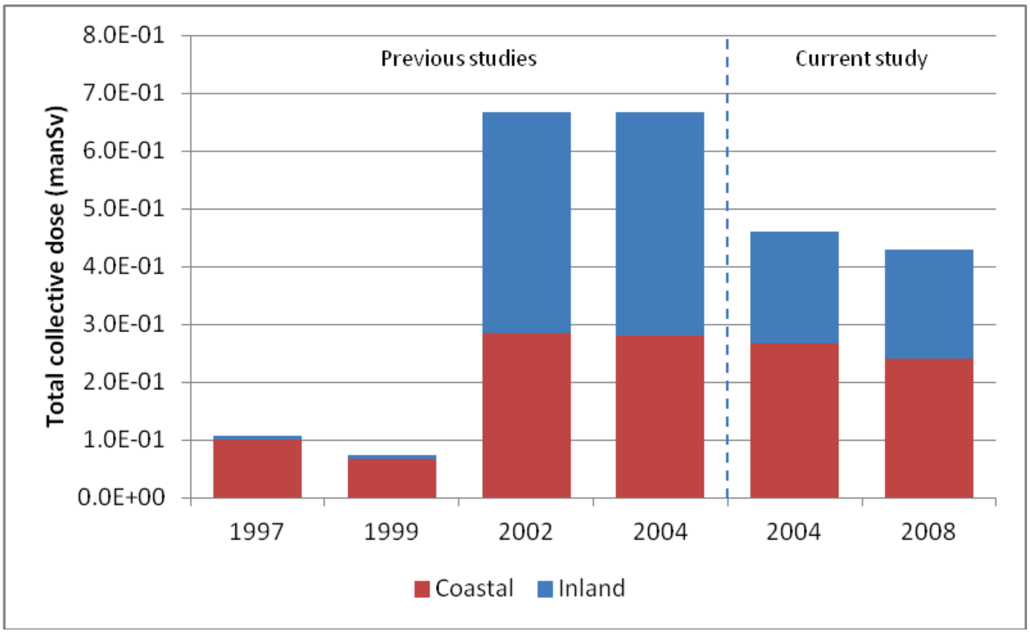

Figure 10: Implied collective doses integrated to 500 y to the EU population arising from reported marine discharges from all nuclear power stations (for some sites reported discharges did not include ^{14}C prior to 2002)

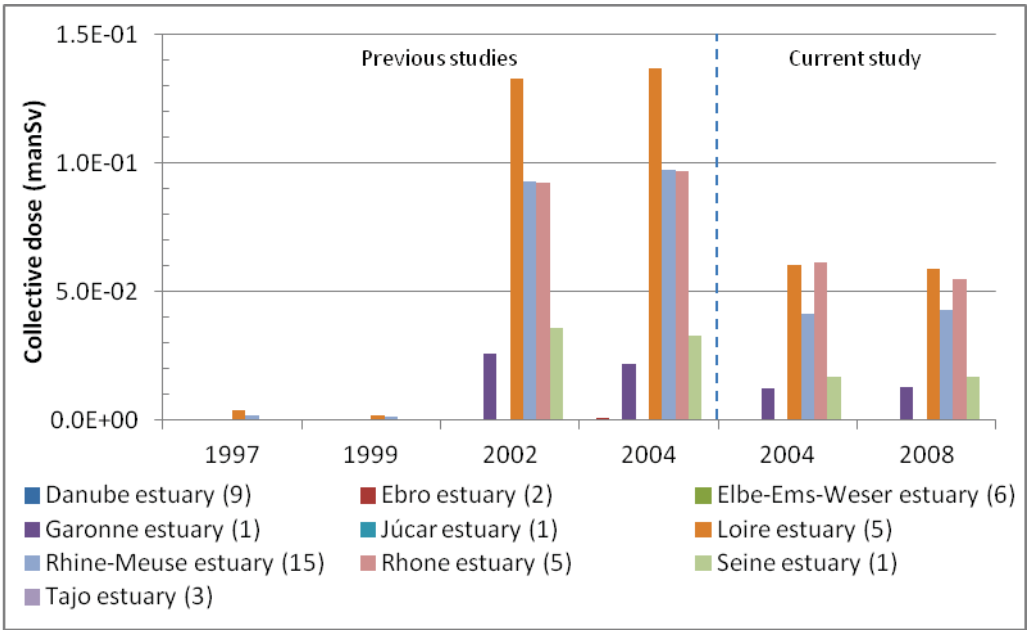

Figure 11: Implied collective doses integrated to 500 y to the EU population arising from reported marine discharges from inland sites (for some sites reported discharges did not include ^{14}C prior to 2002). Legend includes number of sites in brackets

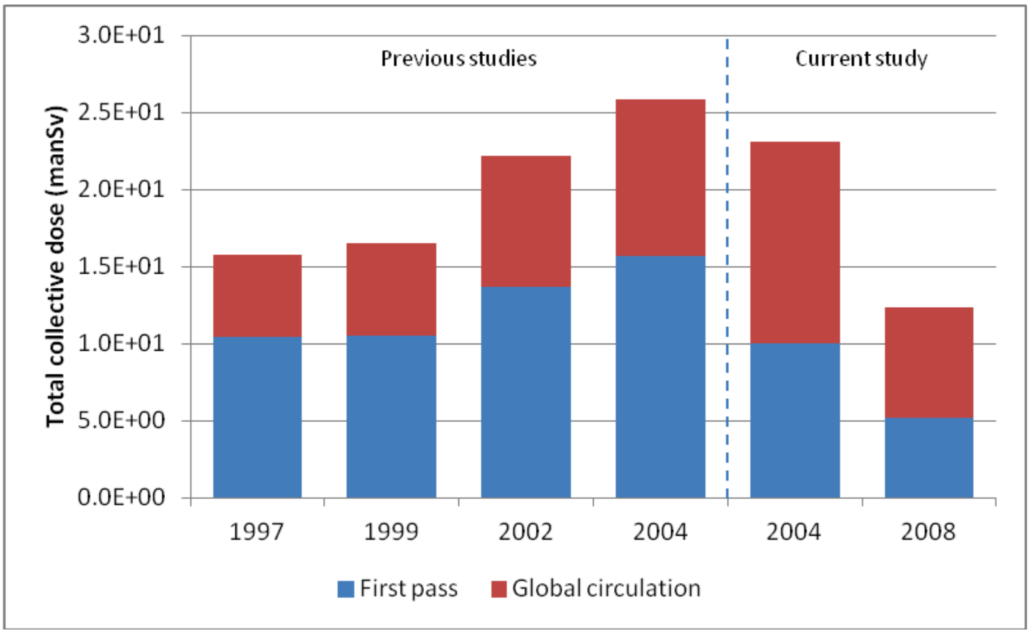

Figure 12: Implied collective doses integrated to 500 y to the EU population arising from reported marine discharges from all sites, showing contributions from global and 'non-global' (first pass) components (for some sites reported discharges did not include ^{14}C prior to 2002)

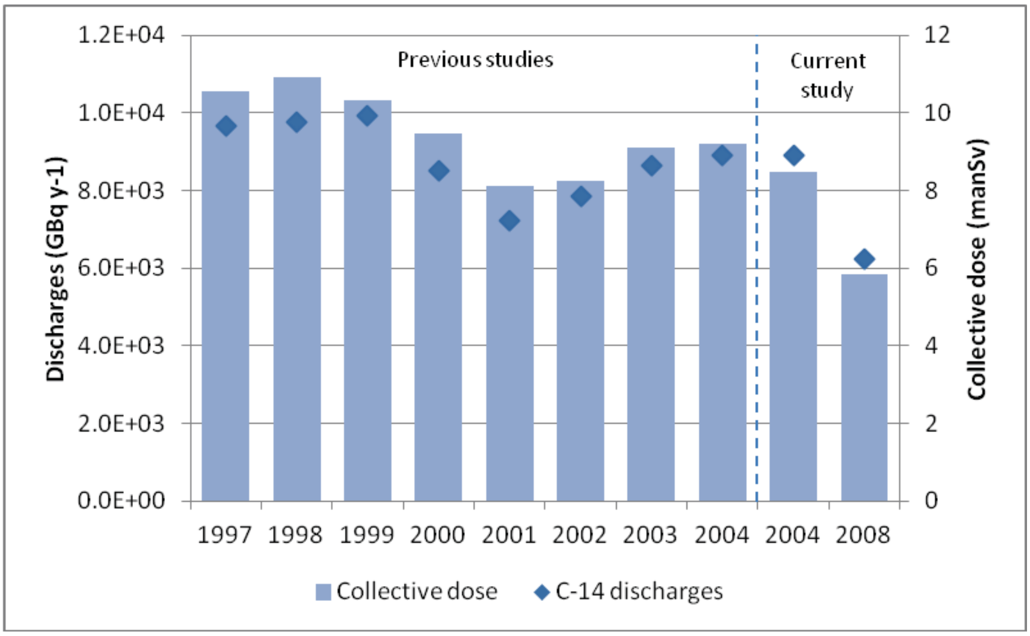

Figure 13: Reported liquid discharges of ^{14}C from Cap de la Hague and implied total collective dose to the EU population integrated to 500 y from exposure to all reported liquid discharges

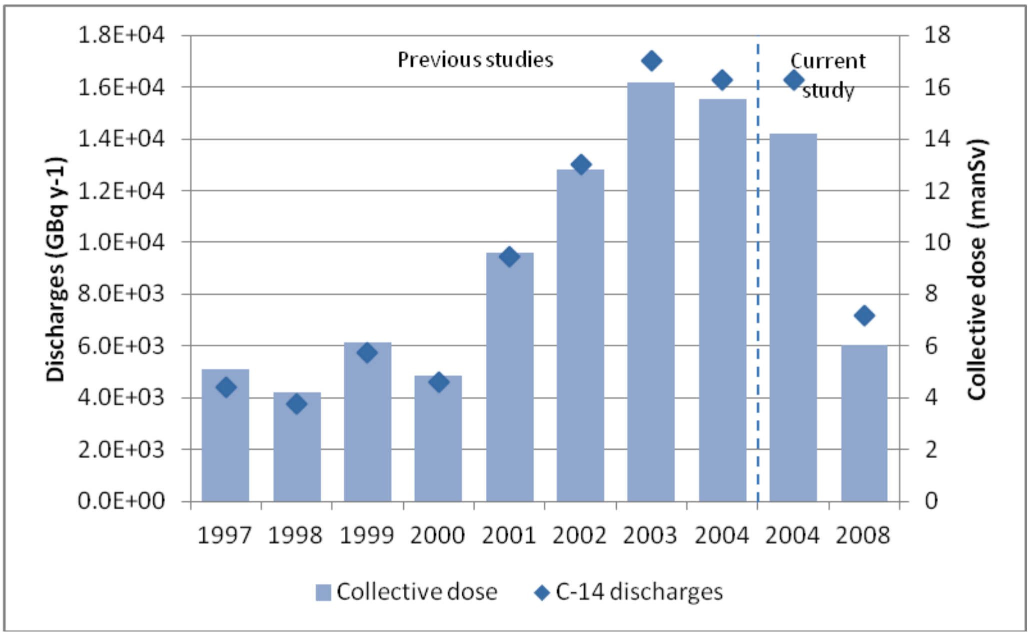

Figure 14: Reported liquid discharges of ^{14}C from Sellafield and implied total collective dose to the EU population integrated to 500 y from exposure to all reported liquid discharges

5.2.1.3 Overall collective doses from liquid discharges

The overall collective dose from liquid discharges included a contribution from the marine environment, as a result of discharges to sea from both inland and coastal sites, as well as a contribution directly from rivers and lakes due to discharges from inland sites. Figures 15 and 16 show, respectively, the total collective doses integrated to 500 years for all sites and for nuclear power stations only. The highest total collective dose integrated to 500 years for liquid discharges from all sites occurred for 2004 discharges and was calculated for this study to be about 24 man Sv, of which almost 98% was from releases to the marine environment. This reflects the importance of the discharges from the two coastal sites, Sellafield and Cap de la Hague.

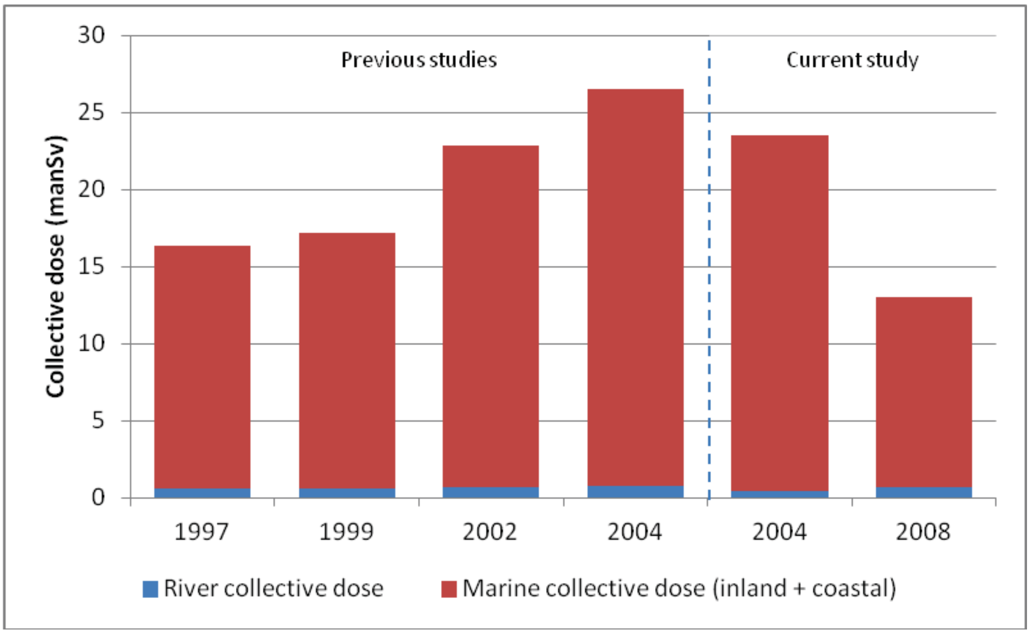

Figure 15: Implied collective doses integrated to 500 y to the EU population arising from reported river and marine discharges for all nuclear sites (for some sites reported discharges did not include ^{14}C prior to 2002)

If the discharges from nuclear power stations only are considered (Figure 16), then the relative importance of the dose from discharges to rivers increases significantly.

The difference in the estimated doses for 2004 between this study and the previous one (EC, 2008) reflect the decrease in seafood catch data and the smaller number of people assumed to be living along the river in this study. This outweighed the slight increase in the dose which resulted from the inclusion of the sites in the new Member States. The increase in dose in 2008 mainly resulted from the increased ^{3}H discharges to the River Elbe from the Temelín site.

As for atmospheric releases, the collective doses given in this section can be put into context by considering the annual collective dose to the EU population from natural radioactivity which is estimated to be several hundred thousand man Sieverts, based on UK data (Watson et al, 2005).

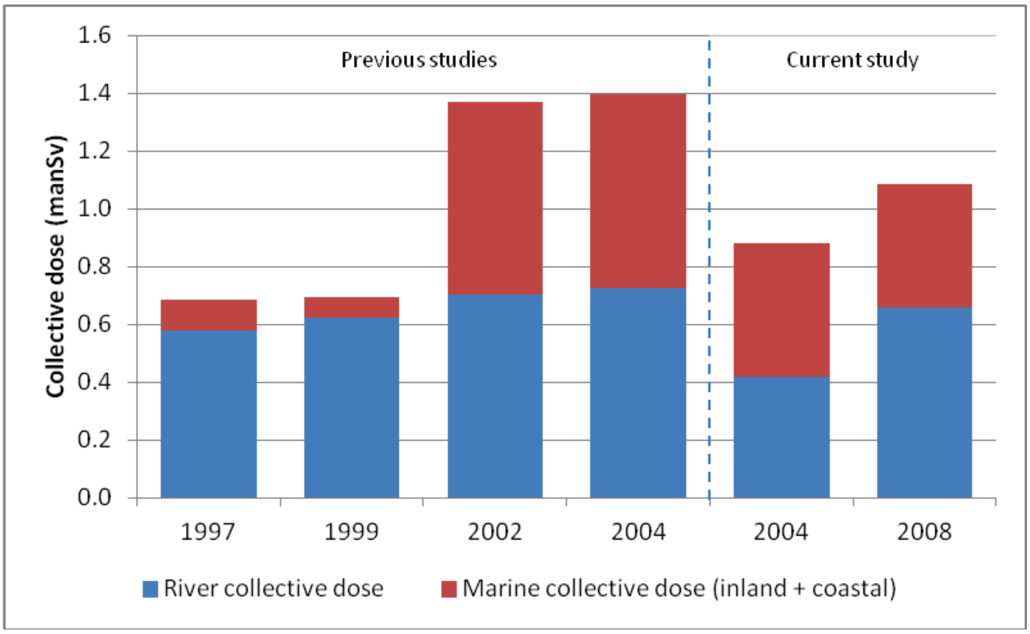

Figure 16: Implied collective doses integrated to 500 y to the EU population arising from reported river and marine discharges for all nuclear power stations (for some sites reported discharges did not include ^{14}C prior to 2002)

5.2.2 Individual doses

5.2.2.1 Individual doses from discharges from inland sites to rivers and lakes

Indicative individual doses to representative adults living along 13 European rivers and 3 lakes were calculated. These results are presented in Table C2 of Appendix C and the highest estimated individual doses for each river are presented in Figure 17 and Table 7. The individual dose from liquid discharges to Lake Druksiai, Stechlin and Trawsfynydd are given in Table 8. From Figure 17 it can be seen that the estimated doses were much higher for discharges following 2002 due to the inclusion of ^{14}C in the discharges reported to the EC.

