Sellafield Ltd

# Monitoring our Environment

## Discharges and Monitoring in the United Kingdom

## Annual Report 2010

## SI Units

| Quantity | SI unit and abbreviation |
|---|---|
| Absorbed dose | Gray (Gy) |
| Dose equivalent | Sievert (Sv) |
| Radioactivity | Becquerel (Bq) |

## Multiples and submultiples of SI units

| Factor | Prefix and abbreviation | Factor | Prefix and abbreviation |
|---|---|---|---|
| $10^{18}$ | exa (E) | $10^{-3}$ | milli (m) |
| $10^{15}$ | peta (P) | $10^{-6}$ | micro (μ) |
| $10^{12}$ | tera (T) | $10^{-9}$ | nano (n) |
| $10^{9}$ | giga (G) | $10^{-12}$ | pico (p) |
| $10^{6}$ | mega (M) | $10^{-15}$ | femto (f) |
| $10^{3}$ | kilo (k) | $10^{-18}$ | atto (a) |

The tonne (metric ton) has the official abbreviation 't'.
However, in this report 'te' has been used to avoid confusion with the British ton.

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# Introduction

## Discharges and Monitoring in the United Kingdom

## Annual Report 2010

## Sellafield Ltd

1. Sellafield Ltd is the company responsible for safely delivering decommissioning, reprocessing, nuclear waste management and fuel manufacturing activities on behalf of the Nuclear Decommissioning Authority. The company has sites at Sellafield in Cumbria and Capenhurst in Cheshire as well as an extensive engineering design capability based at Risley in Warrington. Now under the ownership of Nuclear Management Partners, Sellafield Ltd has the largest concentration of nuclear expertise in Europe, with over 50 years of experience. The strategy and focus of Sellafield Ltd is to deliver accelerated nuclear clean-up programmes, safely and cost-effectively.

2 Sellafield Ltd (established in April 2007) was previously operating as British Nuclear Group Sellafield Ltd. British Nuclear Group Sellafield Ltd was established following the restructuring of its parent company BNFL in response to the formation of the Nuclear Decommissioning Authority (NDA). The NDA is the public body tasked by Her Majesty's Government with taking strategic responsibility for the decommissioning of civil public sector nuclear sites in the UK. In November 2008, Nuclear Management Partners became the Parent Body Organisation after a 2 year competitive process by the NDA to secure a new Parent Body Organisation for Sellafield Ltd. The NDA has contracted the operation of the Sellafield and Capenhurst sites to Sellafield Ltd and will award subsequent contracts on a competitive tender basis.

## Environmental reporting by Sellafield Ltd

3 Before 2004, BNFL produced a single environmental annual report that contained information on all of the Company's UK sites. From 2004, following the formation of the NDA and the restructuring of BNFL, individual site management companies took responsibility for producing their own environmental annual reports.

4 This 2010 report has been produced by Sellafield Ltd and covers the Sellafield Ltd sites in Cumbria (Sellafield) and Cheshire (Capenhurst). It provides detailed information on radioactive discharges and disposals, monitoring of the environment and radiological impact, and also includes information on non-radioactive discharges and disposals. It may be noted that the report provides a summary of the comprehensive data that are available for inspection by members of the public on the Public Registers maintained by the Environment Agency. This report is also available on the Sellafield Ltd website (http://www.sellafieldsites.com).

5 Wherever practicable, this report continues to present annual discharge and disposal data over five years for all radionuclides specified in the environmental permit for radioactive substances; the results of environmental monitoring for the report year; information on trends; and radiological impact in terms of critical group and collective doses. Any non-compliance with numerical limits is reported.

6 For non-radioactive discharges, it would be impracticable to report the discharges of all chemical species and performance against every condition in all authorisations and consents, even more so for a five-year period (many consent conditions relate to concentrations in individual samples). Accordingly, discharges and disposals are normally reported for just the year of the report and other quantitative conditions, such as temperature and pH, are usually only reported where non-compliances have occurred. Information relating to longer-term trends is included where it is of particular interest. Discharges are reported as annual 'loads', which are more practicable to report than effluent concentrations, the form in which limits are often defined, although any non-compliances with such limits are reported.

7 All current authorisations and consents, as well as waste disposal and waste management licences, issued specifically to each site, are available for inspection on the Public Registers referred to in paragraph 4.