The doses in 2004 have increased in this study from the previous one (EC, 2008) due to changes in the modelling of the rivers (as discussed in Section 4.4.1.1) and the ten-fold increase in the concentration factor for ^{14}C for freshwater fish as can be seen in Figure 17

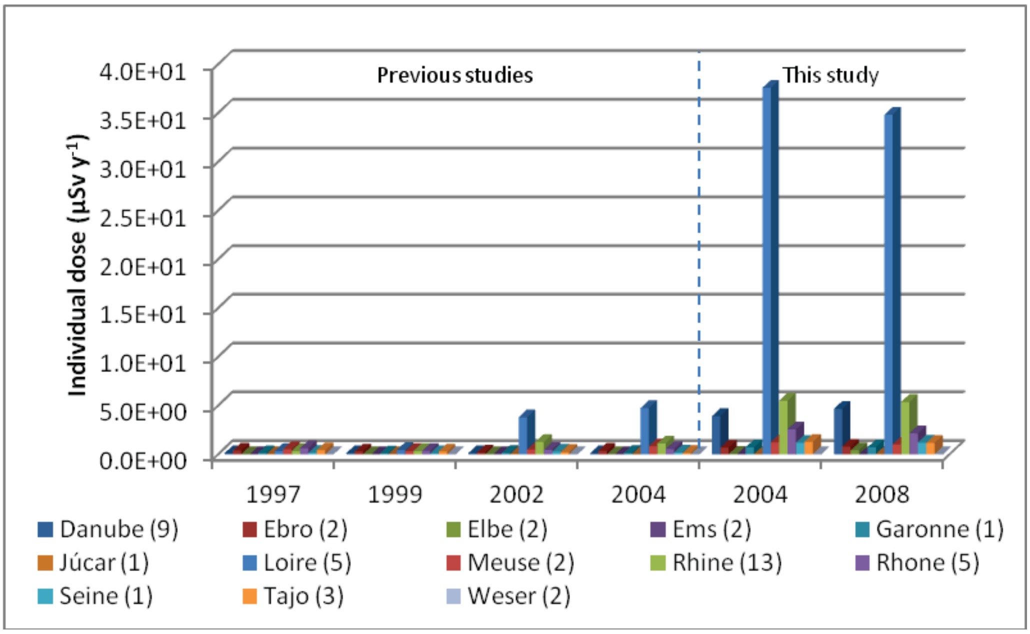

Figure 17: Representative adult doses arising from reported discharges into each river system (for some sites reported discharges did not include ^{14}C prior to 2002). Legend includes number of sites in brackets

Table 7: Estimated adult individual doses to a representative person for each river (µSv y^{-1})

	Previous study		This study		
River	Sites	2004	Sites	2004	2008
Danube	3	$1.1\ 10^{-1}$	9	$3.9\ 10^{0}$	$4.7\ 10^{0}$
Ebro	2	$3.7\ 10^{-1}$	2	$6.9\ 10^{-1}$	$7.9\ 10^{-1}$
Elbe	2	$3.8\ 10^{-4}$	2	$3.3\ 10^{-2}$	$4.2\ 10^{-1}$
Ems	2	$2.9\ 10^{-3}$	2	$2.9\ 10^{-3}$	$3.3\ 10^{-3}$
Garonne	1	$1.3\ 10^{-1}$	1	$7.2\ 10^{-1}$	$7.2\ 10^{-1}$
Júcar	1	$2.2\ 10^{-3}$	1	$3.9\ 10^{-3}$	$1.5\ 10^{-2}$
Loire	5	$4.8\ 10^{0}$	5	$3.8\ 10^{1}$	$3.5\ 10^{1}$
Meuse	2	$8.1\ 10^{-1}$	2	$1.2\ 10^{0}$	$1.0\ 10^{0}$
Rhine	13	$1.1\ 10^{0}$	13	$5.5\ 10^{0}$	$5.4\ 10^{0}$
Rhône	6[#]	$5.4\ 10^{-1}$	5	$2.6\ 10^{0}$	$2.2\ 10^{0}$
Seine	1	$1.9\ 10^{-1}$	1	$1.2\ 10^{0}$	$1.2\ 10^{0}$
Tajo	3	$1.4\ 10^{-1}$	3	$1.3\ 10^{0}$	$1.2\ 10^{0}$
Weser	2	$6.1\ 10^{-3}$	2	$6.3\ 10^{-3}$	$1.5\ 10^{-2}$

[#]: Included Marcoule, which no longer reports discharges

Table 8 Estimated adult individual doses to a representative person for each lake (µSv y^{-1})

	Previous study		This study		
Lake	Sites	2004	Sites	2004	2008
Druksiai	n/a	n/a	1	$6.6\ 10^{-1}$	$6.9\ 10^{-1}$
Stechlin	n/a	n/a	1	$6.3\ 10^{-1}$	$2.6\ 10^{-1}$
Trawsfynydd[#]	1	$6.3\ 10^{0}$	1	$1.8\ 10^{1}$	$4.8\ 10^{0}$

[#] Trawsfynydd has a very low flow rate out of the lake and this leads to a more pronounced build-up of radionuclides such as ^{137}Cs in fish.

5.2.2.2 *Individual doses from discharges to sea*

Individual doses to adult representative persons arising from exposure to radionuclides in the marine environment were calculated based on discharges from both inland and coastal sites. The doses for every site are given in Table C3 in Appendix C. Figure 18 shows the estimated individual doses for representative persons located on a river estuary. For some estuaries the doses were found to be considerably greater than those estimated for representative individuals living along the river (Figure 17). This was due to the assumptions that more types of marine food were consumed and at greater rates than freshwater fish. In addition, aquatic organisms concentrate ^{14}C effectively. This concentration of ^{14}C by aquatic organisms also explains the reason for individual dose from ingestion of drinking water being less significant than the ingestion of marine foods. As noted elsewhere, the higher doses from discharges from 2002 onwards were due to ^{14}C being reported in the discharge inventory for these years.

The doses estimated in 2004 for this study tended to be lower than those calculated for the previous one (EC, 2004) mainly due to changes in the river modelling discussed in Section 4.4.1.1 which, for most radionuclides, resulted in a lower activity concentration in water downstream. This difference was particularly noticeable where the distance between the discharge point and the estuary is large.

The highest doses to the representative person arising for marine discharges were found to occur as a consequence of reported discharges from the Cap de la Hague and Sellafield nuclear sites. For 2004, the doses to an adult representative person from liquid discharges from the Cap de la Hague and Sellafield nuclear sites were about 230 and 160 µSv y^{-1} respectively. In 2008, the doses decreased to about 150 and 50 µSv y^{-1} for Cap de la Hague and Sellafield respectively reflecting the lower discharges reported for that year from both sites.

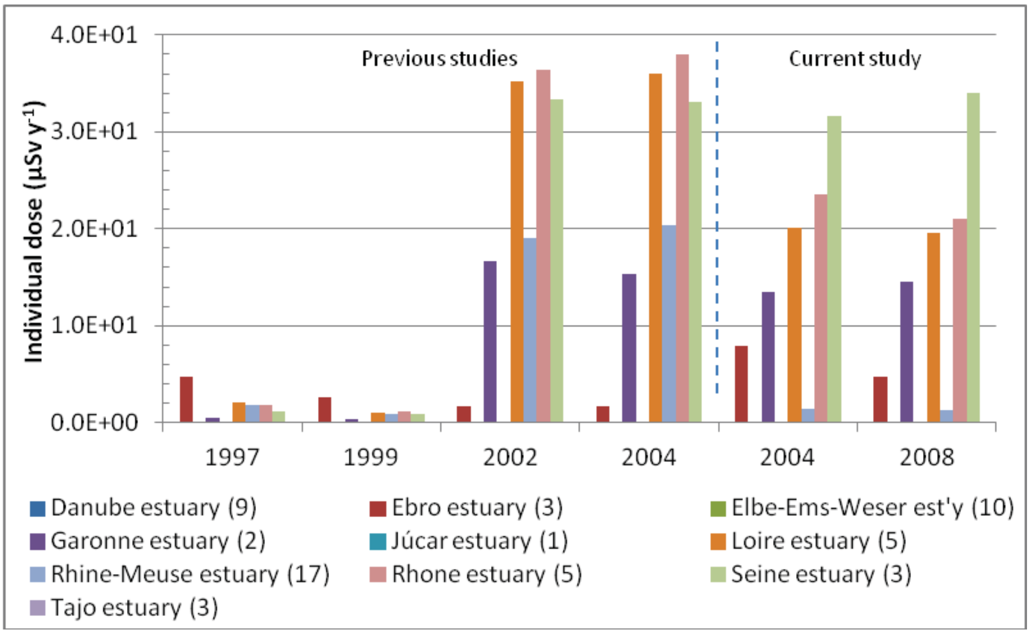

Figure 18: Doses to an adult representative person arising from reported discharges to each river estuary (for some sites reported discharges did not include ^{14}C prior to 2002). Legend includes number of sites in brackets

5.3 Collective doses from all discharges

Figure 19 shows collective doses integrated to 500 years to the EU population from both reported liquid and atmospheric discharges from all nuclear sites considered in this study. It is evident from this figure that atmospheric discharges made the most significant contribution, i.e. between 80% and 90% of the total collective dose. In general, it can be said that the total collective dose has not changed significantly over the period considered in this study. Figure 19 shows that there was an increase in collective dose in 2002, which reflects the more consistent reporting of atmospheric discharges of ^{14}C from this time. It can be seen that the collective dose in 2004 calculated in this study is lower than the dose calculated in the previous study (EC, 2008). The decrease in the collective dose is due to the smaller European population assumed for this study. Between 2004 and 2008 collective doses from both atmospheric and liquid discharges decreased by 20% and 40% respectively. This was mainly as a result of lower discharges from Cap de la Hague and Sellafield.

Figures 20 and 21 show the contributions that liquid and atmospheric discharges made to the collective dose from Cap de la Hague and Sellafield respectively. For Cap de la Hague estimates of collective dose reflect the reported levels of discharge of ^{14}C and these were known to be absent from the reported discharge inventory in the years 1997 to 2001 for atmospheric releases. For Cap de la Hague, both atmospheric and liquid ^{14}C discharges decreased in 2008 to about 80% of their 2004 values. This corresponds to approximately a similar magnitude decrease in dose. For Sellafield the collective dose in 2008 decreased to about 40% of its 2004 value due to a decrease in ^{14}C and ^{129}I discharges.

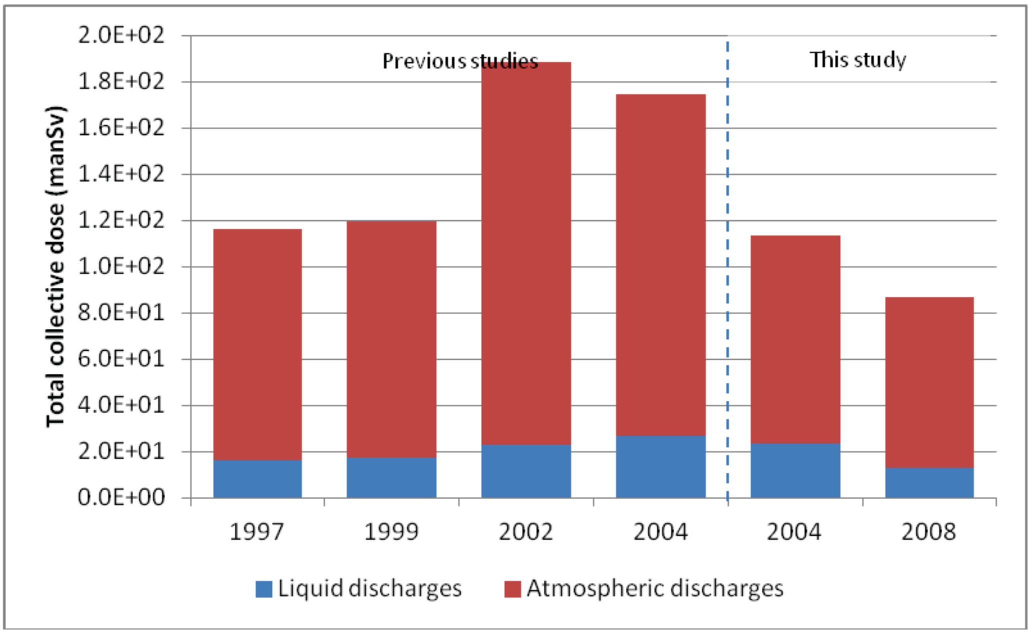

Figure 19: Implied total collective dose integrated to 500 y to the EU population from reported discharges from nuclear sites

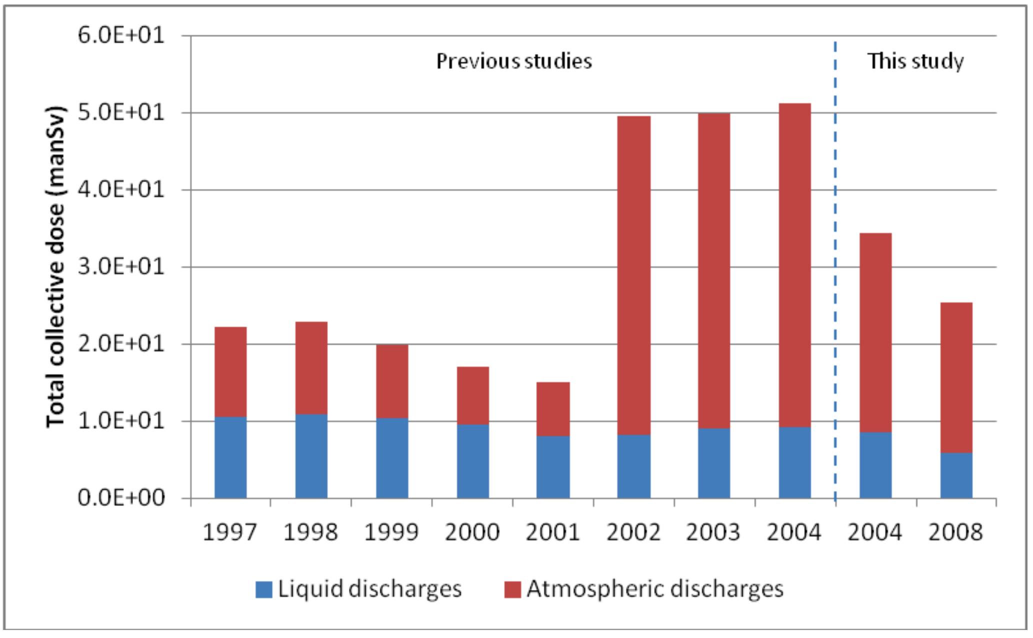

Figure 20: Implied total collective dose integrated to 500 y to the EU population arising from reported discharges from the Cap de la Hague site (before 2002, reported atmospheric discharges did not include ^{14}C)

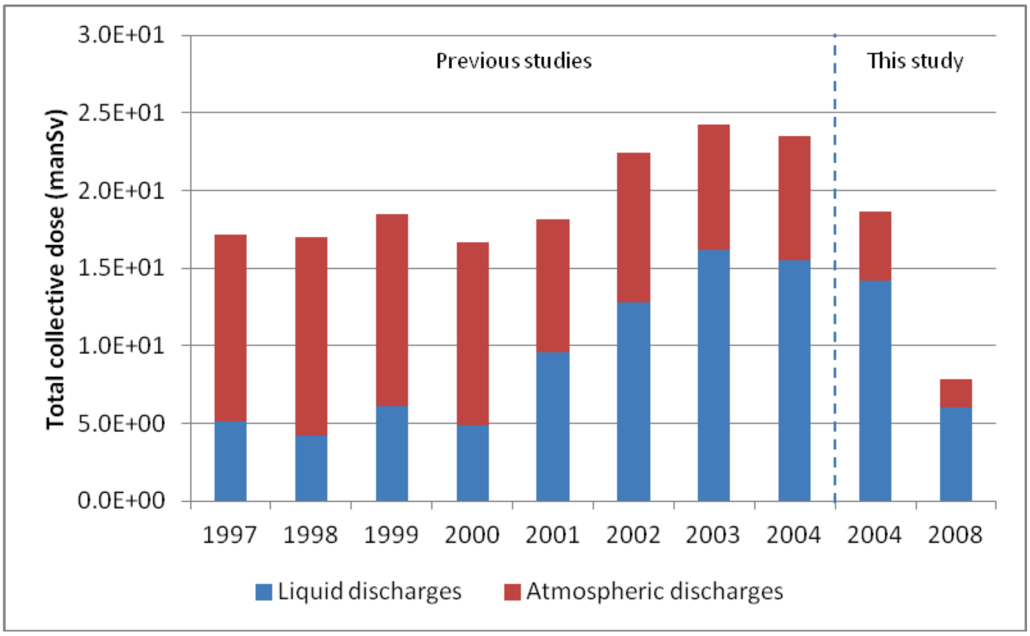

Figure 21: Implied total collective dose integrated to 500 y to the EU population arising from reported discharges from the Sellafield site

6. EFFECT OF SHUTDOWN OF SITES

The reported discharges used in this study included contributions from nuclear sites that closed both prior to and during the reporting period, i.e. 2004 to 2008. Table A1 gives details of the nuclear sites that are finally shut down or being decommissioned and are continuing to report discharges.

It is not always possible to assess the impact of these discharges independently because they are often included in the total discharge inventory of a site that may also contain other nuclear reactors still in operation. Discharges from nuclear sites where all reactors have been decommissioned are low when compared to the discharges of stations still in operation, and only make a small contribution to the dose.

6.1 Effect of shut down for atmospheric discharges

The impact of shutting down an individual nuclear facility varies from one site to the next and depends on a number of factors, such as the activity and type of radionuclides discharged, the reactor type, the discharge routes used, the operating capacity of the site prior to shut down and the decommissioned state of the facility.

Table 9 shows the dose to the representative person and collective dose prior to and following shut down of the Obrigheim (PWR) and Dungeness A (GCR) nuclear power stations. It can be seen that doses arising after the power station closed down are at least a factor of ten less than those received during normal operations.

Table 9 Implied doses arising from reported atmospheric discharges from selected sites before and after shut down

Site	Dose to the representative person at 500 m (μSv y^{-1})	Collective dose (man Sv)	
		First pass	Global
Obrigheim (PWR)	$1.2\ 10^{-1}$ (2004)*	$7.5\ 10^{-2}$ (2004)*	$3.8\ 10^{-2}$ (2004)*
	$5.2\ 10^{-3}$ (2008)#	$3.0\ 10^{-3}$ (2008)#	$1.5\ 10^{-3}$ (2008)#
Dungeness A (GCR)	$4.4\ 10^{1}$ (2004)*	$2.1\ 10^{0}$ (2004)*	$2.5\ 10^{0}$ (2004)*
	$3.1\ 10^{-2}$ (2008)#	$1.2\ 10^{-3}$ (2008)#	$8.9\ 10^{-4}$ (2008)#

* Pre-shut down

\# Post-shut down

In 2008 the total collective dose due to atmospheric discharges from the nuclear power stations and reprocessing sites was about 70 man Sv, the sites that were shut down contributed less than 1% to the dose.

Between 2004 and 2008 six sites were shut down: Barsebäck, Chapelcross, Dungeness A, José Cabrera, Obrigheim and Sizewell A. In 2004 the total collective dose from these sites was calculated to be 8 man Sv but in 2008, when all of these sites had shut down, the collective dose had decreased to 0.1 man Sv. In 2004 about 80% of the total collective dose from these sites was due to ^{14}C discharges from Dungeness A and Sizewell A which are both the older design type of gas-cooled reactors (Magnox reactors), which released a large amount of ^{14}C relative to other reactor types.

6.2 Effect of shutdown for liquid discharges

For those nuclear sites that were shut down between 2004 and 2008 the impact on the total collective dose arising from reported marine discharges was very small. This was because this discharge route was dominated by discharges from Cap de la Hague and Sellafield, which have not closed down. The impact of the sites that have shutdown on the individual doses from marine discharges is hard to distinguish due to the discharges from other sites, for example although Sizewell A has shut, Sizewell B is still operating and discharging to the same marine environment.

José Cabrera and Obrigheim discharge to the rivers Tajo and Neckar respectively. The doses to those living near the river, both collective and individual, are very low relative to other sites.

7. EFFECT OF SITES FROM NEW MEMBER STATES

The contribution of the sites from the new Member States to the total collective dose for atmospheric discharges is small, about 5%. The contribution of the sites to the total collective doses from reported marine discharges was even smaller, less than 0.1%. This was because the main contributions to doses from liquid discharges came from discharges from Cap de la Hague and Sellafield. The collective doses due to discharges to rivers increased mainly as a result of the ^{3}H discharges to the River Elbe from the Temelín site. The doses for these new sites for reported atmospheric and liquid discharges can be seen in Appendices B and C respectively.

8. SUMMARY

This report gives details of an assessment carried out to determine implied adult individual doses and collective doses received by the population of the European Union as a consequence of reported discharges of radionuclides from nuclear sites within the EU. Doses were calculated based on reported discharges in the years 2004 and 2008. In this study the guidance provided in the publications (EC, 2002b) and (Jones et al, 2006) was used to ensure an adequate level of realism in the dose assessment but, it was still recognised that this study only presents an indication of the potential doses received. In order to carry out a more detailed site specific dose assessment for authorisation purposes of the discharges from all the sites included in this study, significantly greater resources than were available would be required.

The doses calculated in this study were based on discharges reported by Member States to the European Commission; these data reflect the statutory reporting requirements that each Member State places on its operators of nuclear sites. There may be some discharged radionuclides that operators are not required to report by their national regulatory authority. Of particular importance is the fact that for some sites, liquid discharges of ^{14}C were not reported. Assessments carried out in this study suggest these discharges can make a significant contribution to dose.

In 2004, 10 new Member States acceded to the European Union. Only five of those states (Czech Republic, Hungary, Lithuania, Slovakia and Slovenia) have nuclear sites, with a total of 20 reactors. These sites were not previously included in the PC-CREAM 08 software used to carry out the assessment and therefore it was necessary to collect a significant amount of data as input to the dose calculations. In addition, agricultural production, population and seafood catch data for the European Union were updated. There are differences between the data and methodology used in this assessment and the previous study (EC, 2008). Generally the collective doses in this study are lower than the previous one (EC, 2008) because of decreases in the population, agricultural production and seafood catch data which are now more appropriate for the Member States being considered. In addition, significant efforts have been made to ensure that only food that is used for human consumption is included. For individual doses, less difference in the doses can be seen between this assessment and the previous study (EC, 2008) with the main factor being the ten-fold increase in the ^{14}C concentration factor in freshwater fish following a review of the literature. These differences are discussed in more detail in Section 4.4.