## Regulation of non-radioactive discharges and disposals

8 The regulation of non-radioactive discharges and disposals is, with the exception of discharges regulated by consents issued by the relevant sewage undertaker (see paragraph 9), the responsibility of the Environment Agency and local authorities who regulate discharges in accordance with the provisions of the Environmental Protection Act 1990 (EPA 1990), the Control of Pollution Act 1974, the Water Resources Act 1991 as amended by the Environment Act 1995 and the Pollution Prevention and Control Act 1999.

9 Discharges to controlled waters of sewage or trade effluent, from processes not subject to EPA 1990 authorisation, are regulated through a system of consents under the Water Resources Act in England and Wales. Where discharges of trade effluent are made to public sewers, they must be subject to a consent issued by the relevant sewage undertaker as required by the Water Industry Act 1991 in England and Wales. In granting consents, the regulatory agencies or sewage undertakers take account of Statutory Water Quality Objectives. Consents place limits on either total quantities discharged (loads) or instantaneous concentrations.

10 Disposals of non-radioactive wastes are regulated through EPA 1990 and the Hazardous Waste Regulations 2005. Where wastes are transferred to another organisation for treatment or disposal, there is a legal Duty of Care on producers, carriers and disposers to ensure that waste is only disposed of under the terms of a Waste Management Licence. Where non-hazardous and inert waste is transferred, it is accompanied by a transfer note which includes a full written description of the waste. Where hazardous waste is transferred in accordance with Hazardous Waste Regulations 2005; it is accompanied by a consignment note. Landfill disposals are subject to the Landfill Regulations which implement the requirements of the Landfill Directive and place additional requirements on both landfill site operators and waste consignors.

## Regulation of radioactive discharges and disposals

11 The control of radioactive wastes is subject to the provisions of the environmental permit for radioactive substances. Under this permit, operators are permitted to discharge and dispose of radioactive waste only in accordance with Certificates of Authorisation issued by the Environment Agency in England and Wales.

12 It is the policy of these agencies to review authorisations regularly. In establishing discharge limits for authorisations, they take into account the radiation protection principles presented in the latest relevant Government White Paper (table 1)[1]. These principles are based on Government policy and the advice of the Health Protection Agency as discussed below in the context of critical group dose limits and constraints (paragraphs 22-25) and collective doses (paragraphs 26-29). Those parts of the Euratom Basic Safety Standards Directive (BSS) 1996 relating to dose limits (paragraph 25) were incorporated into UK law in the Radioactive Substances (Basic Safety Standards) Directive 2000 issued by the appropriate ministers to the Environment Agency. Other provisions of the BSS Directive were implemented through the Ionising Radiation Regulations 1999.

13 All discharges of radioactivity are subject to the requirement to use Best Available Technique (BAT) to limit the amount of radioactivity discharged. To enable the Environment Agency to monitor the application of BPM, Quarterly Notification Levels (QNLs) apply at some sites to discharges of certain radionuclides. Exceeding a QNL requires the operator to submit a written justification of the BPM used to limit discharges.

14 The Food Standards Agency, which reports to health ministers, was formed on 1 April 2000. Its responsibilities include food safety implications of discharges of radioactive waste, in support of which it undertakes a substantial radiological surveillance programme both for marine and terrestrial samples. It has taken on the role, formerly exercised by the Ministry of Agriculture Fisheries and Foods (MAFF), as statutory consultee to the Environment Agency in matters relating to radioactive discharge authorisations. The Office for Nuclear Regulation (ONR) has a similar role as statutory consultee because it regulates the accumulation of radioactive waste on licensed sites and the exposure of the general public to direct radiation from those sites.

**Table 1.** Summary of radiation protection principles in the Government's review of radioactive waste management policy (1995)[1]

| Annual dose | Applicability | Comments |
|---|---|---|
| 1000 μSv | Limits the overall exposure to the general public from man-made controlled sources of radiation (excluding medical uses), including the effects of past and current discharges and summing across all relevant exposure pathways. | The previous flexibility to average exposure over more than one year is no longer considered necessary, and this limit is now a cap on annual exposure. |
| 500 μSv | A 'site constraint' to limit the aggregate exposure from a number of sources with contiguous boundaries at a single location. | Applies irrespective of whether different sources on the site are owned or operated by the same or different organisations. |
| 300 μSv | A 'dose constraint' used as the principal criterion in determining applications for discharge authorisations from new facilities. It applies to the sum of all relevant exposures resulting from the operation of a single new source only. | Existing facilities may seek a higher dose constraint in certain circumstances. In most cases this should not be necessary and, in any case, the dose limit and the ALARA principle continue to apply. |
| 20 μSv | Threshold for optimisation below which the regulators will not seek further reduction in public exposures, provided they are satisfied that 'Best Practicable Means' are being applied to safeguard the public. | The introduction of this concept is consistent with the current practice of the Health and Safety Executive. |

15 The nuclear regulators employed by the Environment Agency regularly pay inspection visits to nuclear sites to critically review operations against radiological protection standards and the application of BAT. Thus the authorisation process is one of continual review (see also paragraph 12). This process not only reviews operations, effluent control and treatment arrangements, on-site sampling and analytical methods, but also the results of environmental monitoring, habits surveys and advances in the methodology for assessing radiological impacts.

16 Thus the authorisation and inspection process embraces important aspects of radiation protection by:

- controlling, monitoring and recording discharges to the environment in accordance with BPM;
- monitoring of the environment to establish resultant radionuclide concentrations;
- carrying out appropriate research, investigations and assessments to determine pathways for the transport of radioactivity through the environment;
- assessing radiation doses to the public;
- predictive assessment of radiation doses to the public arising from future discharges to the environment.

17 The Company is involved in all these activities with respect to discharges from its sites. Under the terms of the discharge authorisations, there is a statutory obligation to carry out defined monitoring programmes, both for discharges and for environmental radioactivity, the latter being known as Statutory Environmental Monitoring Programmes (SEMPs). In addition, the ONR requires the assessment of doses to members of the public from direct radiation.

18 At the Ministerial meeting of the OSPAR Commission at Sintra in Portugal in 1998 (see Glossary), the UK Government agreed to a commitment to reduce concentrations of radioactive and hazardous substances in the marine environment so that, by 2020, discharges will be reduced to levels at which the resulting concentrations additional to historic levels are close to zero. Following Defra's (see Glossary) publication in July 2009 of the UK Strategy for Radioactive Discharges[2], the Company is continuing to work with Government and regulators to achieve the objectives agreed at Sintra.

## Critical group and collective doses

### Critical group doses

19 A key concept for assessment of dose to the public is the 'critical group': the individual members of a population who can realistically be expected to receive the highest dose due to their lifestyle, location and habits[3,4]. This term is equivalent to the term ‘representative person’ used by the International Commission on Radiological Protection (ICRP). The dose to members of a critical group is assessed as the mean of the sums of committed effective doses from intakes of radionuclides during the year and their effective doses from external irradiation (see paragraph 34). These sums are for convenience termed Effective Doses (see Glossary). Effective doses are calculated by combining dose per unit intake data (see Appendix) with estimates of annual radionuclide intake by ingestion and inhalation, taking into account all relevant pathways, such as consumption of specific foods at high rates and inhalation during occupancy of certain areas[5,6].

20 In determining the critical group appropriate to a particular site, it is recognised that the relative doses from different pathways will depend on the habits of particular groups of individuals. Such doses should be summed as required to obtain the critical group dose. Thus a high rate consumer of seafoods may receive only a minor exposure via pathways such as milk consumption or proximity to the site perimeter. For another group, consumption of locally produced meat and milk may combine to result in an elevated exposure. Accordingly, it is common practice to define exposure groups in terms of a dominant pathway or habit (e.g. seafood consumers, boat dwellers, anglers, inhalation pathways etc). For simplicity, these may at times be referred to in this report as 'critical groups', although strictly speaking the Radiation Protection Division of the Health Protection Agency (formerly the National Radiological Protection Board, NRPB)[4] defines only the most exposed group at any given time as the critical group.

21 This report focuses mainly on doses to members of critical groups; the small groups of people that are most exposed to radiation from nuclear facilities. The doses received by the rest of the population, from operations at Sellafield Ltd sites, will be very much less than those received by critical groups.