The implied collective doses estimated in this study, integrated to 500 years, to the EU population from all reported discharges in 2004 and 2008 amount to approximately 110 man Sv and 90 man Sv respectively. In comparison, the annual collective dose to the EC population from natural radioactivity, based on UK data (Watson et al, 2005), is estimated to be several hundred thousand man Sv.

Atmospheric discharges from all sites made a more significant contribution to the total collective dose than liquid discharges, between 80% and 90%. In general, reported atmospheric releases from power production sites only were responsible for slightly less than 70% of the estimated collective dose to the EU population. The collective dose calculated for power production sites was around 60 man Sv in 2004 and reduced to around 50 man Sv in 2008. This was mainly as a result of the closure of three of the older design gas-cooled reactors (also known as Magnox reactors). Between 2004 and 2008 the collective doses from all atmospheric discharges decreased by about 20%.

The collective dose from liquid discharges included discharges directly to sea as well as discharges from rivers which reach the sea. The total collective dose integrated to 500 years for liquid discharges from all sites was about 25 man Sv in 2004 and about 15 man Sv in 2008. About 95% of this dose was as a result of the discharges from the coastal sites of Sellafield and Cap de la Hague. The decrease in the collective dose from 2004 to 2008 reflected the general decrease in discharges from Sellafield and Cap de la Hague, and in particular the decrease of discharges of ^{14}C from Sellafield which fell from 16 10^{12} Bq in 2004 to 7 10^{12} Bq in 2008.

There has been a general decrease in the doses to the representative person resulting from atmospheric discharges. For operating nuclear power stations the number of sites where the dose to the representative person at 500 m is greater than 10 µSv y^{-1} has reduced from eleven in 2004 to five in 2008. In addition the maximum dose to the representative person at 500 m decreased from about 40 µSv y^{-1} in 2004 (Dungeness A) to about 20 µSv y^{-1} in 2008 (Wylfa). For the reprocessing site, Sellafield, there has been a decrease in the estimated dose to the representative person at 500m resulting from atmospheric discharges from around 10 µSv y^{-1} in 2004 to around 5 µSv y^{-1} in 2004. This is mainly a reflection of the decrease in discharges of ^{14}C and ^{129}I.

The highest doses to the representative person arising for marine discharges were found to occur as a consequence of reported discharges from the Cap de la Hague and Sellafield nuclear sites. For 2004, the doses to an adult representative person from liquid discharges from the Cap de la Hague and Sellafield nuclear sites were about 230 and 160 µSv y^{-1} respectively. In 2008, the doses decreased to about 150 and 50 µSv y^{-1} for Cap de la Hague and Sellafield respectively reflecting the lower discharges reported for that year from both sites.

The addition of sites from the new Member States has only led to a small increase in collective doses and some individual doses resulting from discharges to river.

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APPENDIX A SITE DETAILS

This appendix contains site data used in the assessment. These include the stack heights that were used in the assessment of atmospheric releases, the dates of any shut down of sites that occurred before 31/12/2008 and whether the site is inland (discharging to a river or a lake) or coastal (discharging to the sea). Figures A1 and A2 show maps of Northern European and Mediterranean marine compartments respectively.

No discharge data are provided in this report due to the large amount of data held within the EC database (more than 15000 entries). Information on the criteria adopted to disaggregate total discharges by radionuclide used in this assessment is presented in the main text (see Section 3.3).

Table A1 Site details used in the assessment

Country	Site name	Installation type	Discharge region	Date of shutdown if occurred before 31/12/2008	Stack height (m)
Belgium	Doel	PWR	Inland		60
	Tihange	PWR	Inland		100
Czech Republic	Dukovany *	PWR	Inland		125
	Temelín *	PWR	Inland		100
Finland	Loviisa	PWR	Coastal		100
	Olkiluoto	BWR	Coastal		100
France	Belleville	PWR	Inland		60
	Blayais	PWR	Inland		60
	Bugey B	PWR	Inland		60
	Cap de la Hague	NFRP	Coastal		100
	Cattenom	PWR	Inland		60
	Chinon B	PWR	Inland		60
	Chooz B	PWR	Inland		60
	Civaux	PWR	Inland		60
	Creys Malville	FBR	Inland	30/12/1998	60
	Cruas	PWR	Inland		60
	Dampierre	PWR	Inland		60
	Fessenheim	PWR	Inland		60
	Flamanville	PWR	Coastal		100
	Golfech	PWR	Inland		60
	Gravelines	PWR	Coastal		60
	Nogent	PWR	Inland		60
	Paluel	PWR	Coastal		60
	Penly	PWR	Coastal		100
	St Alban	PWR	Inland		60
	St Laurent B	PWR	Inland		60
	Tricastin	PWR	Inland		60
Germany	Biblis A	PWR	Inland		100
	Biblis B	PWR	Inland		100
	Brokdorf	PWR	Inland		60
	Brunsbüttel	BWR	Inland		100
	Emsland	PWR	Inland		100

Table A1 Site details used in the assessment

Country	Site name	Installation type	Discharge region	Date of shutdown if occurred before 31/12/2008	Stack height (m)
	Grafenrheinfeld	PWR	Inland		100
	Greifswald	PWR	Inland	14/02/1990	100
	Grohnde	PWR	Inland		100
	Gundremmingen A	BWR	Inland	31/01/1977	100
	Gundremmingen B+C	BWR	Inland		100
	Isar 1	BWR	Inland		100
	Isar 2	PWR	Inland		100
	Karlsruhe WAK	NFRP	Inland	31/12/1990	100
	Krümmel	BWR	Inland		100
	Lingen	BWR	Inland	05/01/1979	100
	Mülheim-Kärlich	PWR	Inland	09/09/1988	100
	Neckarwestheim 1	PWR	Inland		100
	Neckarwestheim 2	PWR	Inland		100
	Obrigheim	PWR	Inland	11/05/2005	60
	Philippsburg 1	BWR	Inland		100
	Philippsburg 2	PWR	Inland		60
	Rheinsberg	PWR	Inland	01/06/1990	100
	Stade	PWR	Inland	14/11/2003	60
	THTR 300	HTGR	Inland	20/04/1988	100
	Unterweser	PWR	Inland		100
	Würgassen	BWR	Inland	26/08/1994	60
Hungary	Paks*	PWR	Inland		100
Lithuania	Ignalina*#	LWGR	Inland		150
Slovakia	Bohunice A*	HWGR	Inland	22/02/1977	100
	Bohunice B*‡	PWR	Inland		120
	Mochovce*	PWR	Inland		150
Slovenia	Krsko*	PWR	Inland		60
Spain	Almaraz	PWR	Inland		60
	Asco	PWR	Inland		60
	Cofrentes	BWR	Inland		60
	José Cabrera (Zorita)	PWR	Inland	30/04/2006	60
	Sta Maria de Garona	BWR	Inland		60
	Trillo	PWR	Inland		60
	Vandellos 2	PWR	Coastal		60
Sweden	Barsebäck	BWR	Coastal	11/05/2005	100
	Forsmark	BWR	Inland		100
	Oskarshamn	BWR	Coastal		60
	Ringhals 1	BWR	Coastal		100
	Ringhals 2	PWR	Coastal		60
The Netherlands	Borssele	PWR	Inland		60
	Dodewaard	BWR	Inland	26/03/1997	100
United Kingdom	Berkeley	GCR	Coastal	31/03/1989	30
	Bradwell	GCR	Coastal	31/03/2002	30
	Calder Hall	GCR	Coastal	31/03/2003	30

Table A1 Site details used in the assessment

Country	Site name	Installation type	Discharge region	Date of shutdown if occurred before 31/12/2008	Stack height (m)
	Chapelcross	GCR	Coastal	29/06/2004	30
	Dounreay†	NFRP	Coastal		60
	Dungeness A	GCR	Coastal	31/12/2006	30
	Dungeness B	AGR	Coastal		30
	Hartlepool	AGR	Coastal		30
	Heysham 1	AGR	Coastal		30
	Heysham 2	AGR	Coastal		30
	Hinkley Point A	GCR	Coastal	23/05/2000	30
	Hinkley Point B	AGR	Coastal		30
	Hunterston A	GCR	Coastal	30/03/1990	30
	Hunterston B	AGR	Coastal		30
	Oldbury	GCR	Coastal		30
	Sellafield	NFRP	Coastal		100
	Sizewell A	GCR	Coastal	31/12/2006	30
	Sizewell B	PWR	Coastal		30
	Torness	AGR	Coastal		30
	Trawsfynydd	GCR	Inland	06/02/1991	30
	Winfrith	SGHWR	Coastal	11/09/1990	30
	Wylfa	GCR	Coastal		30

*: New site since previous study (EC, 2008)

#: One of the two reactors at Ignalina was shut down on 31/12/2004

‡: Of the four reactors on the site, one was shut down on 31/12/2006 and a second on 31/12/2008

†: Reprocessing operations at Dounreay ceased in 1998

Table A2 River sections and lakes and the sites that discharge into them

River	River model*	Site	Country of exposed individual	Country of marine discharge
Danube	Danube 1	Gundremmingen Isar (1 and 2)	Germany	Romania
	Danube 2		Austria	
	Danube 3a (Jihlava) + Danube 3b (Morava)	Dukovany	Czech Republic	
	Danube 3		Slovakia	
	Danube 4a (Váh)	Bohunice (A and B)		
	Danube 4			
	Danube 5a (Hron)	Mochovce		
	Danube 5	Paks	Hungary	
	Danube 6		Croatia	
	Danube 7		Serbia	
	Danube 8a (Sava)	Krško	Slovenia	
	Danube 8		Serbia	
	Danube 9		Bulgaria	
	Danube 10		Romania	
Druksiai (Lake)	Druksiai (Lake model)	Ignalina	Lithuania/ Belarus	Latvia
	Provra			
	Dysna			
	Daugava			
Ebro	Rhône 1	Santa María de Garoña	Spain	Spain
	Rhône 2			
	Rhône 3			
	Rhône 4			
	Rhône 5			
	Rhône 6			
	Rhône 7	Ascó		
	Rhône 8			
Elbe	Rhine 1a (Vltava)	Temelín	Czech Republic	Germany
	Rhine 1		Germany	
	Rhine 2			
	Rhine 4			
	Rhine 6			
	Rhine 8			
	Rhine 10	Krümmel		
Ems	Rhine 10	Emsland Lingen	Germany	Germany
Garonne	Loire 3	Golfech	France	France
	Loire 4			
Júcar	Rhône 7	Cofrentes	Spain	Spain
Loire	Loire 1	Belleville Dampierre	France	France
	Loire 2	Saint-Laurent B		
	Loire 3a (Vienne)	Civaux		
	Loire 3	Chinon B		
	Loire 4			
Meuse 1	Rhine 8	Chooz B	France	Netherlands

Table A2 River sections and lakes and the sites that discharge into them

River	River model*	Site	Country of exposed individual	Country of marine discharge
	Rhine 10		Netherlands	
Meuse 2	Rhine 8	Tihange	Belgium	Netherlands
	Rhine 10		Netherlands	
Rhine	Rhine 1	Fessenheim	France	Netherlands
	Rhine 2	Karlksruhe WAK Philippsburg (1 and 2)	Germany	
	Rhine 3 (Neckar)	Obringheim Neckarwestheim (1 and 2)		
	Rhine 4	Biblis (A and B)		
	Rhine 5 (Main)	Grafenrheinfeld		
	Rhine 6			
	Rhine 7 (Moselle)	Cattenom	France	
	Rhine 8	Mülheim-Kärlich	Germany	
	Rhine 10	Dodewaard	Netherlands	
Rhône	Rhône 1	Creys Malville Bugey B	France	France
	Rhône 2			
	Rhône 3			
	Rhône 4	Saint-Alban		
	Rhône 5	Cruas		
	Rhône 6	Tricastin		
	Rhône 7			
	Rhône 8			
Seine	Loire 2	Nogent	France	France
	Loire 3			
	Loire 4			
Stechlin	Lake	Rheinsberg	Germany	(No discharge to sea)
Tajo	Loire 1	José Cabrera Trillo	Spain	Portugal
	Loire 2			
	Loire 3	Almaraz		
	Loire 4			
Trawsfynydd	Lake	Trawsfynydd	UK	UK
Weser	Rhine 8	Grohnde Würgassen	Germany	Germany
	Rhine 10			

Note

*: Name of tributary is given in brackets

Table A3 Populations along sections of rivers

River	Section	Country	Population centres	Population	Drinking water fraction
Danube	1	Germany	Neuburg an der Donau, Ingolstadt, Kelheim, Regensburg, Straubing, Deggendorf, Landau an der Isar, Passau	446 970	1
	2	Austria	Linz, Krems, Tulln, Wien	1 961 651	0.01
	Jihlava	Czech Republic	Břeclav	25 716	0.5
	Morava	Czech Republic	–	–	0.5
	3	Slovakia	Bratislava	462 603	0.1
	Váh	Slovakia	Hlohovec, Sereď, Šaľa, Kolárovo	74 419	0.5
	4	Slovakia	Komárno	36 279	0.1
	Hron	Slovakia	Levice	35 980	0.5
	5	Hungary, Slovakia	Komárom, Štúrovo, Esztergom, Vác, Szentendre, Göd, Budapest, Százhalombatta, Dunaújváros, Paks, Kalocsa, Baja, Mohács	2 033 958	0.1
	6	Serbia, Croatia	Not members of EU	n/a	n/a
	7	Serbia	Not member of EU	n/a	n/a
	Sava	Slovenia	Brežice	24 483	0.5
		Croatia, Bosnia	Not members of EU	n/a	n/a
	8	Serbia	Not member of EU	n/a	n/a
		Romania	Not part of 25 EU Member States considered in the study	n/a	n/a
	9	Bulgaria, Romania	Not part of 25 EU Member States considered in the study	n/a	n/a
	10	Bulgaria, Romania	Not part of 25 EU Member States considered in the study	n/a	n/a
		Moldova, Ukraine	Not members of EU	n/a	n/a
Ebro	1	Spain	Miranda de Ebro, Haro	51 850	0.5
	2	Spain	Logroño, Calahorra	178 523	0.5
	3	Spain	–	0	0.5
	4	Spain	Tudela, Utebo	52 716	0.5
	5	Spain	–	0	0.5
	6	Spain	Zaragosa (Saragossa)	701 090	0.5
	7	Spain	–	0	0.5
	8	Spain	Tortosa, Amposta, Deltebre	67 589	0.5
Elbe	Vltava	Czech Republic	Prague, Kralupy nad Vltavou, Mělník, Roudnice nad Labem, Litoměřice, Ústí nad Labem, Děčín	1 486 440	0.5
	1	Germany	Pirna, Dresden, Meißen	596 071	0.5
	2	Germany	Riesa, Torgau	52 961	0.5
	3	Germany	Wittenberg, Coswig, Dessau-Roßlau	149 689	0.5
	4	Germany	Schönebeck, Magdeburg	265 413	0.5
	5	Germany	Wittenberge	18 278	0.5
	6	Germany	Biozenburg, Geesthacht, Hamburg	1 841 960	0.5
Ems	1	Germany	Lingen, Geeste, Meppen, Haren, Papenburg, Weener, Leer, Emden, Delfzijl	284 542	0.5
Garonne	1	France	Agen	33 920	0.5
	2	France	Marmande, Bordeaux, Ambarès-et-Lagrave	266 194	0.5

Table A3 Populations along sections of rivers

River	Section	Country	Population centres	Population	Drinking water fraction
Júcar	1	Spain	Alzira, Sueca, Cullera	98 711	0.5
Loire	1	France	Gien, Orléans	131 822	0.5
	2	France	Blois, Amboise, Montlouis-sur-Loire, Tours	204 184	0.5
	Vienne	France	Châtellerault	35 569	0.5
	3	France	Saumur, Angers	177 162	0.5
	4	France	Nantes, Couëron, Saint-Nazaire	373 055	0.5
Meuse		France, Belgium	Givet, Dinant, Profondeville, Namur, Andenne, Wanze, Huy	201 280	0.5
		Belgium	Amay, Liège, Herstal, Oupeye, Visé	288 061	0.5
		Netherlands, Belgium	Maastricht, Stein, Masseik, Roermond, Reuver, Blerick, Venlo, Boxmeer, Gennep, Cuijk, Grave, 's-Hertogenbosch, Heusden, Aalburg, Geertruidenberg	660 662	0.5
Rhine	1	France, Germany	Breisach am Rhein, Strasbourg, Rheinau (Baden)	298 757	0.5
	2	Germany	Karlsruhe, Wörth am Rhein, Eggenstein-Leopoldshafen, Germersheim, Rheinsheim, Speyer	410 712	0.5
	Neckar	Germany	Lauffen am Necker, Heilbronn, Neckarsulm, Bad Friedrichshall, Mosbach, Eberbach, Heidelberg	365 746	0.5
	4	Germany	Mannheim, Ludwigshafen, Worms	559 261	0.5
	Main	Germany	Kitzingen, Ochsenfurt, Würzburg, Karlstadt am Main, Gemünden am Main, Lohr am Main, Marktheidenfeld, Wertheim am Main, Aschaffenburg, Seligenstadt, Hainburg, Hanau, Mühlheim am Main, Maintal, Offenbach, Frankfurt am Main, Hattersheim, Raunheim, Flörsheim, Rüsselsheim, Hochheim am Main	1 436 304	0.5
	6	Germany	Ginsheim-Gustavsburg, Mainz, Wiesbaden, Eltville, Ingelheim am Rhein, Geisenheim, Bingen am Rhein, Boppard, Lahnstein	602 326	0.5
	Moselle	France, Germany	Konz, Trier	123 183	0.5
	8	Germany	Koblenz, Bendorf, Neuwied, Andernach, Sinzig, Remagen, Bad Honnef, Königswinter, Bonn, Niederkassel, Wesseling, Köln, Leverkusen, Monheim, Dormagen, Düsseldorf, Neuss, Meerbusch, Krefeld	3 017 859	0.5
	10	Netherlands, Germany	Duisberg, Moers, Wesel, Xanten, Rees, Emmerich am Rhein, Arnhem, Nijmegen, Rhenen, Tiel, Wijk bij Duurstede, Zaltbommel, Culemborg, Vianen, Gorinchem, Schoonhoven, Dordrechsteden, Ridderkerk, Rotterdam, Schiedam, Vlaardingen, Spijkenisse	2 376 378	0.5
Rhône	1	France	Bouvesse-Quirieu, Serrières-de-Briord, Montalieu-Vercieu, Villebois, Sault-Brénaz, Saint-Sorlin-en-Bugey, Lagnieu, Saint-Romain-de-Jalionas, Loyettes, Chavanoz	24 393	0.5
	2	France	Meyzieu, Décines-Charpieu, Vaulx-en-Velin, Villeurbanne, Lyon	717 168	0.5

Table A3 Populations along sections of rivers

River	Section	Country	Population centres	Population	Drinking water fraction
	3	France	Saint-Fons, Givors, Vienne	65 260	0.5
	4	France	Tournon-sur-Rhône	10 607	0.5
	5	France	Bourg-lès-Valence, Valence	84 957	0.5
	6	France	Montélimar, Pierrelatte	49 087	0.5
	7	France	Bollène, Pont-Saint-Esprit, Sorgues, Villeneuve-lès-Avignon, Le Pontet	72 704	0.5
	8	France	Avignon, Beaucaire, Tarascon	123 632	0.5
	9	France	Arles, Saint-Gilles	66 464	0.5
Seine	1	France	Fontainebleau, Vaux-le-Pénil, Melun, Le Mée-sur-Seine, Dammarie-lès-Lys, Saint-Fargeau-Pointhierry, Mennecy, Évry, Ris-Orangis, Viry-Châtillon, Draveil, Savigny-sur-Orge, Athis-Mons	342 002	0.5
	2	France	Paris, Argenteuil, Carrières-sur-Seine, Chatou, Croissy-sur-Seine, Le Pecq, Sartrouville, Maisons-Laffitte, Cormeilles-en-Parisis, Montigny-lès-Cormeilles, Conflons-Sainte-Honorine, Andrésy, Poissy, Verneuil-sur-Seine, Les Mureaux, Mantes-la-Jolie, Vernon, Val-de-Reuil, Elbeuf	7 099 134	0.5
	3	France	Rouen	111 000	0.5
Tajo	1	Spain	Sacedón	1 865	0.5
	2	Spain	Aranjuez, Toledo, Talavera de la Reina	226 028	0.5
	3	Spain	El Puente del Arzobispo, Garrovillas de Alconétar, Alcántara	5 456	0.5
	4	Portugal	Abrantes, Entroncamento, Chamusca, Santarèm, Alverca do Ribatejo, Sacavém, Montijo, Barreiro, Lisboa	739 305	0.5
Weser	1	Germany	Beverungen, Höxter, Holzminden, Hameln, Hessisch Oberdorf, Rinteln, Vlotho, Bad Oeynhausen	236 039	0.5
	2	Germany	Porta Westfalica, Minden, Petershagen, Nienburg, Achim, Bremen, Brake	768 101	0.5