### Critical group dose limits and constraints

22 UK dose limits and constraints, which are applicable to controlled releases of radioactivity, are based on the '1990 Recommendations' of the ICRP[3] in which it reviewed the quantities used in radiological protection, the biological effects of radiation relevant to radiological protection, the conceptual framework of radiological protection and recommendations on dose limitation. Under these recommendations, the primary dose quantity was redefined as effective dose (see paragraph 19 and the Glossary), taking into account 'weighting factors' which reflect the sensitivity of different body organs to induction of cancer following exposure to radiation. For members of the public, the ICRP recommended an annual limit on effective dose of 1000 μSv.

23 The '1990 Recommendations' also placed emphasis on the optimisation of radiological protection (see paragraph 29) and on the concept of source-related restrictions on individual dose, relating to the optimisation process, termed 'dose constraints'. A dose constraint is an upper bound on the annual dose to the overall critical group, summed over all exposure pathways, from the planned operation of a controlled source[3]. Dose constraints may introduce additional restrictions within the overall dose limit.

24 In 1993, the NRPB published guidance based on ICRP's '1990 Recommendations' and recommended that for proposed new controlled sources, the maximum dose constraint should be 300 μSv per year[4]. Constraints lower than this could be set where such doses are readily achievable. Existing facilities are expected to operate within the appropriate constraints but where it is not possible to comply with the recommended dose constraint, the Health Protection Agency advise that the operating regime be reviewed with the regulatory body to ensure that doses are 'as low as reasonably achievable'. Exposures arising from past controlled releases should be included in any comparison with the 1000 μSv dose limit but not in comparison with the dose constraint of 300 μSv. Health Protection Agency advice includes the caveat that doses should in any case be below the 1000 μSv limit on annual dose.

25 The 1000 μSv dose limit was incorporated into the Euratom Basic Standards Directive 1996 and implemented in UK law through Radioactive Substances (Basic Safety Standards) Direction 2000 (paragraph 12). Ministers have directed the Environment Agency, when discharging their duties under RSA 1993, to ensure that the Directive limit on annual dose to the public is not exceeded, and that a maximum source constraint of 300 μSv and a site constraint of 500 μSv are applied for authorising radioactive discharges. The annual dose limit of 1000 μSv should be compared with the sum of doses from the sites, from discharges from all other sources, and from any historical accumulation of radionuclides in the environment from past discharges.

### Collective doses

26 In addition to estimating doses to critical groups, doses to populations as a whole can be estimated[7]. This involves the concept of 'collective dose': the summation of all individual radiation doses received by a population over some defined period of time. Since radionuclides persist in the environment, subject to processes of dilution, dispersion, radioactive decay, and ingrowth of daughter products, the public will continue to receive radiation doses (generally at a decreasing rate) for some time after a discharge is made. Calculating the collective dose therefore involves predicting the behaviour of radionuclides over extended periods following the discharge.

27 In practice, collective doses are often dominated by the summation of a large number of exceedingly small doses received by individuals who are remote, in both space and time, from the point of discharge. Consequently, the calculation of collective dose relies heavily on the use of theoretical models that predict the dispersion of radionuclides over large geographical areas and long timescales. The unit for collective dose is the man Sievert (man Sv) which emphasises that the value quoted is the sum of doses received by a number of individuals.

28 The time and geographical area over which a collective dose is integrated is necessarily stated with the estimated value. Current Health Protection Agency advice emphasises a 500 year integration period[8] and this is used throughout this report. Doses are generally calculated to the populations of UK, Europe (including the UK) and the world. Detailed information is given in the Appendix.

29 Collective doses play an important role in the optimisation of radiological protection using the ALARA (As Low As Reasonably Achievable) principle. This is recognised by the Health Protection Agency[4] as being a useful technique for aiding decisions between different options for radiological protection. Its advice gives monetary values for unit collective doses, which allows the cost of collective doses to be compared with the capital and operating costs of preventing those doses from arising.

## Monitoring of environmental radioactivity and dose assessment

30 The structure of the Statutory Environmental Monitoring Programmes (paragraph 17) reflects the emphasis placed on assessing radiation doses to the public in the areas local to Sellafield Ltd's sites. The essential considerations are to:

- take account of the most important pathways by which radiation exposure of the public may occur;
- conduct appropriate sampling and analysis to determine radionuclide concentrations or radiation levels relevant to those pathways;
- combine the monitoring results with data on foodstuff consumption and other habits, and with data on the biokinetic behaviour of radionuclides, to yield estimates of radiation dose to the public.

31 It should be noted that these dose estimates, being based on environmental concentrations, will include contributions from radionuclides discharged in earlier years. They will therefore differ from those dose estimates in technical submissions to authorisation reviews which relate to projected doses at expected future levels of discharge and at proposed discharge limits.

32 Data identifying critical groups and their habits by pathway have been provided by the Food Standards Agency, Environment Agency and the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), or their predecessors, based on published survey work[9,10,11]. Site-specific habits data used in dose assessments may relate to single years or to five-year averages as appropriate. Generalised food consumption rates for use in radiological dose assessments (particularly for terrestrial pathways) have been reviewed by the Health Protection Agency and revised guidelines issued in 2003[12]. Where appropriate, such generalised advice may be supplemented by other Health Protection Agency advice[13], or by information from local habits surveys.

33 In assessing doses, the Company takes account of research studies carried out both nationally and internationally, and also sponsors environmental research focusing specifically on the behaviour of radionuclides released from its sites. In addition, throughout this report the guidance of the Health Protection Agency[13], the National Dose Assessment Working Group[14] and the most recent dose coefficients in ICRP Publication 72[15] are adopted where available and appropriate. For the specific calculation of the dose from krypton-85, where the Health Protection Agency does not provide advice, a cloud immersion dose is calculated from the recommendations of the ICRP[3,16]. In general, default values recommended by the ICRP for each radionuclide are assumed for the purpose of dose calculations unless specific studies indicate that an alternative is appropriate as discussed in the Appendix.

34 In accordance with regulatory guidance[17], radiation dose rates in air ('air kerma') are generally measured in primary units of $\mu Gy\ h^{-1}$. In order to express this as an effective dose rate, $\mu Sv\ h^{-1}$, a conversion factor of 0.86 µSv per µGy is appropriate in most cases[17]. This reflects the differing energy deposition of ionising radiation in differing media: in this case air and tissue. By expressing the radiation dose rate in µSv h-1 and making allowance for background dose rates[9,10,18,19], a direct estimate of the dose to man can be obtained.

35 Independent environmental monitoring programmes and dose assessments in the areas both local to Sellafield Ltd's sites and further afield are carried out and reported by government agencies and other groups[9,10,20-23].

36 Collective doses have been calculated, using a 500 year integration period (paragraph 28), based on the most recent EU methodology[24,25]. This approach is consistent with the dosimetric basis used to calculate critical group doses, as assessed by both Sellafield Ltd and independently by the Food Standards Agency[9]. A summary of collective dose per unit release factors is included in the Appendix.

### Analytical measurements, limits of detection and rounding of data

37 All measurements of radioactive discharges, concentrations of radionuclides in the environment and radiation dose rates are subject, as with any other type of measurement, to uncertainties arising from the measurement process itself. These may become important when the quantities involved are very small compared with the measurement uncertainty, and the result is then quoted as a 'limit of detection' (i.e. with a '<' sign). This value is chosen to give a high degree of confidence that the actual result is less than that value.

38 Results from the Company's environmental monitoring programmes are reported here as the arithmetic means of measurements taken throughout the year. The concentrations of many radionuclides in the environment are now sufficiently low that most measurements are reported as limit of detection values, as explained above. They continue to be included in the monitoring and analysis programmes

for reassurance that new pathways involving, for example, remobilised historical materials, have not arisen. Dose calculations either conservatively use such 'limit of detection' values, or use more realistic estimates of concentrations derived using environmental models.