Table A4 Location of marine representative person with the sites discharging to each location

Location of representative person*	Sites discharging to location	Country of origin of discharge	Country of representative person
Mediterranean Sea			
Danube estuary (Black Sea)	Gundremmingen	Germany	Romania
	Isar (1 and 2)	Germany	
	Dukovanny	Czech Republic	
	Paks	Hungary	
	Bohunice (A and B)	Slovakia	
	Mochovce	Slovakia	
	Krsko	Slovenia	
Rhône estuary (Gulf of Lions)	Creys Malville	France	France
	Bugey B	France	
	St Alban	France	
	Cruas	France	
	Tricastin	France	
Ebro estuary (Liguro Povencal Basin)	Asco	Spain	Spain
	Santa Maria de Garona	Spain	
	Vandellos 2	Spain	
Jucar estuary (Liguro Povencal Basin)	Cofrentes	Spain	Spain
North East Atlantic (Europe excluding UK)			
Loire estuary (French Continental Shelf)	Belleville	France	France
	Chinon B	France	
	Civaux	France	
	Dampierre	France	
	St Laurent B	France	
Gironde estuary (French Continental Shelf)	Blayais	France	France
	Golfech	France	
English Channel South East	Flamanville	France	France
	Cap de la Hague	France	France
Seine estuary (English Channel South East)	Paluel	France	France
	Penly	France	
	Nogent	France	
North Sea South East	Gravelines	France	France
Rhine and Meuse estuary North Sea South East	Biblis A	Germany	Netherlands
	Biblis B	Germany	
	Borssele	Netherlands	
	Cattenom	France	
	Chooz B	France	
	Dodewaard	Netherlands	
	Doel	Belgium	
	Fessenheim	France	
	Grafenrheinfeld	Germany	
	Karlsruhe WAK	Germany	
	Mülheim-Kärlich	Germany	
	Neckar (1 and 2)	Germany	
	Obrigheim	Germany	
	Philippsburg (1 and 2)	Germany	
	Tihange	Belgium	

Table A4 Location of marine representative person with the sites discharging to each location

Location of representative person*	Sites discharging to location	Country of origin of discharge	Country of representative person
Ems Elbe and Weser Estuary (North Sea East)	Brokdorf	Germany	Germany
	Brunsbüttel	Germany	
	Emsland	Germany	
	Grohnde	Germany	
	Krümmel	Germany	
	Lingen	Germany	
	Stade	Germany	
	Unterweser	Germany	
	Würgassen	Germany	
	Temelín	Czech Republic	
Tajo Estuary (Portuguese Continental Shelf)	Almaraz	Spain	Portugal
	José Cabrera (Zorita)	Spain	
	Trillo	Spain	
Baltic region			
Baltic Sea West	Oskarshamn	Sweden	Sweden
Belt Sea	Barseback	Sweden	Sweden
	Greifswald	Germany	Germany
Bothnian Sea	Olkiluoto	Finland	Finland
	Forsmark	Sweden	Sweden
Gulf of Riga	Ignalina	Lithuania/Belarus	Latvia
Gulf of Finland	Loviisa	Finland	Finland
Kattegat	Ringhals (1 and 2)	Sweden	Sweden
United Kingdom			
North Sea South West	Bradwell	UK	UK
Bristol Channel	Oldbury	UK	UK
	Berkeley	UK	
Irish Sea North East	Chapelcross	UK	UK
Scottish Waters East	Dounreay	UK	UK
English Channel North East	Dungeness (A and B)	UK	UK
North Sea Central	Hartlepool	UK	UK
Liverpool and Morecombe Bay	Heysham (1 and 2)	UK	UK
Bristol Channel	Hinkley Point (A and B)	UK	UK
Scottish Waters West	Hunterston (A and B)	UK	UK
Cumbrian Waters	Sellafield	UK	UK
North Sea South West (2)	Sizewell (A and B)	UK	UK
Irish Sea South	Trawsfynydd	UK	UK
North Sea Central	Torness	UK	UK
English Channel West	Winfrith	UK	UK
Irish Sea West	Wylfa	UK	UK

*: Associated regional compartment is given in brackets if applicable

Figure A1: Northern European regional compartments as modified for PC-CREAM 08

Compartment names

1	Other oceans	**29**	English Channel W.
2	Atlantic North N.E. (surface 0-1000m)	**30**	Channel Islands
3	Atlantic North N.E. (middle 1000-2000m)	**31**	Cap de la Hague
4	Atlantic North N.E. (deep 2000-4000m)	**32**	Lyme Bay
5	Other Atlantic	**33**	Baie de la Seine
6	Arctic Ocean	**34**	Sam's Beach
7	Arctic South	**35**	Central Channel S.E.
8	Spitzbergen	**36**	Central Channel N.E.
9	Kara and Barents sea	**37**	Isle of Wight
10	Norwegian Waters	**38**	North Sea S.W.
11	Scottish Waters W.	**39**	North Sea S.E.
12	Scottish Waters E.	**40**	North Sea Central
13	Irish Sea N.W.	**41**	North Sea E.
14	Irish Sea N.	**42**	North Sea N.
15	Irish Sea N.E.	**43**	Skagerrak
16	Irish Sea W.	**44**	Kattegat (surface 0-20m)
17	Irish Sea S.E.	**45**	Kattegat (bottom 20-120m)
18	Cumbrian Waters	**46**	Belt Sea (surface 0-14m)
19	Irish Sea S.	**47**	Belt Sea (bottom 14-44m)
20	Liverpool and Morecambe Bays	**48**	Bothnian Bay
21	Celtic Sea	**49**	Bothnian Sea
22	Bristol Channel	**50**	Baltic Sea W. (surface 0-49m)
23	Bay of Biscay	**51**	Baltic Sea E. (surface 0-53m)
24	French Continental Shelf	**52**	Baltic Sea W. (bottom 49-159m)
25	Cantabrian Sea	**53**	Baltic Sea E. (bottom 53-163m)
26	Portuguese Continental Shelf	**54**	Gulf of Finland
27	Gulf of Cadiz	**55**	Gulf of Riga
28	Mediterranean (see Figure A2 for more detailed map of Mediterranean model)		

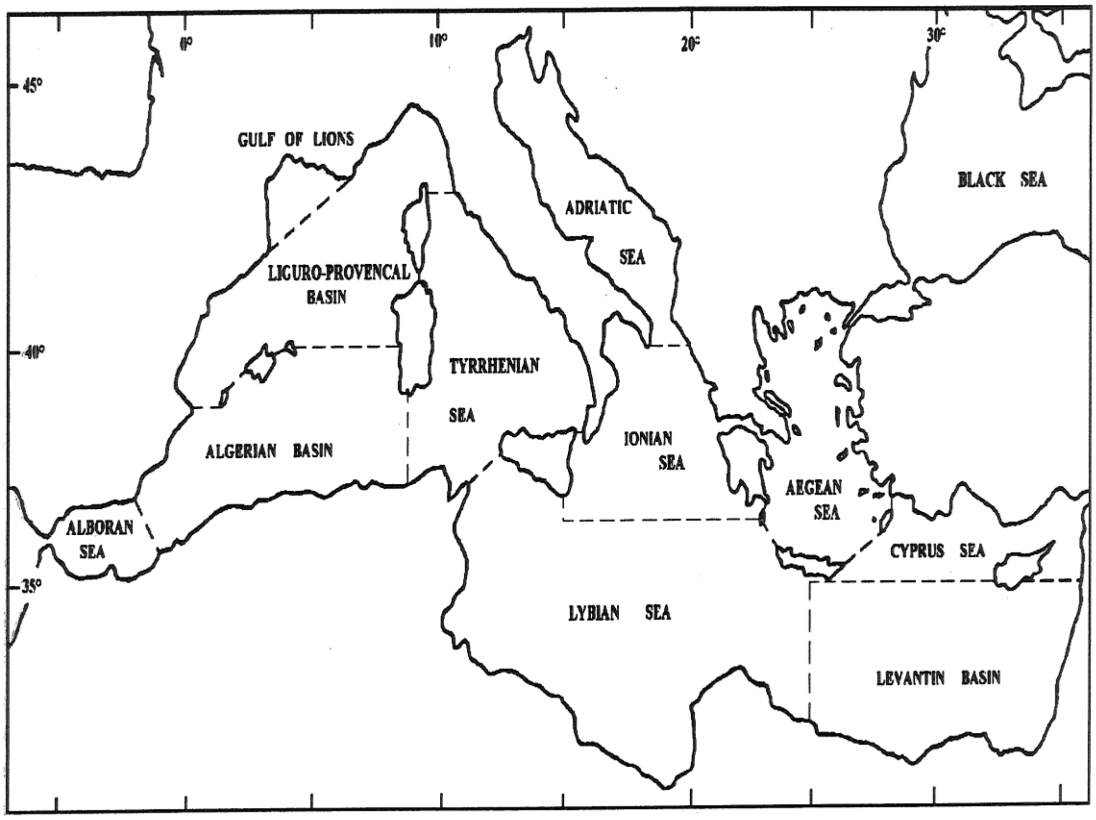

Figure A2: Surface compartments of the Mediterranean Sea Model

APPENDIX B DETAILED RESULTS FOR ATMOSPHERIC DISCHARGES

Table B1 Implied collective doses (manSv) integrated to 500 years to EU population from reported annual atmospheric releases (shut down sites are marked in orange)

		Previous study		This study			
	Site	2004		2004		2008	
Country		First pass	Total	First pass	Total	First pass	Total
Belgium	Doel	$1.5\ 10^{-3}$	$1.5\ 10^{-3}$	$1.1\ 10^{-3}$	$1.1\ 10^{-3}$	$6.3\ 10^{-3}$	$6.3\ 10^{-3}$
Belgium	Tihange	$2.5\ 10^{-2}$	$2.5\ 10^{-2}$	$5.1\ 10^{-2}$	$5.1\ 10^{-2}$	$7.3\ 10^{-2}$	$7.3\ 10^{-2}$
Czech Republic	Dukovany	n/a	n/a	$5.7\ 10^{-1}$	$1.2\ 10^{0}$	$4.9\ 10^{-1}$	$1.0\ 10^{0}$
Czech Republic	Temelín	n/a	n/a	$6.4\ 10^{-1}$	$9.7\ 10^{-1}$	$7.0\ 10^{-1}$	$1.1\ 10^{0}$
Finland	Loviisa	$2.4\ 10^{-1}$	$6.3\ 10^{-1}$	$7.3\ 10^{-2}$	$3.3\ 10^{-1}$	$7.6\ 10^{-2}$	$3.4\ 10^{-1}$
Finland	Olkiluoto	$5.3\ 10^{-1}$	$1.6\ 10^{0}$	$1.9\ 10^{-1}$	$8.7\ 10^{-1}$	$2.0\ 10^{-1}$	$9.1\ 10^{-1}$
France	Belleville	$8.8\ 10^{-1}$	$1.5\ 10^{0}$	$3.9\ 10^{-1}$	$7.6\ 10^{-1}$	$3.2\ 10^{-1}$	$6.3\ 10^{-1}$
France	Blayais	$4.7\ 10^{-1}$	$1.2\ 10^{0}$	$3.0\ 10^{-1}$	$7.8\ 10^{-1}$	$3.3\ 10^{-1}$	$8.6\ 10^{-1}$
France	Bugey B	$7.8\ 10^{-1}$	$1.5\ 10^{0}$	$5.2\ 10^{-1}$	$1.0\ 10^{0}$	$5.2\ 10^{-1}$	$1.0\ 10^{0}$
France	Cap de la Hague	$1.6\ 10^{1}$	$4.2\ 10^{1}$	$8.8\ 10^{0}$	$2.6\ 10^{1}$	$6.8\ 10^{0}$	$2.0\ 10^{1}$
France	Cattenom	$2.4\ 10^{0}$	$3.5\ 10^{0}$	$1.3\ 10^{0}$	$1.9\ 10^{0}$	$1.2\ 10^{0}$	$1.9\ 10^{0}$
France	Chinon B	$9.8\ 10^{-1}$	$1.7\ 10^{0}$	$4.8\ 10^{-1}$	$9.4\ 10^{-1}$	$4.9\ 10^{-1}$	$9.6\ 10^{-1}$
France	Chooz B	$9.4\ 10^{-1}$	$1.5\ 10^{0}$	$3.7\ 10^{-1}$	$7.7\ 10^{-1}$	$4.2\ 10^{-1}$	$8.7\ 10^{-1}$
France	Civaux	$8.8\ 10^{-1}$	$1.6\ 10^{0}$	$4.5\ 10^{-1}$	$8.9\ 10^{-1}$	$4.1\ 10^{-1}$	$8.2\ 10^{-1}$
France	Creys Malville	$3.3\ 10^{-4}$	$3.3\ 10^{-4}$	$2.0\ 10^{-4}$	$2.1\ 10^{-4}$	$9.6\ 10^{-4}$	$9.7\ 10^{-4}$
France	Cruas	$4.5\ 10^{-1}$	$1.2\ 10^{0}$	$2.6\ 10^{-1}$	$7.2\ 10^{-1}$	$2.5\ 10^{-1}$	$6.9\ 10^{-1}$
France	Dampierre	$1.1\ 10^{0}$	$1.8\ 10^{0}$	$4.7\ 10^{-1}$	$9.2\ 10^{-1}$	$4.9\ 10^{-1}$	$9.6\ 10^{-1}$
France	Fessenheim	$7.8\ 10^{-1}$	$1.1\ 10^{0}$	$4.0\ 10^{-1}$	$6.1\ 10^{-1}$	$3.9\ 10^{-1}$	$5.9\ 10^{-1}$
France	Flamanville	$4.0\ 10^{-1}$	$9.3\ 10^{-1}$	$2.1\ 10^{-1}$	$5.5\ 10^{-1}$	$1.3\ 10^{-1}$	$3.4\ 10^{-1}$
France	Golfech	$4.1\ 10^{-1}$	$8.9\ 10^{-1}$	$2.7\ 10^{-1}$	$5.8\ 10^{-1}$	$2.8\ 10^{-1}$	$6.1\ 10^{-1}$
France	Gravelines	$1.1\ 10^{0}$	$2.2\ 10^{0}$	$5.4\ 10^{-1}$	$1.3\ 10^{0}$	$5.2\ 10^{-1}$	$1.2\ 10^{0}$
France	Nogent	$7.6\ 10^{-1}$	$1.2\ 10^{0}$	$3.3\ 10^{-1}$	$6.3\ 10^{-1}$	$3.3\ 10^{-1}$	$6.4\ 10^{-1}$

Table B1 Implied collective doses (manSv) integrated to 500 years to EU population from reported annual atmospheric releases (shut down sites are marked in orange)

		Previous study		This study			
	Site	2004		2004		2008	
Country		First pass	Total	First pass	Total	First pass	Total
France	Paluel	$9.0\ 10^{-1}$	$1.8\ 10^{0}$	$4.2\ 10^{-1}$	$1.0\ 10^{0}$	$4.8\ 10^{-1}$	$1.2\ 10^{0}$
France	Penly	$4.8\ 10^{-1}$	$1.0\ 10^{0}$	$2.1\ 10^{-1}$	$5.5\ 10^{-1}$	$2.4\ 10^{-1}$	$6.2\ 10^{-1}$
France	Saint-Alban	$5.5\ 10^{-1}$	$1.2\ 10^{0}$	$3.1\ 10^{-1}$	$7.0\ 10^{-1}$	$1.8\ 10^{-1}$	$4.1\ 10^{-1}$
France	Saint-Laurent B	$5.9\ 10^{-1}$	$9.7\ 10^{-1}$	$2.6\ 10^{-1}$	$5.1\ 10^{-1}$	$2.7\ 10^{-1}$	$5.3\ 10^{-1}$
France	Tricastin	$5.4\ 10^{-1}$	$1.2\ 10^{0}$	$3.0\ 10^{-1}$	$7.5\ 10^{-1}$	$1.5\ 10^{-1}$	$3.6\ 10^{-1}$
Germany	Biblis A	$4.1\ 10^{-1}$	$5.7\ 10^{-1}$	$1.8\ 10^{-1}$	$2.8\ 10^{-1}$	$1.5\ 10^{-1}$	$2.4\ 10^{-1}$
Germany	Biblis B	$9.4\ 10^{-1}$	$1.3\ 10^{0}$	$4.1\ 10^{-1}$	$6.5\ 10^{-1}$	$2.1\ 10^{-1}$	$3.3\ 10^{-1}$
Germany	Brokdorf	$4.8\ 10^{-1}$	$8.4\ 10^{-1}$	$2.1\ 10^{-1}$	$4.4\ 10^{-1}$	$2.7\ 10^{-1}$	$5.8\ 10^{-1}$
Germany	Brunsbüttel	$3.4\ 10^{-1}$	$6.6\ 10^{-1}$	$1.4\ 10^{-1}$	$3.5\ 10^{-1}$	$6.3\ 10^{-2}$	$1.6\ 10^{-1}$
Germany	Emsland	$4.3\ 10^{-1}$	$7.5\ 10^{-1}$	$2.1\ 10^{-1}$	$4.2\ 10^{-1}$	$2.0\ 10^{-1}$	$4.0\ 10^{-1}$
Germany	Grafenrheinfeld	$7.6\ 10^{-1}$	$1.2\ 10^{0}$	$3.5\ 10^{-1}$	$6.0\ 10^{-1}$	$3.3\ 10^{-1}$	$5.7\ 10^{-1}$
Germany	Greifswald	$5.5\ 10^{-5}$	$5.5\ 10^{-5}$	$1.0\ 10^{-5}$	$1.0\ 10^{-5}$	$8.7\ 10^{-6}$	$8.7\ 10^{-6}$
Germany	Grohnde	$5.5\ 10^{-1}$	$9.3\ 10^{-1}$	$2.1\ 10^{-1}$	$4.6\ 10^{-1}$	$2.4\ 10^{-1}$	$5.3\ 10^{-1}$
Germany	Gundremmingen A	$9.8\ 10^{-5}$	$9.8\ 10^{-5}$	$4.5\ 10^{-5}$	$4.5\ 10^{-5}$	$2.4\ 10^{-6}$	$2.4\ 10^{-6}$
Germany	Gundremmingen B+C	$2.1\ 10^{0}$	$3.1\ 10^{0}$	$9.1\ 10^{-1}$	$1.6\ 10^{0}$	$9.3\ 10^{-1}$	$1.6\ 10^{0}$
Germany	Isar 1	$7.4\ 10^{-1}$	$1.2\ 10^{0}$	$4.3\ 10^{-1}$	$7.0\ 10^{-1}$	$3.6\ 10^{-1}$	$5.8\ 10^{-1}$
Germany	Isar 2	$5.9\ 10^{-1}$	$9.2\ 10^{-1}$	$3.2\ 10^{-1}$	$5.4\ 10^{-1}$	$7.5\ 10^{-1}$	$1.3\ 10^{0}$
Germany	Karlsruhe WAK	$7.7\ 10^{-2}$	$1.1\ 10^{-1}$	$3.6\ 10^{-2}$	$5.4\ 10^{-2}$	$9.7\ 10^{-2}$	$1.4\ 10^{-1}$
Germany	Krümmel	$2.4\ 10^{-1}$	$4.5\ 10^{-1}$	$1.1\ 10^{-1}$	$2.4\ 10^{-1}$	$2.4\ 10^{-2}$	$5.6\ 10^{-2}$
Germany	Lingen	$1.1\ 10^{-3}$	$1.9\ 10^{-3}$	$5.1\ 10^{-4}$	$1.0\ 10^{-3}$	No discharges reported	
Germany	Mülheim-Kärlich	$2.3\ 10^{-3}$	$3.2\ 10^{-3}$	$1.0\ 10^{-3}$	$1.6\ 10^{-3}$	$9.6\ 10^{-4}$	$1.5\ 10^{-3}$
Germany	Neckarwestheim 1	$9.0\ 10^{-1}$	$1.2\ 10^{0}$	$3.9\ 10^{-1}$	$6.1\ 10^{-1}$	$2.6\ 10^{-1}$	$4.2\ 10^{-1}$
Germany	Neckarwestheim 2	$1.4\ 10^{0}$	$1.9\ 10^{0}$	$5.8\ 10^{-1}$	$9.2\ 10^{-1}$	$3.4\ 10^{-1}$	$5.5\ 10^{-1}$
Germany	Obrigheim	$1.7\ 10^{-1}$	$2.3\ 10^{-1}$	$7.5\ 10^{-2}$	$1.1\ 10^{-1}$	$3.0\ 10^{-3}$	$4.4\ 10^{-3}$
Germany	Philippsburg 1	$8.6\ 10^{-1}$	$1.4\ 10^{0}$	$3.9\ 10^{-1}$	$7.2\ 10^{-1}$	$4.0\ 10^{-1}$	$7.4\ 10^{-1}$

Table B1 Implied collective doses (manSv) integrated to 500 years to EU population from reported annual atmospheric releases (shut down sites are marked in orange)

		Previous study		This study			
	Site	2004		2004		2008	
Country		First pass	Total	First pass	Total	First pass	Total
Germany	Philippsburg 2	$4.1\ 10^{-1}$	$6.2\ 10^{-1}$	$1.8\ 10^{-1}$	$3.2\ 10^{-1}$	$1.2\ 10^{-1}$	$2.1\ 10^{-1}$
Germany	Rheinsberg	$1.9\ 10^{-7}$	$1.9\ 10^{-7}$	$3.5\ 10^{-5}$	$3.5\ 10^{-5}$	$1.4\ 10^{-5}$	$1.4\ 10^{-5}$
Germany	Stade	$3.2\ 10^{-1}$	$5.7\ 10^{-1}$	$1.3\ 10^{-1}$	$2.9\ 10^{-1}$	$2.4\ 10^{-2}$	$5.4\ 10^{-2}$
Germany	THTR 300	$7.1\ 10^{-7}$	$7.1\ 10^{-7}$	$4.0\ 10^{-7}$	$4.0\ 10^{-7}$	$2.6\ 10^{-7}$	$2.6\ 10^{-7}$
Germany	Unterweser	$5.0\ 10^{-2}$	$9.7\ 10^{-2}$	$2.4\ 10^{-2}$	$5.4\ 10^{-2}$	$2.1\ 10^{-1}$	$4.8\ 10^{-1}$
Germany	Würgassen	$1.7\ 10^{-3}$	$2.7\ 10^{-3}$	$7.2\ 10^{-4}$	$1.4\ 10^{-3}$	$1.1\ 10^{-3}$	$2.2\ 10^{-3}$
Hungary	Paks	n/a	n/a	$2.5\ 10^{-1}$	$8.1\ 10^{-1}$	$2.3\ 10^{-1}$	$5.8\ 10^{-1}$
Lithuania	Ignalina	n/a	n/a	$1.5\ 10^{-2}$	$1.5\ 10^{-2}$	$1.8\ 10^{-2}$	$3.6\ 10^{-2}$
Netherlands	Borssele	$1.6\ 10^{-1}$	$2.8\ 10^{-1}$	$7.7\ 10^{-2}$	$1.5\ 10^{-1}$	$9.8\ 10^{-2}$	$2.0\ 10^{-1}$
Netherlands	Dodewaard	$1.3\ 10^{-4}$	$2.4\ 10^{-4}$	$6.1\ 10^{-5}$	$1.3\ 10^{-4}$	No discharges reported	
Slovakia	Bohunice A	n/a	n/a	$6.2\ 10^{-5}$	$6.2\ 10^{-5}$	$8.8\ 10^{-5}$	$8.8\ 10^{-5}$
Slovakia	Bohunice B	n/a	n/a	$2.5\ 10^{-1}$	$4.3\ 10^{-1}$	$5.0\ 10^{-1}$	$9.0\ 10^{-1}$
Slovakia	Mochovce	n/a	n/a	$7.5\ 10^{-2}$	$1.4\ 10^{-1}$	$2.6\ 10^{-1}$	$5.4\ 10^{-1}$
Slovenia	Krško	n/a	n/a	$2.6\ 10^{-1}$	$3.6\ 10^{-1}$	$7.3\ 10^{-2}$	$9.3\ 10^{-2}$
Spain	Almaraz	$8.2\ 10^{-3}$	$8.3\ 10^{-3}$	$6.0\ 10^{-3}$	$6.0\ 10^{-3}$	$1.4\ 10^{-1}$	$2.5\ 10^{-1}$
Spain	Ascó	$7.5\ 10^{-3}$	$7.5\ 10^{-3}$	$5.0\ 10^{-3}$	$5.0\ 10^{-3}$	$2.8\ 10^{0}$	$4.1\ 10^{0}$
Spain	Cofrentes	$1.5\ 10^{-2}$	$1.5\ 10^{-2}$	$1.8\ 10^{-2}$	$1.8\ 10^{-2}$	$6.8\ 10^{-1}$	$9.3\ 10^{-1}$
Spain	José Cabrera	$1.0\ 10^{-3}$	$1.0\ 10^{-3}$	$3.4\ 10^{-4}$	$3.4\ 10^{-4}$	$3.7\ 10^{-5}$	$3.7\ 10^{-5}$
Spain	Santa María de Garoña	$1.1\ 10^{-3}$	$1.1\ 10^{-3}$	$8.0\ 10^{-4}$	$8.0\ 10^{-4}$	$3.2\ 10^{-1}$	$5.1\ 10^{-1}$
Spain	Trillo	$4.1\ 10^{-2}$	$8.0\ 10^{-2}$	$3.1\ 10^{-2}$	$5.6\ 10^{-2}$	$2.9\ 10^{-2}$	$5.3\ 10^{-2}$
Spain	Vandellos 2	$3.2\ 10^{-4}$	$3.2\ 10^{-4}$	$2.2\ 10^{-4}$	$2.2\ 10^{-4}$	$1.3\ 10^{-1}$	$2.5\ 10^{-1}$
Sweden	Barsebäck	$4.1\ 10^{-1}$	$9.2\ 10^{-1}$	$6.4\ 10^{-1}$	$9.7\ 10^{-1}$	$2.0\ 10^{-5}$	$2.0\ 10^{-5}$
Sweden	Forsmark	$1.5\ 10^{0}$	$4.2\ 10^{0}$	$5.9\ 10^{-1}$	$2.4\ 10^{0}$	$5.6\ 10^{-1}$	$2.2\ 10^{0}$
Sweden	Oskarshamn	$7.3\ 10^{-1}$	$1.8\ 10^{0}$	$4.1\ 10^{-1}$	$1.1\ 10^{0}$	$2.7\ 10^{-1}$	$8.9\ 10^{-1}$
Sweden	Ringhals 1	$4.2\ 10^{-1}$	$1.0\ 10^{0}$	$2.4\ 10^{-1}$	$6.3\ 10^{-1}$	$1.6\ 10^{-1}$	$4.7\ 10^{-1}$

Table B1 Implied collective doses (manSv) integrated to 500 years to EU population from reported annual atmospheric releases (shut down sites are marked in orange)

		Previous study		This study			
	Site	2004		2004		2008	
Country		First pass	Total	First pass	Total	First pass	Total
Sweden	Ringhals 2	$7.2\ 10^{-1}$	$1.6\ 10^{0}$	$3.3\ 10^{-1}$	$9.1\ 10^{-1}$	$2.1\ 10^{-1}$	$5.9\ 10^{-1}$
United Kingdom	Berkeley	$4.6\ 10^{-4}$	$7.2\ 10^{-4}$	$2.4\ 10^{-4}$	$4.1\ 10^{-4}$	$3.1\ 10^{-4}$	$5.4\ 10^{-4}$
United Kingdom	Bradwell	$3.4\ 10^{-3}$	$6.6\ 10^{-3}$	$1.8\ 10^{-3}$	$3.9\ 10^{-3}$	$7.5\ 10^{-4}$	$1.7\ 10^{-3}$
United Kingdom	Calder Hall	$3.9\ 10^{-4}$	$8.8\ 10^{-4}$	$2.2\ 10^{-4}$	$5.4\ 10^{-4}$	No discharges reported	
United Kingdom	Chapelcross	$1.3\ 10^{0}$	$1.3\ 10^{0}$	$7.9\ 10^{-1}$	$8.0\ 10^{-1}$	$9.1\ 10^{-2}$	$9.2\ 10^{-2}$
United Kingdom	Dounreay	$4.5\ 10^{-3}$	$5.1\ 10^{-3}$	$2.9\ 10^{-3}$	$3.4\ 10^{-3}$	$2.5\ 10^{-3}$	$3.1\ 10^{-3}$
United Kingdom	Dungeness A	$4.5\ 10^{0}$	$8.3\ 10^{0}$	$2.1\ 10^{0}$	$4.5\ 10^{0}$	$1.2\ 10^{-3}$	$2.1\ 10^{-3}$
United Kingdom	Dungeness B	$1.0\ 10^{0}$	$1.8\ 10^{0}$	$4.8\ 10^{-1}$	$1.0\ 10^{0}$	$5.3\ 10^{-1}$	$1.1\ 10^{0}$
United Kingdom	Hartlepool	$1.9\ 10^{0}$	$3.7\ 10^{0}$	$8.2\ 10^{-1}$	$2.0\ 10^{0}$	$1.3\ 10^{-2}$	$2.6\ 10^{-2}$
United Kingdom	Heysham 1	$5.2\ 10^{-1}$	$1.4\ 10^{0}$	$2.8\ 10^{-1}$	$8.2\ 10^{-1}$	$2.3\ 10^{-2}$	$5.0\ 10^{-2}$
United Kingdom	Heysham 2	$1.1\ 10^{0}$	$2.8\ 10^{0}$	$5.6\ 10^{-1}$	$1.7\ 10^{0}$	$6.7\ 10^{-1}$	$2.0\ 10^{0}$
United Kingdom	Hinkley Point A	$2.7\ 10^{-3}$	$4.6\ 10^{-3}$	$1.5\ 10^{-3}$	$2.7\ 10^{-3}$	$8.8\ 10^{-4}$	$1.5\ 10^{-3}$
United Kingdom	Hinkley Point B	$2.5\ 10^{0}$	$4.1\ 10^{0}$	$1.3\ 10^{0}$	$2.4\ 10^{0}$	$1.1\ 10^{0}$	$2.0\ 10^{0}$
United Kingdom	Hunterston A	$1.6\ 10^{-4}$	$3.3\ 10^{-4}$	$6.9\ 10^{-5}$	$1.8\ 10^{-4}$	$6.6\ 10^{-5}$	$1.7\ 10^{-4}$
United Kingdom	Hunterston B	$2.2\ 10^{0}$	$4.6\ 10^{0}$	$9.8\ 10^{-1}$	$2.6\ 10^{0}$	$6.7\ 10^{-1}$	$1.7\ 10^{0}$
United Kingdom	Oldbury	$3.3\ 10^{0}$	$5.2\ 10^{0}$	$1.7\ 10^{0}$	$2.9\ 10^{0}$	$1.0\ 10^{0}$	$1.8\ 10^{0}$
United Kingdom	Sellafield	$4.7\ 10^{0}$	$8.0\ 10^{0}$	$2.3\ 10^{0}$	$4.5\ 10^{0}$	$8.7\ 10^{-1}$	$1.8\ 10^{0}$
United Kingdom	Sizewell A	$1.4\ 10^{0}$	$2.7\ 10^{0}$	$7.5\ 10^{-1}$	$1.6\ 10^{0}$	$3.0\ 10^{-2}$	$6.7\ 10^{-2}$
United Kingdom	Sizewell B	$2.3\ 10^{-1}$	$4.8\ 10^{-1}$	$1.2\ 10^{-1}$	$2.8\ 10^{-1}$	$2.0\ 10^{-1}$	$4.7\ 10^{-1}$
United Kingdom	Torness	$4.4\ 10^{-1}$	$1.2\ 10^{0}$	$1.7\ 10^{-1}$	$6.4\ 10^{-1}$	$2.4\ 10^{-1}$	$9.1\ 10^{-1}$
United Kingdom	Trawsfynydd	$8.6\ 10^{-4}$	$2.3\ 10^{-3}$	$5.0\ 10^{-4}$	$1.4\ 10^{-3}$	$9.2\ 10^{-4}$	$2.6\ 10^{-3}$
United Kingdom	Winfrith	$1.7\ 10^{-2}$	$1.8\ 10^{-2}$	$1.1\ 10^{-2}$	$1.1\ 10^{-2}$	$1.3\ 10^{-2}$	$1.4\ 10^{-2}$
United Kingdom	Wylfa	$1.0\ 10^{0}$	$2.7\ 10^{0}$	$6.0\ 10^{-1}$	$1.7\ 10^{0}$	$6.3\ 10^{-1}$	$1.8\ 10^{0}$
Total		$7.6\ 10^{1}$	$1.5\ 10^{2}$	$4.0\ 10^{1}$	$9.2\ 10^{1}$	$3.4\ 10^{1}$	$7.5\ 10^{1}$

Table B2: Implied collective doses (manSv) integrated to 500 years to EU population from reported annual atmospheric discharges from Sellafield and Cap de la Hague

		Collective dose (manSv)									
		Previous study								This study	
Site	Type of dose	1997	1998	1999	2000	2001	2002	2003	2004	2004	2008
Sellafield	Total	12.0	12.8	12.4	11.8	8.6	9.6	8.0	8.0	4.5	1.8
	First pass	8.2	7.6	7.3	7.1	5.4	6.6	4.9	4.7	2.3	0.9
Cap de la Hague	Total	11.6	11.9	9.5	7.6	7.0	41.2	40.8	42.0	25.8	19.5
	First pass	6.2	6.1	4.2	3.4	2.9	16.0	16.0	16.0	8.8	6.8

Table B3: Implied doses to an adult representative person (µSv y^{-1}) from reported atmospheric discharges from Sellafield and Cap de la Hague

	Individual dose (µSv y^{-1})			
	Sellafield		Cap de la Hague	
Year	500 m	5000 m	500 m	5000 m
1997 (previous study)	$2.0\ 10^{1}$	$9.4\ 10^{0}$	$2.9\ 10^{1}$	$1.2\ 10^{1}$
1998 (previous study)	$1.9\ 10^{1}$	$8.1\ 10^{0}$	$2.7\ 10^{1}$	$1.1\ 10^{1}$
1999 (previous study)	$1.8\ 10^{1}$	$7.7\ 10^{0}$	$1.5\ 10^{1}$	$6.1\ 10^{0}$
2000 (previous study)	$1.8\ 10^{1}$	$7.5\ 10^{0}$	$1.3\ 10^{1}$	$5.1\ 10^{0}$
2001 (previous study)	$1.5\ 10^{1}$	$6.2\ 10^{0}$	$9.4\ 10^{0}$	$3.7\ 10^{0}$
2002 (previous study)	$1.9\ 10^{1}$	$7.7\ 10^{0}$	$1.4\ 10^{1}$	$7.7\ 10^{0}$
2003 (previous study)	$1.3\ 10^{1}$	$5.7\ 10^{0}$	$1.4\ 10^{1}$	$7.5\ 10^{0}$
2004 (previous study)	$1.3\ 10^{1}$	$5.3\ 10^{0}$	$1.4\ 10^{1}$	$7.7\ 10^{0}$
2004 (this study)	$1.3\ 10^{1}$	$5.4\ 10^{0}$	$1.6\ 10^{1}$	$8.9\ 10^{0}$
2008 (this study)	$4.5\ 10^{0}$	$1.9\ 10^{0}$	$1.6\ 10^{1}$	$8.3\ 10^{0}$

Table B4 Implied doses to adult representative person ($\mu Sv\ y^{-1}$) from reported atmospheric discharges from nuclear sites (shut down sites are marked in orange)

		Individual doses at 500 m from the release point ($\mu Sv\ y^{-1}$)			Individual doses at 5000 m from the release point ($\mu Sv\ y^{-1}$)		
Country	Site	2004 (previous study)	2004 (this study)	2008	2004 (previous study)	2004 (this study)	2008
Belgium	Doel	$8.9\ 10^{-3}$	$8.4\ 10^{-3}$	$5.7\ 10^{-2}$	$1.2\ 10^{-3}$	$1.2\ 10^{-3}$	$7.9\ 10^{-3}$
Belgium	Tihange	$5.5\ 10^{-2}$	$5.8\ 10^{-2}$	$7.5\ 10^{-2}$	$1.4\ 10^{-2}$	$1.6\ 10^{-2}$	$1.9\ 10^{-2}$
Czech Republic	Dukovany	n/a	$1.8\ 10^{0}$	$1.6\ 10^{0}$	n/a	$1.4\ 10^{-1}$	$1.2\ 10^{-1}$
Czech Republic	Temelín	n/a	$5.3\ 10^{-1}$	$5.7\ 10^{-1}$	n/a	$7.0\ 10^{-2}$	$7.7\ 10^{-2}$
Finland	Loviisa	$6.6\ 10^{-2}$	$7.2\ 10^{-2}$	$6.7\ 10^{-2}$	$7.4\ 10^{-2}$	$8.5\ 10^{-2}$	$8.8\ 10^{-2}$
Finland	Olkiluoto	$2.7\ 10^{-1}$	$3.2\ 10^{-1}$	$3.3\ 10^{-1}$	$1.8\ 10^{-1}$	$2.1\ 10^{-1}$	$2.2\ 10^{-1}$
France	Belleville	$1.1\ 10^{0}$	$1.3\ 10^{0}$	$1.1\ 10^{0}$	$1.6\ 10^{-1}$	$1.9\ 10^{-1}$	$1.5\ 10^{-1}$
France	Blayais	$1.1\ 10^{0}$	$1.3\ 10^{0}$	$1.4\ 10^{0}$	$1.8\ 10^{-1}$	$2.1\ 10^{-1}$	$2.3\ 10^{-1}$
France	Bugey B	$1.4\ 10^{0}$	$1.7\ 10^{0}$	$1.7\ 10^{0}$	$2.1\ 10^{-1}$	$2.4\ 10^{-1}$	$2.4\ 10^{-1}$
France	Cap de la Hague	$1.4\ 10^{1}$	$1.6\ 10^{1}$	$1.6\ 10^{1}$	$7.7\ 10^{0}$	$8.9\ 10^{0}$	$8.3\ 10^{0}$
France	Cattenom	$2.2\ 10^{0}$	$2.5\ 10^{0}$	$2.3\ 10^{0}$	$3.1\ 10^{-1}$	$3.6\ 10^{-1}$	$3.3\ 10^{-1}$
France	Chinon B	$1.4\ 10^{0}$	$1.6\ 10^{0}$	$1.6\ 10^{0}$	$1.9\ 10^{-1}$	$2.3\ 10^{-1}$	$2.3\ 10^{-1}$
France	Chooz B	$1.2\ 10^{0}$	$1.4\ 10^{0}$	$1.6\ 10^{0}$	$1.7\ 10^{-1}$	$2.0\ 10^{-1}$	$2.2\ 10^{-1}$
France	Civaux	$1.3\ 10^{0}$	$1.5\ 10^{0}$	$1.4\ 10^{0}$	$1.9\ 10^{-1}$	$2.2\ 10^{-1}$	$2.0\ 10^{-1}$
France	Creys Malville	$3.1\ 10^{-3}$	$2.8\ 10^{-3}$	$1.0\ 10^{-2}$	$4.1\ 10^{-4}$	$3.7\ 10^{-4}$	$1.5\ 10^{-3}$
France	Cruas	$1.4\ 10^{0}$	$1.6\ 10^{0}$	$1.5\ 10^{0}$	$1.9\ 10^{-1}$	$2.3\ 10^{-1}$	$2.2\ 10^{-1}$
France	Dampierre	$1.3\ 10^{0}$	$1.6\ 10^{0}$	$1.7\ 10^{0}$	$1.9\ 10^{-1}$	$2.3\ 10^{-1}$	$2.4\ 10^{-1}$
France	Fessenheim	$6.1\ 10^{-1}$	$7.1\ 10^{-1}$	$6.8\ 10^{-1}$	$8.7\ 10^{-2}$	$1.0\ 10^{-1}$	$9.7\ 10^{-2}$
France	Flamanville	$8.8\ 10^{-2}$	$1.0\ 10^{-1}$	$6.3\ 10^{-2}$	$8.7\ 10^{-2}$	$1.0\ 10^{-1}$	$6.2\ 10^{-2}$
France	Golfech	$9.4\ 10^{-1}$	$1.1\ 10^{0}$	$1.2\ 10^{0}$	$1.3\ 10^{-1}$	$1.6\ 10^{-1}$	$1.7\ 10^{-1}$
France	Gravelines	$1.7\ 10^{0}$	$2.0\ 10^{0}$	$1.9\ 10^{0}$	$2.8\ 10^{-1}$	$3.3\ 10^{-1}$	$3.2\ 10^{-1}$
France	Nogent	$1.2\ 10^{0}$	$1.4\ 10^{0}$	$1.1\ 10^{0}$	$1.6\ 10^{-1}$	$1.9\ 10^{-1}$	$1.6\ 10^{-1}$
France	Paluel	$1.4\ 10^{0}$	$1.6\ 10^{0}$	$1.9\ 10^{0}$	$2.4\ 10^{-1}$	$2.8\ 10^{-1}$	$3.1\ 10^{-1}$
France	Penly	$9.1\ 10^{-2}$	$1.1\ 10^{-1}$	$1.2\ 10^{-1}$	$8.9\ 10^{-2}$	$1.0\ 10^{-1}$	$1.2\ 10^{-1}$
France	Saint-Alban	$1.2\ 10^{0}$	$1.4\ 10^{0}$	$8.1\ 10^{-1}$	$1.7\ 10^{-1}$	$2.0\ 10^{-1}$	$1.2\ 10^{-1}$