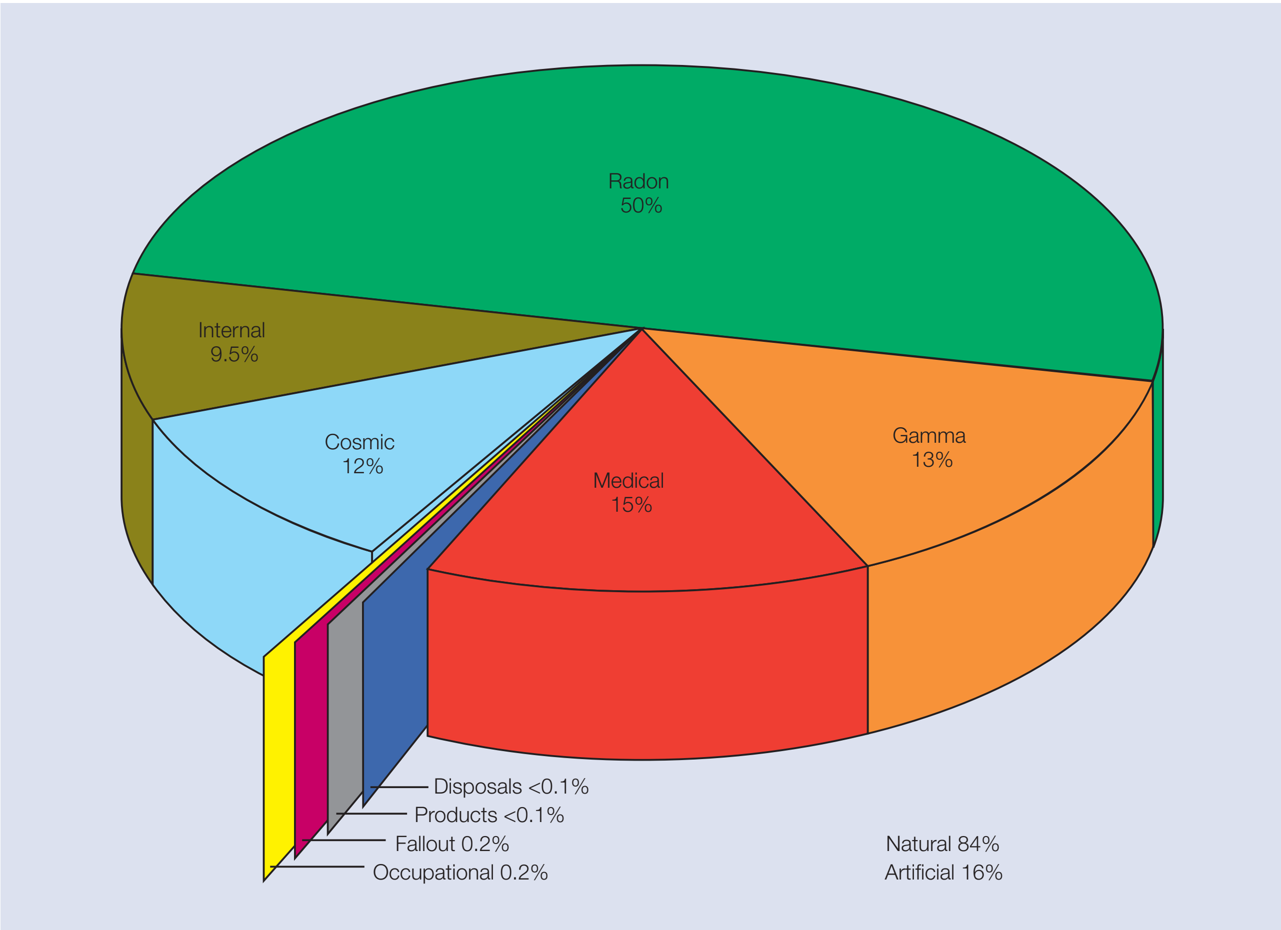
39 For clarity of presentation (and after calculations have been completed) discharges, concentration and dose rate data are normally rounded to two significant figures, or just one where the numbers are very small. Dashes are shown in tables to indicate where data have not been collected.

40 It should also be noted that measurements of 'total alpha' and 'total beta' activity do not necessarily equate to the sum of individually measured radionuclides. This is because of differing counting efficiencies and the presence of naturally occurring radionuclides.

## Protection of the environment

41 In its 1990 Recommendations[3], the ICRP considered that 'the standard of environmental control needed to protect man to the degree presently thought desirable will ensure that other species are not put at risk.' This view is defensible in most situations, particularly where critical groups are exposed in the areas of highest environmental concentrations, close to the point of discharge, through a variety of pathways. However, ICRP acknowledges that the protection of the environment needs to be considered in the wider sense, and has work underway which is addressing this matter. It was recognised in the Ministerial Statement of the OSPAR Convention at Sintra (1998), that the protection of biota for the preservation of biodiversity and bioresources is necessary in its own right. Sellafield Ltd is contributing to a number of initiatives intended to develop criteria for the protection of the environment. In addition, Sellafield Ltd is carrying out assessments of exposure against the guidelines given in national and international publications[26,27,28,29] and, on the basis of work to date, there is no reason to believe that radioactive discharges from Sellafield Ltd are harming the environment.