Table B4 Implied doses to adult representative person ($\mu Sv\ y^{-1}$) from reported atmospheric discharges from nuclear sites (shut down sites are marked in orange)

		Individual doses at 500 m from the release point ($\mu Sv\ y^{-1}$)			Individual doses at 5000 m from the release point ($\mu Sv\ y^{-1}$)		
Country	Site	2004 (previous study)	2004 (this study)	2008	2004 (previous study)	2004 (this study)	2008
France	Saint-Laurent B	$7.2\ 10^{-1}$	$8.5\ 10^{-1}$	$9.0\ 10^{-1}$	$1.0\ 10^{-1}$	$1.2\ 10^{-1}$	$1.3\ 10^{-1}$
France	Tricastin	$1.3\ 10^{0}$	$1.6\ 10^{0}$	$7.8\ 10^{-1}$	$1.9\ 10^{-1}$	$2.2\ 10^{-1}$	$1.1\ 10^{-1}$
Germany	Biblis A	$5.5\ 10^{-2}$	$6.0\ 10^{-2}$	$5.1\ 10^{-2}$	$2.5\ 10^{-2}$	$2.8\ 10^{-2}$	$2.4\ 10^{-2}$
Germany	Biblis B	$1.3\ 10^{-1}$	$1.4\ 10^{-1}$	$6.9\ 10^{-2}$	$5.9\ 10^{-2}$	$6.4\ 10^{-2}$	$3.2\ 10^{-2}$
Germany	Brokdorf	$6.6\ 10^{-1}$	$7.3\ 10^{-1}$	$9.5\ 10^{-1}$	$9.5\ 10^{-2}$	$1.0\ 10^{-1}$	$1.4\ 10^{-1}$
Germany	Brunsbüttel	$1.2\ 10^{-1}$	$1.3\ 10^{-1}$	$5.7\ 10^{-2}$	$5.2\ 10^{-2}$	$5.8\ 10^{-2}$	$2.6\ 10^{-2}$
Germany	Emsland	$1.1\ 10^{-1}$	$1.2\ 10^{-1}$	$1.2\ 10^{-1}$	$5.2\ 10^{-2}$	$5.7\ 10^{-2}$	$5.5\ 10^{-2}$
Germany	Grafenrheinfeld	$1.3\ 10^{-1}$	$1.5\ 10^{-1}$	$1.4\ 10^{-1}$	$6.3\ 10^{-2}$	$6.8\ 10^{-2}$	$6.4\ 10^{-2}$
Germany	Greifswald	$3.5\ 10^{-4}$	$3.0\ 10^{-4}$	$2.6\ 10^{-4}$	$4.9\ 10^{-5}$	$4.3\ 10^{-5}$	$3.7\ 10^{-5}$
Germany	Grohnde	$1.3\ 10^{-1}$	$1.5\ 10^{-1}$	$1.7\ 10^{-1}$	$6.1\ 10^{-2}$	$6.7\ 10^{-2}$	$7.7\ 10^{-2}$
Germany	Gundremmingen A	$5.9\ 10^{-5}$	$5.3\ 10^{-5}$	$4.1\ 10^{-6}$	$2.8\ 10^{-5}$	$2.5\ 10^{-5}$	$1.4\ 10^{-6}$
Germany	Gundremmingen B+C	$3.4\ 10^{-1}$	$3.7\ 10^{-1}$	$3.8\ 10^{-1}$	$1.6\ 10^{-1}$	$1.7\ 10^{-1}$	$1.8\ 10^{-1}$
Germany	Isar 1	$1.4\ 10^{-1}$	$1.7\ 10^{-1}$	$1.4\ 10^{-1}$	$6.7\ 10^{-2}$	$7.8\ 10^{-2}$	$6.6\ 10^{-2}$
Germany	Isar 2	$1.1\ 10^{-1}$	$1.3\ 10^{-1}$	$2.9\ 10^{-1}$	$5.3\ 10^{-2}$	$5.8\ 10^{-2}$	$1.3\ 10^{-1}$
Germany	Karlsruhe WAK	$1.8\ 10^{-2}$	$1.9\ 10^{-2}$	$4.8\ 10^{-2}$	$7.5\ 10^{-3}$	$7.8\ 10^{-3}$	$2.2\ 10^{-2}$
Germany	Krümmel	$7.6\ 10^{-2}$	$8.3\ 10^{-2}$	$1.8\ 10^{-2}$	$3.5\ 10^{-2}$	$3.8\ 10^{-2}$	$8.3\ 10^{-3}$
Germany	Lingen	$2.7\ 10^{-4}$	$3.0\ 10^{-4}$	No discharges reported	$1.3\ 10^{-4}$	$1.4\ 10^{-4}$	No discharges reported
Germany	Mülheim-Kärlich	$3.3\ 10^{-4}$	$3.6\ 10^{-4}$	$3.2\ 10^{-4}$	$1.5\ 10^{-4}$	$1.7\ 10^{-4}$	$1.5\ 10^{-4}$
Germany	Neckarwestheim 1	$1.2\ 10^{-1}$	$1.3\ 10^{-1}$	$9.0\ 10^{-2}$	$5.5\ 10^{-2}$	$6.0\ 10^{-2}$	$4.1\ 10^{-2}$
Germany	Neckarwestheim 2	$1.8\ 10^{-1}$	$1.9\ 10^{-1}$	$1.2\ 10^{-1}$	$8.2\ 10^{-2}$	$9.0\ 10^{-2}$	$5.3\ 10^{-2}$
Germany	Obrigheim	$1.1\ 10^{-1}$	$1.2\ 10^{-1}$	$5.2\ 10^{-3}$	$1.6\ 10^{-2}$	$1.7\ 10^{-2}$	$7.4\ 10^{-4}$
Germany	Philippsburg 1	$1.8\ 10^{-1}$	$2.0\ 10^{-1}$	$2.0\ 10^{-1}$	$8.3\ 10^{-2}$	$9.3\ 10^{-2}$	$9.3\ 10^{-2}$
Germany	Philippsburg 2	$4.0\ 10^{-1}$	$4.4\ 10^{-1}$	$2.9\ 10^{-1}$	$5.6\ 10^{-2}$	$6.1\ 10^{-2}$	$4.0\ 10^{-2}$
Germany	Rheinsberg	$1.8\ 10^{-4}$	$1.4\ 10^{-4}$	$5.4\ 10^{-5}$	$4.7\ 10^{-5}$	$4.6\ 10^{-5}$	$2.0\ 10^{-5}$
Germany	Stade	$4.7\ 10^{-1}$	$5.2\ 10^{-1}$	$9.2\ 10^{-2}$	$6.7\ 10^{-2}$	$7.3\ 10^{-2}$	$1.3\ 10^{-2}$

Table B4 Implied doses to adult representative person ($\mu Sv\ y^{-1}$) from reported atmospheric discharges from nuclear sites (shut down sites are marked in orange)

		Individual doses at 500 m from the release point ($\mu Sv\ y^{-1}$)			Individual doses at 5000 m from the release point ($\mu Sv\ y^{-1}$)		
Country	Site	2004 (previous study)	2004 (this study)	2008	2004 (previous study)	2004 (this study)	2008
Germany	THTR 300	$5.9\ 10^{-7}$	$5.3\ 10^{-7}$	$3.5\ 10^{-7}$	$2.7\ 10^{-7}$	$2.5\ 10^{-7}$	$1.6\ 10^{-7}$
Germany	Unterweser	$1.9\ 10^{-2}$	$2.1\ 10^{-2}$	$1.6\ 10^{-1}$	$8.1\ 10^{-3}$	$8.8\ 10^{-3}$	$7.3\ 10^{-2}$
Germany	Würgassen	$3.0\ 10^{-3}$	$3.1\ 10^{-3}$	$3.9\ 10^{-3}$	$4.2\ 10^{-4}$	$4.3\ 10^{-4}$	$5.5\ 10^{-4}$
Hungary	Paks	n/a	$1.6\ 10^{0}$	$1.1\ 10^{0}$	n/a	$1.6\ 10^{-1}$	$1.3\ 10^{-1}$
Lithuania	Ignalina	n/a	$4.4\ 10^{-1}$	$4.2\ 10^{-1}$	n/a	$1.1\ 10^{-1}$	$1.1\ 10^{-1}$
Netherlands	Borssele	$1.7\ 10^{-1}$	$2.2\ 10^{-1}$	$2.7\ 10^{-1}$	$2.3\ 10^{-2}$	$3.0\ 10^{-2}$	$3.8\ 10^{-2}$
Netherlands	Dodewaard	$3.4\ 10^{-5}$	$4.3\ 10^{-5}$	No discharges reported	$1.4\ 10^{-5}$	$1.8\ 10^{-5}$	No discharges reported
Slovakia	Bohunice A	n/a	$4.2\ 10^{-4}$	$6.9\ 10^{-4}$	n/a	$7.3\ 10^{-5}$	$1.1\ 10^{-4}$
Slovakia	Bohunice B	n/a	$1.6\ 10^{-1}$	$8.8\ 10^{-2}$	n/a	$6.9\ 10^{-2}$	$7.0\ 10^{-2}$
Slovakia	Mochovce	n/a	$5.6\ 10^{-2}$	$1.6\ 10^{-1}$	n/a	$1.6\ 10^{-2}$	$5.0\ 10^{-2}$
Slovenia	Krško	n/a	$8.1\ 10^{-1}$	$3.6\ 10^{-1}$	n/a	$6.8\ 10^{-2}$	$3.4\ 10^{-2}$
Spain	Almaraz	$6.4\ 10^{-2}$	$5.9\ 10^{-2}$	$3.6\ 10^{-1}$	$1.3\ 10^{-2}$	$1.2\ 10^{-2}$	$8.5\ 10^{-2}$
Spain	Ascó	$5.6\ 10^{-2}$	$5.5\ 10^{-2}$	$2.8\ 10^{0}$	$1.0\ 10^{-2}$	$9.8\ 10^{-3}$	$5.7\ 10^{-1}$
Spain	Cofrentes	$2.9\ 10^{-1}$	$3.4\ 10^{-1}$	$1.1\ 10^{0}$	$4.4\ 10^{-2}$	$5.6\ 10^{-2}$	$3.5\ 10^{-1}$
Spain	José Cabrera	$5.1\ 10^{-2}$	$5.1\ 10^{-2}$	$4.3\ 10^{-4}$	$3.9\ 10^{-3}$	$3.9\ 10^{-3}$	$7.4\ 10^{-5}$
Spain	Santa María de Garoña	$8.8\ 10^{-3}$	$8.6\ 10^{-3}$	$8.7\ 10^{-1}$	$1.7\ 10^{-3}$	$1.6\ 10^{-3}$	$2.8\ 10^{-1}$
Spain	Trillo	$6.0\ 10^{-2}$	$7.0\ 10^{-2}$	$6.8\ 10^{-2}$	$1.2\ 10^{-2}$	$1.4\ 10^{-2}$	$1.3\ 10^{-2}$
Spain	Vandellos 2	$2.3\ 10^{-3}$	$2.2\ 10^{-3}$	$2.6\ 10^{-1}$	$4.5\ 10^{-4}$	$4.2\ 10^{-4}$	$5.2\ 10^{-2}$
Sweden	Barsebäck	$2.5\ 10^{-1}$	$4.9\ 10^{-1}$	$2.7\ 10^{-4}$	$1.1\ 10^{-1}$	$2.7\ 10^{-1}$	$5.2\ 10^{-5}$
Sweden	Forsmark	$8.2\ 10^{-1}$	$9.2\ 10^{-1}$	$8.6\ 10^{-1}$	$5.4\ 10^{-1}$	$6.1\ 10^{-1}$	$5.7\ 10^{-1}$
Sweden	Oskarshamn	$1.8\ 10^{0}$	$3.1\ 10^{0}$	$1.6\ 10^{0}$	$3.5\ 10^{-1}$	$1.1\ 10^{0}$	$3.7\ 10^{-1}$
Sweden	Ringhals 1	$2.0\ 10^{-1}$	$2.8\ 10^{-1}$	$1.8\ 10^{-1}$	$1.2\ 10^{-1}$	$1.8\ 10^{-1}$	$1.2\ 10^{-1}$
Sweden	Ringhals 2	$1.5\ 10^{0}$	$1.8\ 10^{0}$	$9.6\ 10^{-1}$	$3.4\ 10^{-1}$	$3.9\ 10^{-1}$	$2.2\ 10^{-1}$
United Kingdom	Berkeley	$1.8\ 10^{-3}$	$1.9\ 10^{-3}$	$2.4\ 10^{-3}$	$8.6\ 10^{-5}$	$9.5\ 10^{-5}$	$1.2\ 10^{-4}$
United Kingdom	Bradwell	$2.2\ 10^{-2}$	$2.5\ 10^{-2}$	$8.9\ 10^{-3}$	$1.1\ 10^{-3}$	$1.3\ 10^{-3}$	$4.3\ 10^{-4}$

Table B4 Implied doses to adult representative person (μSv y^{-1}) from reported atmospheric discharges from nuclear sites (shut down sites are marked in orange)

		Individual doses at 500 m from the release point (μSv y^{-1})			Individual doses at 5000 m from the release point (μSv y^{-1})		
Country	Site	2004 (previous study)	2004 (this study)	2008	2004 (previous study)	2004 (this study)	2008
United Kingdom	Calder Hall	$7.4\ 10^{-3}$	$7.5\ 10^{-3}$	No discharges reported	$3.7\ 10^{-4}$	$3.8\ 10^{-4}$	No discharges reported
United Kingdom	Chapelcross	$3.8\ 10^{1}$	$3.6\ 10^{1}$	$3.9\ 10^{0}$	$1.8\ 10^{0}$	$1.7\ 10^{0}$	$1.9\ 10^{-1}$
United Kingdom	Dounreay	$2.6\ 10^{-1}$	$2.6\ 10^{-1}$	$2.9\ 10^{-1}$	$3.8\ 10^{-2}$	$3.9\ 10^{-2}$	$4.3\ 10^{-2}$
United Kingdom	Dungeness A	$4.0\ 10^{1}$	$4.4\ 10^{1}$	$3.1\ 10^{-2}$	$2.0\ 10^{0}$	$2.1\ 10^{0}$	$1.8\ 10^{-3}$
United Kingdom	Dungeness B	$6.7\ 10^{0}$	$7.3\ 10^{0}$	$8.2\ 10^{0}$	$3.5\ 10^{-1}$	$3.8\ 10^{-1}$	$4.2\ 10^{-1}$
United Kingdom	Hartlepool	$1.2\ 10^{1}$	$1.4\ 10^{1}$	$4.5\ 10^{-1}$	$6.3\ 10^{-1}$	$7.0\ 10^{-1}$	$2.6\ 10^{-2}$
United Kingdom	Heysham 1	$5.1\ 10^{0}$	$5.8\ 10^{0}$	$8.9\ 10^{-1}$	$2.5\ 10^{-1}$	$2.9\ 10^{-1}$	$5.2\ 10^{-2}$
United Kingdom	Heysham 2	$1.0\ 10^{1}$	$1.1\ 10^{1}$	$1.3\ 10^{1}$	$4.9\ 10^{-1}$	$5.6\ 10^{-1}$	$6.4\ 10^{-1}$
United Kingdom	Hinkley Point A	$1.4\ 10^{-2}$	$1.5\ 10^{-2}$	$1.2\ 10^{-2}$	$6.7\ 10^{-4}$	$7.3\ 10^{-4}$	$5.8\ 10^{-4}$
United Kingdom	Hinkley Point B	$1.5\ 10^{1}$	$1.7\ 10^{1}$	$1.3\ 10^{1}$	$8.3\ 10^{-1}$	$9.0\ 10^{-1}$	$7.2\ 10^{-1}$
United Kingdom	Hunterston A	$9.8\ 10^{-4}$	$1.1\ 10^{-3}$	$1.1\ 10^{-3}$	$4.8\ 10^{-5}$	$5.4\ 10^{-5}$	$5.4\ 10^{-5}$
United Kingdom	Hunterston B	$1.3\ 10^{1}$	$1.5\ 10^{1}$	$1.2\ 10^{1}$	$6.5\ 10^{-1}$	$7.4\ 10^{-1}$	$6.0\ 10^{-1}$
United Kingdom	Oldbury	$1.5\ 10^{1}$	$1.6\ 10^{1}$	$9.5\ 10^{0}$	$7.8\ 10^{-1}$	$8.6\ 10^{-1}$	$4.9\ 10^{-1}$
United Kingdom	Sellafield	$1.3\ 10^{1}$	$1.3\ 10^{1}$	$4.5\ 10^{0}$	$5.3\ 10^{0}$	$5.4\ 10^{0}$	$1.9\ 10^{0}$
United Kingdom	Sizewell A	$3.8\ 10^{1}$	$3.9\ 10^{1}$	$4.6\ 10^{-1}$	$1.9\ 10^{0}$	$1.9\ 10^{0}$	$2.3\ 10^{-2}$
United Kingdom	Sizewell B	$1.4\ 10^{0}$	$1.6\ 10^{0}$	$2.5\ 10^{0}$	$6.5\ 10^{-2}$	$7.5\ 10^{-2}$	$1.2\ 10^{-1}$
United Kingdom	Torness	$4.6\ 10^{0}$	$5.2\ 10^{0}$	$6.5\ 10^{0}$	$2.4\ 10^{-1}$	$2.6\ 10^{-1}$	$3.2\ 10^{-1}$
United Kingdom	Trawsfynydd	$1.1\ 10^{-2}$	$1.1\ 10^{-2}$	$2.1\ 10^{-2}$	$5.1\ 10^{-4}$	$5.5\ 10^{-4}$	$1.0\ 10^{-3}$
United Kingdom	Winfrith	$2.6\ 10^{-1}$	$2.4\ 10^{-1}$	$2.8\ 10^{-1}$	$1.3\ 10^{-2}$	$1.2\ 10^{-2}$	$1.4\ 10^{-2}$
United Kingdom	Wylfa	$1.7\ 10^{1}$	$1.9\ 10^{1}$	$1.8\ 10^{1}$	$9.5\ 10^{-1}$	$1.0\ 10^{0}$	$9.6\ 10^{-1}$

APPENDIX C DETAILED RESULTS FOR LIQUID DISCHARGES

Table C1 Implied collective doses (manSv) integrated to 500 years to EU population from reported annual liquid releases (shut down sites are marked in orange)

Point of discharge	Estuary	Site name	Country	Inland/ coastal	2004 (previous study) Marine	Total*	2004 (this study) Marine	Total*	2008 Marine	Total*
Mediterranean Sea										
Black Sea	Danube	Gundremmingen B+C	Germany	Inland	$2.7\ 10^{-5}$	$4.3\ 10^{-4}$	$1.7\ 10^{-5}$	$2.4\ 10^{-3}$	$6.9\ 10^{-6}$	$9.1\ 10^{-4}$
		Isar 1	Germany	Inland	$1.4\ 10^{-6}$	$8.1\ 10^{-6}$	$1.0\ 10^{-6}$	$1.4\ 10^{-4}$	$5.1\ 10^{-7}$	$7.2\ 10^{-5}$
		Isar 2	Germany	Inland	$4.1\ 10^{-5}$	$2.6\ 10^{-4}$	$3.2\ 10^{-5}$	$4.7\ 10^{-3}$	$4.1\ 10^{-5}$	$6.1\ 10^{-3}$
		Dukovany	Czech Republic	Inland	n/a	n/a	$2.8\ 10^{-5}$	$4.2\ 10^{-2}$	$2.3\ 10^{-5}$	$5.2\ 10^{-2}$
		Bohunice A	Slovakia	Inland	n/a	n/a	$2.2\ 10^{-5}$	$1.6\ 10^{-3}$	$6.4\ 10^{-7}$	$2.7\ 10^{-6}$
		Bohunice B	Slovakia	Inland	n/a	n/a	$2.4\ 10^{-5}$	$1.7\ 10^{-3}$	$1.6\ 10^{-5}$	$1.2\ 10^{-3}$
		Mochovce	Slovakia	Inland	n/a	n/a	$1.8\ 10^{-5}$	$1.8\ 10^{-3}$	$1.5\ 10^{-5}$	$1.5\ 10^{-3}$
		Paks	Hungary	Inland	n/a	n/a	$3.6\ 10^{-5}$	$5.5\ 10^{-4}$	$6.8\ 10^{-5}$	$9.1\ 10^{-4}$
		Krško	Slovenia	Inland	n/a	n/a	$2.1\ 10^{-5}$	$2.2\ 10^{-4}$	$1.3\ 10^{-5}$	$1.5\ 10^{-4}$
Gulf of Lions	Rhône	Creys Malville	France	Inland	$1.3\ 10^{-7}$	$1.7\ 10^{-6}$	$8.1\ 10^{-8}$	$1.1\ 10^{-6}$	$9.4\ 10^{-8}$	$1.6\ 10^{-6}$
		Bugey B	France	Inland	$2.6\ 10^{-2}$	$5.5\ 10^{-2}$	$1.1\ 10^{-2}$	$2.4\ 10^{-2}$	$1.1\ 10^{-2}$	$2.4\ 10^{-2}$
		Saint-Alban	France	Inland	$2.1\ 10^{-2}$	$2.4\ 10^{-2}$	$1.3\ 10^{-2}$	$1.6\ 10^{-2}$	$7.8\ 10^{-3}$	$9.6\ 10^{-3}$
		Cruas	France	Inland	$2.5\ 10^{-2}$	$2.7\ 10^{-2}$	$1.8\ 10^{-2}$	$1.9\ 10^{-2}$	$1.7\ 10^{-2}$	$1.9\ 10^{-2}$
		Tricastin	France	Inland	$2.5\ 10^{-2}$	$2.6\ 10^{-2}$	$1.9\ 10^{-2}$	$2.0\ 10^{-2}$	$1.9\ 10^{-2}$	$2.0\ 10^{-2}$
Liguro-Provençal Basin	Ebro	Santa María de Garoña	Spain	Inland	$5.9\ 10^{-6}$	$1.0\ 10^{-4}$	$2.2\ 10^{-6}$	$5.0\ 10^{-5}$	$1.3\ 10^{-6}$	$8.6\ 10^{-5}$
		Ascó	Spain	Inland	$8.2\ 10^{-4}$	$1.0\ 10^{-3}$	$3.9\ 10^{-4}$	$7.9\ 10^{-4}$	$2.3\ 10^{-4}$	$7.2\ 10^{-4}$
		Vandellos 2	Spain	Coastal	$3.0\ 10^{-4}$	$3.0\ 10^{-4}$	$1.3\ 10^{-4}$	$1.3\ 10^{-4}$	$9.0\ 10^{-5}$	$9.0\ 10^{-5}$
	Júcar	Cofrentes	Spain	Inland	$4.1\ 10^{-7}$	$1.1\ 10^{-6}$	$4.1\ 10^{-7}$	$1.2\ 10^{-6}$	$3.5\ 10^{-6}$	$8.2\ 10^{-6}$
North East Atlantic (excluding UK)										
Portuguese Continental Shelf	Tajo	José Cabrera	Spain	Inland	$6.0\ 10^{-6}$	$6.8\ 10^{-3}$	$5.1\ 10^{-6}$	$2.4\ 10^{-3}$	$2.5\ 10^{-7}$	$1.8\ 10^{-3}$
		Trillo	Spain	Inland	$8.3\ 10^{-5}$	$6.4\ 10^{-2}$	$5.3\ 10^{-5}$	$6.6\ 10^{-3}$	$3.1\ 10^{-5}$	$4.3\ 10^{-3}$
		Almaraz	Spain	Inland	$1.6\ 10^{-4}$	$1.7\ 10^{-2}$	$9.4\ 10^{-5}$	$4.6\ 10^{-3}$	$1.1\ 10^{-4}$	$2.8\ 10^{-3}$

Table C1 Implied collective doses (manSv) integrated to 500 years to EU population from reported annual liquid releases (shut down sites are marked in orange)

				Inland/	2004 (previous study)		2004 (this study)		2008	
Point of discharge	Estuary	Site name	Country	coastal	Marine	Total*	Marine	Total*	Marine	Total*
French Continental Shelf	Loire	Belleville	France	Inland	$2.5\ 10^{-2}$	$3.8\ 10^{-2}$	$8.9\ 10^{-3}$	$2.1\ 10^{-2}$	$7.4\ 10^{-3}$	$1.8\ 10^{-2}$
		Dampierre	France	Inland	$3.1\ 10^{-2}$	$4.2\ 10^{-2}$	$1.1\ 10^{-2}$	$2.0\ 10^{-2}$	$1.1\ 10^{-2}$	$2.1\ 10^{-2}$
		Saint-Laurent B	France	Inland	$1.7\ 10^{-2}$	$2.2\ 10^{-2}$	$7.9\ 10^{-3}$	$1.1\ 10^{-2}$	$8.3\ 10^{-3}$	$1.2\ 10^{-2}$
		Civaux	France	Inland	$3.0\ 10^{-2}$	$4.2\ 10^{-2}$	$1.5\ 10^{-2}$	$2.6\ 10^{-2}$	$1.4\ 10^{-2}$	$3.0\ 10^{-2}$
		Chinon B	France	Inland	$3.3\ 10^{-2}$	$3.8\ 10^{-2}$	$1.8\ 10^{-2}$	$2.1\ 10^{-2}$	$1.8\ 10^{-2}$	$2.1\ 10^{-2}$
	Garonne	Golfech	France	Inland	$2.2\ 10^{-2}$	$3.1\ 10^{-2}$	$1.2\ 10^{-2}$	$1.5\ 10^{-2}$	$1.3\ 10^{-2}$	$1.5\ 10^{-2}$
		Blayais	France	Coastal	$3.6\ 10^{-2}$	$3.6\ 10^{-2}$	$2.8\ 10^{-2}$	$2.8\ 10^{-2}$	$3.1\ 10^{-2}$	$3.1\ 10^{-2}$
English Channel south-east		Flamanville	France	Coastal	$3.9\ 10^{2}$	$3.9\ 10^{2}$	$2.8\ 10^{-2}$	$2.8\ 10^{-2}$	$1.7\ 10^{-2}$	$1.7\ 10^{-2}$
		Cap de la Hague	France	Coastal	$3.9\ 10^{2}$	$3.9\ 10^{2}$	$8.5\ 10^{0}$	$8.5\ 10^{0}$	$5.9\ 10^{0}$	$5.9\ 10^{0}$
	Seine	Nogent	France	Inland	$3.3\ 10^{-2}$	$1.6\ 10^{-1}$	$1.7\ 10^{-2}$	$9.9\ 10^{-2}$	$1.7\ 10^{-2}$	$9.0\ 10^{-2}$
		Paluel	France	Coastal	$7.0\ 10^{-2}$	$7.0\ 10^{-2}$	$6.0\ 10^{-2}$	$6.0\ 10^{-2}$	$7.0\ 10^{-2}$	$7.0\ 10^{-2}$
		Penly	France	Coastal	$3.9\ 10^{-2}$	$3.9\ 10^{-2}$	$3.3\ 10^{-2}$	$3.3\ 10^{-2}$	$3.8\ 10^{-2}$	$3.8\ 10^{-2}$
North Sea south-east		Gravelines	France	Coastal	$6.8\ 10^{-2}$	$6.8\ 10^{-2}$	$5.6\ 10^{-2}$	$5.6\ 10^{-2}$	$5.4\ 10^{-2}$	$5.4\ 10^{-2}$
	Rhine-Meuse-Scheldt	Fessenheim	France	Inland	$1.5\ 10^{-2}$	$5.7\ 10^{-2}$	$4.1\ 10^{-3}$	$2.1\ 10^{-2}$	$4.0\ 10^{-3}$	$1.9\ 10^{-2}$
		Karlsruhe WAK	Germany	Inland	$1.9\ 10^{-6}$	$1.4\ 10^{-3}$	$2.1\ 10^{-6}$	$6.0\ 10^{-4}$	$3.3\ 10^{-6}$	$9.6\ 10^{-4}$
		Philippsburg 1	Germany	Inland	$1.4\ 10^{-5}$	$1.2\ 10^{-3}$	$5.2\ 10^{-6}$	$3.1\ 10^{-4}$	$7.0\ 10^{-6}$	$2.5\ 10^{-4}$
		Philippsburg 2	Germany	Inland	$3.1\ 10^{-5}$	$1.9\ 10^{-2}$	$3.3\ 10^{-5}$	$9.6\ 10^{-3}$	$3.7\ 10^{-5}$	$1.1\ 10^{-2}$
		Obrigheim	Germany	Inland	$1.4\ 10^{-5}$	$9.3\ 10^{-3}$	$1.4\ 10^{-5}$	$7.7\ 10^{-3}$	$3.6\ 10^{-7}$	$1.2\ 10^{-4}$
		Neckarwestheim 1	Germany	Inland	$1.5\ 10^{-5}$	$1.3\ 10^{-2}$	$1.6\ 10^{-5}$	$9.1\ 10^{-3}$	$1.1\ 10^{-5}$	$6.3\ 10^{-3}$
		Neckarwestheim 2	Germany	Inland	$3.6\ 10^{-5}$	$3.0\ 10^{-2}$	$3.8\ 10^{-5}$	$2.2\ 10^{-2}$	$4.5\ 10^{-5}$	$2.6\ 10^{-2}$
		Biblis A	Germany	Inland	$3.5\ 10^{-5}$	$2.1\ 10^{-2}$	$3.7\ 10^{-5}$	$9.9\ 10^{-3}$	$1.6\ 10^{-5}$	$4.4\ 10^{-3}$
		Biblis B	Germany	Inland	$2.3\ 10^{-5}$	$1.3\ 10^{-2}$	$2.4\ 10^{-5}$	$6.4\ 10^{-3}$	$2.4\ 10^{-5}$	$6.4\ 10^{-3}$
		Grafenrheinfeld	Germany	Inland	$3.4\ 10^{-5}$	$1.4\ 10^{-1}$	$3.6\ 10^{-5}$	$3.8\ 10^{-2}$	$3.2\ 10^{-5}$	$3.3\ 10^{-2}$
		Cattenom	France	Inland	$5.1\ 10^{-2}$	$1.8\ 10^{-1}$	$2.0\ 10^{-2}$	$7.5\ 10^{-2}$	$1.9\ 10^{-2}$	$8.1\ 10^{-2}$
		Mülheim-Kärlich	Germany	Inland	$4.0\ 10^{-8}$	$8.8\ 10^{-6}$	$5.0\ 10^{-8}$	$3.4\ 10^{-6}$	$2.0\ 10^{-8}$	$1.9\ 10^{-7}$
		Dodewaard	Netherlands	Inland	$1.3\ 10^{-4}$	$3.7\ 10^{-4}$	$9.3\ 10^{-5}$	$1.4\ 10^{-4}$	n/a	n/a

Table C1 Implied collective doses (manSv) integrated to 500 years to EU population from reported annual liquid releases (shut down sites are marked in orange)

Point of discharge	Estuary	Site name	Country	Inland/ coastal	2004 (previous study)		2004 (this study)		2008	
					Marine	Total*	Marine	Total*	Marine	Total*
		Chooz B	France	Inland	$3.1\ 10^{-2}$	$3.2\ 10^{-2}$	$1.7\ 10^{-2}$	$2.0\ 10^{-2}$	$1.9\ 10^{-2}$	$2.3\ 10^{-2}$
		Tihange	Belgium	Inland	$4.8\ 10^{-4}$	$1.7\ 10^{-3}$	$3.5\ 10^{-4}$	$4.8\ 10^{-3}$	$1.9\ 10^{-4}$	$3.4\ 10^{-3}$
		Doel	Belgium	Coastal	$4.9\ 10^{-4}$	$4.9\ 10^{-4}$	$4.8\ 10^{-4}$	$4.8\ 10^{-4}$	$2.9\ 10^{-4}$	$2.9\ 10^{-4}$
		Borssele	Netherlands	Coastal	$2.5\ 10^{-5}$	$2.5\ 10^{-5}$	$2.2\ 10^{-5}$	$2.2\ 10^{-5}$	$1.8\ 10^{-5}$	$1.8\ 10^{-5}$
North Sea east	Ems-Elbe-Weser	Emsland	Germany	Inland	$3.9\ 10^{-5}$	$1.6\ 10^{-4}$	$4.4\ 10^{-5}$	$4.4\ 10^{-4}$	$4.9\ 10^{-5}$	$4.9\ 10^{-4}$
		Lingen	Germany	Inland	$3.2\ 10^{-9}$	$3.6\ 10^{-9}$	$9.0\ 10^{-9}$	$1.1\ 10^{-8}$	$3.7\ 10^{-8}$	$5.4\ 10^{-8}$
		Temelín	Czech Republic	Inland	n/a	n/a	$5.7\ 10^{-6}$	$1.2\ 10^{-2}$	$1.3\ 10^{-4}$	$2.7\ 10^{-1}$
		Krümmel	Germany	Inland	$1.2\ 10^{-6}$	$7.4\ 10^{-5}$	$1.4\ 10^{-6}$	$8.1\ 10^{-5}$	$1.7\ 10^{-7}$	$1.0\ 10^{-5}$
		Stade	Germany	Coastal	$3.4\ 10^{-5}$	$3.4\ 10^{-5}$	$4.0\ 10^{-5}$	$4.0\ 10^{-5}$	$3.0\ 10^{-7}$	$3.0\ 10^{-7}$
		Brokdorf	Germany	Coastal	$3.5\ 10^{-5}$	$3.5\ 10^{-5}$	$4.0\ 10^{-5}$	$4.0\ 10^{-5}$	$5.5\ 10^{-5}$	$5.5\ 10^{-5}$
		Brunsbüttel	Germany	Coastal	$2.4\ 10^{-5}$	$2.4\ 10^{-5}$	$2.8\ 10^{-5}$	$2.8\ 10^{-5}$	$7.6\ 10^{-5}$	$7.6\ 10^{-5}$
		Grohnde	Germany	Inland	$4.8\ 10^{-5}$	$2.8\ 10^{-3}$	$5.4\ 10^{-5}$	$1.8\ 10^{-3}$	$5.3\ 10^{-5}$	$1.7\ 10^{-3}$
		Würgassen	Germany	Inland	$1.4\ 10^{-7}$	$3.8\ 10^{-6}$	$3.7\ 10^{-7}$	$3.1\ 10^{-6}$	$1.8\ 10^{-7}$	$3.5\ 10^{-6}$
		Unterweser	Germany	Coastal	$3.6\ 10^{-5}$	$3.6\ 10^{-5}$	$4.0\ 10^{-5}$	$4.0\ 10^{-5}$	$4.9\ 10^{-5}$	$4.9\ 10^{-5}$
Baltic region										
Kattegat		Ringhals 1	Sweden	Coastal	$1.2\ 10^{-4}$	$1.2\ 10^{-4}$	$6.1\ 10^{-5}$	$6.1\ 10^{-5}$	$1.4\ 10^{-5}$	$1.4\ 10^{-5}$
		Ringhals 2	Sweden	Coastal	$1.3\ 10^{-4}$	$1.3\ 10^{-4}$	$9.6\ 10^{-5}$	$9.6\ 10^{-5}$	$5.8\ 10^{-5}$	$5.8\ 10^{-5}$
Belt Sea		Barsebäck	Sweden	Coastal	$2.7\ 10^{-4}$	$2.7\ 10^{-4}$	$2.3\ 10^{-4}$	$2.3\ 10^{-4}$	$3.7\ 10^{-5}$	$3.7\ 10^{-5}$
		Greifswald	Germany	Coastal	$5.4\ 10^{-6}$	$5.4\ 10^{-6}$	$2.3\ 10^{-6}$	$2.3\ 10^{-6}$	$4.7\ 10^{-7}$	$4.7\ 10^{-7}$
Baltic Sea west		Oskarshamn	Sweden	Coastal	$1.5\ 10^{-4}$	$1.5\ 10^{-4}$	$3.2\ 10^{-4}$	$3.2\ 10^{-4}$	$7.9\ 10^{-5}$	$7.9\ 10^{-5}$
Gulf of Riga		Ignalina	Lithuania	Inland	n/a	n/a	$3.8\ 10^{-6}$	$1.1\ 10^{-3}$	$3.9\ 10^{-6}$	$1.0\ 10^{-3}$
Gulf of Finland		Loviisa	Finland	Coastal	$1.1\ 10^{-4}$	$1.1\ 10^{-4}$	$8.9\ 10^{-5}$	$8.9\ 10^{-5}$	$6.1\ 10^{-5}$	$6.1\ 10^{-5}$
Bothnian Sea		Olkiluoto	Finland	Coastal	$2.9\ 10^{-5}$	$2.9\ 10^{-5}$	$1.3\ 10^{-5}$	$1.3\ 10^{-5}$	$1.3\ 10^{-5}$	$1.3\ 10^{-5}$
		Forsmark	Sweden	Coastal	$1.0\ 10^{-4}$	$1.0\ 10^{-4}$	$4.2\ 10^{-5}$	$4.2\ 10^{-5}$	$1.1\ 10^{-5}$	$1.1\ 10^{-5}$
United Kingdom										
Scottish waters east		Dounreay	United Kingdom	Coastal	$9.8\ 10^{-4}$	$9.8\ 10^{-4}$	$6.2\ 10^{-4}$	$6.2\ 10^{-4}$	$2.3\ 10^{-4}$	$2.3\ 10^{-4}$

Table C1 Implied collective doses (manSv) integrated to 500 years to EU population from reported annual liquid releases (shut down sites are marked in orange)

Point of discharge	Estuary	Site name	Country	Inland/ coastal	2004 (previous study) Marine	2004 (previous study) Total*	2004 (this study) Marine	2004 (this study) Total*	2008 Marine	2008 Total*
North Sea central		Torness	United Kingdom	Coastal	$7.0\ 10^{-4}$	$7.0\ 10^{-4}$	$1.1\ 10^{-2}$	$1.1\ 10^{-2}$	$1.2\ 10^{-2}$	$1.2\ 10^{-2}$
		Hartlepool	United Kingdom	Coastal	$6.8\ 10^{-4}$	$6.8\ 10^{-4}$	$7.8\ 10^{-4}$	$7.8\ 10^{-4}$	$7.6\ 10^{-5}$	$7.6\ 10^{-5}$
North Sea south-west		Sizewell A	United Kingdom	Coastal	$3.5\ 10^{-2}$	$3.5\ 10^{-2}$	$1.8\ 10^{-2}$	$1.8\ 10^{-2}$	$4.8\ 10^{-3}$	$4.8\ 10^{-3}$
		Sizewell B	United Kingdom	Coastal	$1.2\ 10^{-3}$	$1.2\ 10^{-3}$	$5.9\ 10^{-4}$	$5.9\ 10^{-4}$	$3.7\ 10^{-4}$	$3.7\ 10^{-4}$
		Bradwell	United Kingdom	Coastal	$2.0\ 10^{-2}$	$2.0\ 10^{-2}$	$1.1\ 10^{-2}$	$1.1\ 10^{-2}$	$2.5\ 10^{-3}$	$2.5\ 10^{-3}$
English Channel north-east		Dungeness A	United Kingdom	Coastal	$7.6\ 10^{-3}$	$7.6\ 10^{-3}$	$5.3\ 10^{-3}$	$5.3\ 10^{-3}$	$6.6\ 10^{-4}$	$6.6\ 10^{-4}$
		Dungeness B	United Kingdom	Coastal	$3.1\ 10^{-3}$	$3.1\ 10^{-3}$	$2.1\ 10^{-3}$	$2.1\ 10^{-3}$	$4.3\ 10^{-4}$	$4.3\ 10^{-4}$
English Channel west		Winfrith	United Kingdom	Coastal	$2.1\ 10^{-3}$	$2.1\ 10^{-3}$	$1.5\ 10^{-3}$	$1.5\ 10^{-3}$	$4.0\ 10^{-3}$	$4.0\ 10^{-3}$
Bristol Channel		Hinkley Point A	United Kingdom	Coastal	$4.1\ 10^{-3}$	$4.1\ 10^{-3}$	$1.3\ 10^{-3}$	$1.3\ 10^{-3}$	$1.3\ 10^{-3}$	$1.3\ 10^{-3}$
		Hinkley Point B	United Kingdom	Coastal	$7.0\ 10^{-4}$	$7.0\ 10^{-4}$	$6.8\ 10^{-4}$	$6.8\ 10^{-4}$	$1.5\ 10^{-4}$	$1.5\ 10^{-4}$
		Berkeley	United Kingdom	Coastal	$3.8\ 10^{-6}$	$3.8\ 10^{-6}$	$1.6\ 10^{-6}$	$1.6\ 10^{-6}$	$4.3\ 10^{-6}$	$4.3\ 10^{-6}$
		Oldbury	United Kingdom	Coastal	$5.4\ 10^{-3}$	$5.4\ 10^{-3}$	$2.3\ 10^{-3}$	$2.3\ 10^{-3}$	$1.7\ 10^{-3}$	$1.7\ 10^{-3}$
Irish Sea south		Trawsfynydd	United Kingdom	Inland	$1.2\ 10^{-4}$	$1.6\ 10^{-3}$	$2.2\ 10^{-4}$	$1.2\ 10^{-2}$	$2.8\ 10^{-5}$	$2.6\ 10^{-3}$
Irish Sea west		Wylfa	United Kingdom	Coastal	$4.5\ 10^{-4}$	$4.5\ 10^{-4}$	$1.0\ 10^{-3}$	$1.0\ 10^{-3}$	$1.5\ 10^{-4}$	$1.5\ 10^{-4}$
Liverpool and Morecambe Bay		Heysham 1	United Kingdom	Coastal	$1.4\ 10^{-3}$	$1.4\ 10^{-3}$	$1.1\ 10^{-3}$	$1.1\ 10^{-3}$	$1.5\ 10^{-4}$	$1.5\ 10^{-4}$
		Heysham 2	United Kingdom	Coastal	$7.7\ 10^{-4}$	$7.7\ 10^{-4}$	$7.7\ 10^{-4}$	$7.7\ 10^{-4}$	$6.2\ 10^{-4}$	$6.2\ 10^{-4}$
Cumbrian waters		Sellafield	United Kingdom	Coastal	$1.6\ 10^{1}$	$1.6\ 10^{1}$	$1.4\ 10^{1}$	$1.4\ 10^{1}$	$6.0\ 10^{0}$	$6.0\ 10^{0}$
Irish Sea north-east		Chapelcross	United Kingdom	Coastal	$3.3\ 10^{-4}$	$3.3\ 10^{-4}$	$2.2\ 10^{-4}$	$2.2\ 10^{-4}$	$3.7\ 10^{-5}$	$3.7\ 10^{-5}$
Scottish waters west		Hunterston A	United Kingdom	Coastal	$1.2\ 10^{-3}$	$1.2\ 10^{-3}$	$5.7\ 10^{-4}$	$5.7\ 10^{-4}$	$1.5\ 10^{-4}$	$1.5\ 10^{-4}$
		Hunterston B	United Kingdom	Coastal	$1.4\ 10^{-3}$	$1.4\ 10^{-3}$	$1.1\ 10^{-3}$	$1.1\ 10^{-3}$	$2.6\ 10^{-4}$	$2.6\ 10^{-4}$
Inland only										
Stechlinsee		Rheinsberg	Germany	Inland	$4.6\ 10^{-8}$	$6.8\ 10^{-7}$	n/a	$3.0\ 10^{-5}$	n/a	$1.4\ 10^{-5}$

*: The total dose presented in this column is the sum of the dose from the marine and river environments

Table C2: Implied doses to an adult representative person (μSv y^{-1}) living near rivers (includes upstream contributions and based on reported discharges to rivers) (shut down sites are marked in orange)

River	Section	Total doses integrated to 50 years (μSv) 2004 (previous study)	2004 (this study)	2008	Site	Country of representative person
Danube	1	1.1 10^{-1}	8.7 10^{-2}	6.5 10^{-2}	Gundremmingen B + C Isar 1 Isar 2	Germany
	Jihlava	n/a	3.9 10^{0}	4.7 10^{0}	Dukovany	Czech Republic
	Vàh	n/a	8.2 10^{-2}	3.4 10^{-2}	Bohunice A Bohunice B	Slovakia
	Hron	n/a	8.8 10^{-2}	7.0 10^{-2}	Mochovce	Slovakia
	5	n/a	5.2 10^{-2}	5.2 10^{-2}	Paks	Hungary
	Sava	n/a	2.2 10^{-2}	1.3 10^{-2}	Krško	Slovenia
Ebro	1	2.2 10^{-2}	3.1 10^{-2}	1.6 10^{-2}	Santa María de Garoña	Spain
	7	3.7 10^{-1}	6.9 10^{-1}	7.9 10^{-1}	Ascó	Spain
Elbe	Vltava	n/a	3.3 10^{-2}	4.2 10^{-1}	Temelín	Czech Republic
	6	3.8 10^{-4}	8.7 10^{-4}	1.1 10^{-2}	Krümmel	Germany
Ems	1	2.9 10^{-3}	2.9 10^{-3}	3.3 10^{-3}	Emsland Lingen	Germany
Garonne	1	1.3 10^{-1}	7.2 10^{-1}	7.2 10^{-1}	Golfech	France
Júcar	1	2.2 10^{-3}	3.9 10^{-3}	1.5 10^{-2}	Cofrentes	Spain
Loire	1	6.5 10^{-1}	3.9 10^{0}	3.7 10^{0}	Belleville Dampierre	France
	2	6.1 10^{-1}	3.3 10^{0}	3.2 10^{0}	Saint-Laurent B	France
	Vienne	4.8 10^{0}	3.8 10^{1}	3.5 10^{1}	Civaux	France
	3	6.5 10^{-1}	3.5 10^{0}	3.3 10^{0}	Chinon B	France
Meuse	1 (FR)	6.8 10^{-2}	3.7 10^{-1}	4.1 10^{-1}	Chooz B	France
	1 (BE)	8.1 10^{-1}	8.5 10^{-1}	6.2 10^{-1}	Tihange	Belgium
Rhine	1	9.6 10^{-2}	6.0 10^{-1}	6.1 10^{-1}	Fessenheim	France
	2	5.2 10^{-2}	2.6 10^{-1}	2.6 10^{-1}	Karlsruhe WAK Philippsburg 1 Philippsburg 2	Germany
	Neckar	1.1 10^{0}	1.2 10^{-1}	1.1 10^{-1}	Obrigheim Neckarwestheim 1 Neckarwestheim 2	Germany
	3	6.6 10^{-2}	2.3 10^{-1}	2.2 10^{-1}	Biblis A Biblis B	Germany
	Main	5.6 10^{-2}	5.2 10^{-2}	4.4 10^{-2}	Grafenrheinfeld	Germany
	Moselle	1.1 10^{0}	5.5 10^{0}	5.4 10^{0}	Cattenom	France
	5	1.2 10^{-1}	4.9 10^{-1}	4.8 10^{-1}	Mülheim-Kärlich	Germany
	6	2.9 10^{-1}	3.1 10^{-1}	1.3 10^{-1}	Dodewaard	Netherlands
Rhône	1	3.4 10^{-1}	2.1 10^{0}	2.1 10^{0}	Creys Malville Bugey B	France
	4	4.3 10^{-1}	1.9 10^{0}	1.3 10^{0}	Saint-Alban	France
	5	4.7 10^{-1}	2.0 10^{0}	1.5 10^{0}	Cruas	France
	6	5.4 10^{-1}	2.6 10^{0}	2.2 10^{0}	Tricastin	France
Seine	1	1.9 10^{-1}	1.2 10^{0}	1.2 10^{0}	Nogent	France
Tajo	1	4.7 10^{-2}	5.4 10^{-2}	6.7 10^{-2}	José Cabrera Trillo	Spain
Tajo	3	1.4 10^{-1}	1.3 10^{0}	1.2 10^{0}	Almaraz	Spain
Weser	1	6.1 10^{-3}	6.3 10^{-3}	1.5 10^{-2}	Grohnde Würgassen	Germany

* For some sections of rivers, discharges from a number of sites contribute to the dose for that section. Where only one site, which is shut down, discharges into a section of river, the dose has also been marked in orange

Table C3: Implied individual doses (µSv y^{-1}) to adult representative individual living near the coast (includes contributions from inland and coastal sites, based on reported discharges) (shut down sites are marked in orange)*

Point of discharge	Estuary	Total doses*			Site name	Country	Inland/ coastal
		2004 (previous study)	2004 (this study)	2008			
Mediterranean Sea							
Black Sea	Danube	$1.3\ 10^{-2}$	$2.0\ 10^{-3}$	$3.1\ 10^{-3}$	Gundremmingen B+C	Germany	Inland
					Isar 1	Germany	Inland
					Isar 2	Germany	Inland
					Dukovany	Czech Republic	Inland
					Bohunice A	Slovakia	Inland
					Bohunice B	Slovakia	Inland
					Mochovce	Slovakia	Inland
					Paks	Hungary	Inland
					Krško	Slovenia	Inland
Gulf of Lions	Rhône	$3.8\ 10^{1}$	$2.4\ 10^{1}$	$2.1\ 10^{1}$	Creys Malville	France	Inland
					Bugey B	France	Inland
					Saint-Alban	France	Inland
					Cruas	France	Inland
					Tricastin	France	Inland
Liguro-Provençal Basin	Ebro	$1.7\ 10^{0}$	$7.8\ 10^{0}$	$4.8\ 10^{0}$	Santa María de Garoña	Spain	Inland
					Ascó	Spain	Inland
					Vandellos 2	Spain	Coastal
	Júcar	$9.0\ 10^{-4}$	$1.8\ 10^{-2}$	$7.8\ 10^{-2}$	Cofrentes	Spain	Inland
North East Atlantic (Europe excluding UK)							
Portuguese Continental Shelf	Tajo	$5.9\ 10^{-2}$	$9.3\ 10^{-2}$	$1.3\ 10^{-1}$	José Cabrera	Spain	Inland
					Trillo	Spain	Inland
					Almaraz	Spain	Inland
French Continental Shelf	Loire	$3.6\ 10^{1}$	$2.0\ 10^{1}$	$2.0\ 10^{1}$	Belleville	France	Inland
					Dampierre	France	Inland

Table C3: Implied individual doses (μSv y^{-1}) to adult representative individual living near the coast (includes contributions from inland and coastal sites, based on reported discharges) (shut down sites are marked in orange)*

Point of discharge	Estuary	Total doses*			Site name	Country	Inland/ coastal
		2004 (previous study)	2004 (this study)	2008			
					Saint-Laurent B	France	Inland
					Civaux	France	Inland
					Chinon B	France	Inland
	Garonne	$1.5\ 10^{1}$	$1.3\ 10^{1}$	$1.5\ 10^{1}$	Golfech	France	Inland
					Blayais	France	Coastal
English Channel south-east		$4.7\ 10^{-1}$	$4.9\ 10^{-1}$	$3.0\ 10^{-1}$	Flamanville	France	Coastal
		$2.1\ 10^{2}$	$2.3\ 10^{2}$	$1.5\ 10^{2}$	Cap de la Hague	France	Coastal
	Seine	$3.3\ 10^{1}$	$3.2\ 10^{1}$	$3.4\ 10^{1}$	Nogent	France	Inland
					Paluel	France	Coastal
					Penly	France	Coastal
North Sea south-east		$1.0\ 10^{0}$	$1.1\ 10^{0}$	$1.0\ 10^{0}$	Gravelines	France	Coastal
	Rhine-Meuse-Scheldt	$2.0\ 10^{1}$	$1.5\ 10^{0}$	$1.3\ 10^{0}$	Fessenheim	France	Inland
					Karlsruhe WAK	Germany	Inland
					Philippsburg 1	Germany	Inland
					Philippsburg 2	Germany	Inland
					Obrigheim	Germany	Inland
					Neckarwestheim 1	Germany	Inland
					Neckarwestheim 2	Germany	Inland
					Biblis A	Germany	Inland
					Biblis B	Germany	Inland
					Grafenrheinfeld	Germany	Inland
					Cattenom	France	Inland
					Mülheim-Kärlich	Germany	Inland
					Dodewaard	Netherlands	Inland

Table C3: Implied individual doses ($\mu Sv\ y^{-1}$) to adult representative individual living near the coast (includes contributions from inland and coastal sites, based on reported discharges) (shut down sites are marked in orange)*

Point of discharge	Estuary	Total doses*			Site name	Country	Inland/ coastal
		2004 (previous study)	2004 (this study)	2008			
					Chooz B	France	Inland
					Tihange	Belgium	Inland
					Doel	Belgium	Coastal
					Borssele	Netherlands	Coastal
North Sea east	Ems-Elbe-Weser	$8.0\ 10^{-3}$	$4.2\ 10^{-2}$	$3.8\ 10^{-2}$	Emsland	Germany	Inland
					Lingen	Germany	Inland
					Temelín	Czech Republic	Inland
					Krümmel	Germany	Inland
					Stade	Germany	Coastal
					Brokdorf	Germany	Coastal
					Brunsbüttel	Germany	Coastal
					Grohnde	Germany	Inland
					Würgassen	Germany	Inland
					Unterweser	Germany	Coastal
Baltic region							
Kattegat		$1.8\ 10^{-1}$	$3.4\ 10^{-1}$	$7.2\ 10^{-2}$	Ringhals 1	Sweden	Coastal
					Ringhals 2	Sweden	Coastal
Belt Sea		$2.1\ 10^{-1}$	$4.1\ 10^{-1}$	$7.9\ 10^{-2}$	Barsebäck	Sweden	Coastal
		$1.4\ 10^{-4}$	$2.5\ 10^{-4}$	$1.5\ 10^{-4}$	Greifswald	Germany	Coastal
Baltic Sea west		$1.8\ 10^{-1}$	$8.2\ 10^{-1}$	$1.5\ 10^{-1}$	Oskarshamn	Sweden	Coastal
Gulf of Riga		n/a	$1.7\ 10^{-4}$	$1.6\ 10^{-4}$	Ignalina	Lithuania	Inland
Gulf of Finland		$1.4\ 10^{-2}$	$6.5\ 10^{-2}$	$5.8\ 10^{-3}$	Loviisa	Finland	Coastal
Bothnian Sea		$1.0\ 10^{-2}$	$4.6\ 10^{-2}$	$2.5\ 10^{-2}$	Olkiluoto	Finland	Coastal
		$4.8\ 10^{-2}$	$2.2\ 10^{-1}$	$3.6\ 10^{-3}$	Forsmark	Sweden	Coastal
United Kingdom							
Scottish waters east		$2.6\ 10^{-2}$	$1.0\ 10^{-1}$	$2.6\ 10^{-1}$	Dounreay	United Kingdom	Coastal
North Sea central		$6.0\ 10^{-2}$	$3.5\ 10^{-2}$	$4.6\ 10^{-2}$	Torness	United Kingdom	Coastal

Table C3: Implied individual doses (μSv y^{-1}) to adult representative individual living near the coast (includes contributions from inland and coastal sites, based on reported discharges) (shut down sites are marked in orange)*

Point of discharge	Estuary	Total doses*			Site name	Country	Inland/ coastal
		2004 (previous study)	2004 (this study)	2008			
		$8.7\ 10^{-2}$	$3.5\ 10^{-2}$	$4.6\ 10^{-2}$	Hartlepool	United Kingdom	Coastal
North Sea south-west		$1.8\ 10^{0}$	$1.3\ 10^{1}$	$3.6\ 10^{0}$	Sizewell A	United Kingdom	Coastal
					Sizewell B	United Kingdom	Coastal
		$2.0\ 10^{0}$	$1.5\ 10^{1}$	$2.3\ 10^{0}$	Bradwell	United Kingdom	Coastal
English Channel north-east		$1.3\ 10^{-1}$	$9.3\ 10^{-1}$	$4.4\ 10^{-1}$	Dungeness A	United Kingdom	Coastal
					Dungeness B	United Kingdom	Coastal
English Channel west		$6.6\ 10^{-2}$	$4.0\ 10^{-1}$	$8.4\ 10^{-1}$	Winfrith	United Kingdom	Coastal
Bristol Channel		$7.7\ 10^{-2}$	$4.8\ 10^{-1}$	$2.1\ 10^{-1}$	Hinkley Point A	United Kingdom	Coastal
					Hinkley Point B	United Kingdom	Coastal
		$2.2\ 10^{0}$	$1.7\ 10^{1}$	$1.3\ 10^{1}$	Berkeley	United Kingdom	Coastal
					Oldbury	United Kingdom	Coastal
Irish Sea south		$1.3\ 10^{-2}$	$7.1\ 10^{-2}$	$1.4\ 10^{-2}$	Trawsfynydd	United Kingdom	Inland
Irish Sea west		$4.0\ 10^{-1}$	$1.8\ 10^{-1}$	$2.7\ 10^{-2}$	Wylfa	United Kingdom	Coastal
Liverpool and Morecambe Bay		$1.6\ 10^{0}$	$5.1\ 10^{-1}$	$1.6\ 10^{-1}$	Heysham 1	United Kingdom	Coastal
					Heysham 2	United Kingdom	Coastal
Cumbrian waters		$4.1\ 10^{2}$	$1.4\ 10^{1}$	$6.0\ 10^{0}$	Sellafield	United Kingdom	Coastal
Irish Sea north-east		$3.2\ 10^{-2}$	$1.1\ 10^{-2}$	$1.6\ 10^{-3}$	Chapelcross	United Kingdom	Coastal
Scottish waters west		$3.4\ 10^{-2}$	$2.2\ 10^{-1}$	$1.2\ 10^{-1}$	Hunterston A	United Kingdom	Coastal
					Hunterston B	United Kingdom	Coastal

* Discharges from a number of sites contribute can contribute to the dose. Where only one site, which is shut down, discharges into a coastal area, the dose has also been marked in orange.

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