**Figure 1.** Sources of annual average radiation dose to the UK population[17]

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## Natural radioactivity

42 To put into context the data presented in this report, it is important to recognise that natural radioactivity is the dominant source of radiation exposure to the population as a whole, including individuals living close to nuclear establishments. In addition, the widespread radioactive fallout from the testing of nuclear weapons and from the Chernobyl disaster make small contributions to overall doses. The subject has been reviewed comprehensively by the Health Protection Agency[18,19] and others[30].

43 Individual doses from natural radioactivity in the UK range broadly from 1000 μSv to 100,000 μSv per year[18]. The upper end of the range stems from homes with particularly high indoor levels of radon and its decay products. Dose limits set for the industry do not apply to natural background radiation, such as that from radon. Nevertheless, it may be noted, for comparative purposes only, that these upper figures substantially exceed the dose limits to the public (and indeed the workforce) applicable to the operation of nuclear establishments (see paragraphs 12, 25, and table 1). The Health Protection Agency recommends that measures be taken to reduce levels of radon in homes if the average annual indoor activity concentrations exceed 200 Bq $m^{-3}$ and suggests that a radon-222 concentration of 20 Bq $m^{-3}$ corresponds to an annual dose of 1200 μSv from the short-lived decay products of the gas[18].

44 The measurements in this report relate to environmental radioactivity that is mainly attributable to discharges from Company sites. However, natural radioactivity makes an appreciable contribution to the reported values in some instances. Where it is practicable to do so, the appropriate correction is made and noted. Thus, gamma dose rates quoted in this report are total dose rates including natural terrestrial background and cosmic ray contributions. For dose assessment purposes, the natural contributions are deducted.

45 A comparison of annually averaged doses to individuals in the UK population from all sources of radioactivity is presented in table 2 and figure 1. Typically, natural background accounts for some 84% of the total dose and medical uses of radiation for a further 15%. On this basis, the annual average dose is around 2700 μSv, of which 2230 μSv is derived from natural sources (mainly cosmic rays, rocks and soils, radon gas and foodstuffs - see table 2), 410 μSv from medical exposures, 6 μSv from occupational exposure, 6 μSv from nuclear weapons fallout, 0.9 μSv from discharges and disposals, including those from the nuclear industry, and 0.1 μSv from consumer products[18]. In areas of higher natural background radiation (e.g. Cornwall), the average dose may exceed 7000 μSv per year[19].

**Table 2.** Summary of doses to the UK population from natural sources[17]

| Source | Annual dose (μSv) | |
|---|---|---|
| | Average | Range |
| Cosmic radiation | 330 | 200 - 400 |
| Terrestrial gamma radiation | 350 | 100 - 1000 |
| Irradiation from internal radionuclides | 250 | 100 - 1000 |
| Exposure to radon and progeny | 1200 | 300 - 100,000 |
| Exposure to thoron and progeny | 100 | 50 - 500 |
| Total | 2230 | 1000 - 100,000 |

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The Capenhurst chapter was written by the QEH&S Department at Sellafield Ltd Capenhurst. Urenco UK Ltd at Capenhurst collected the environmental samples and measured environmental dose rates. Samples are analysed at the Urenco UK Ltd laboratories and external laboratories are used by the Environment Agency.

Members of the public who co-operated with the staff collecting samples and making measurements at all sites are especially thanked.


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# Sellafield

## Discharges and Monitoring in the United Kingdom

## Annual Report 2010

## Summary


1 There was only one instance in 2010 of non-compliance with numerical limits in authorisations regulating discharges and disposals of radioactive wastes at Sellafield. This was an aerial discharge of antimony-125 of 7.4 GBq compared to a limit of 6.9 GBq caused by increased reprocessing of fuel with higher burn-up (coupled with relatively low fuel cooling). An increased limit of 30 GBq was agreed with the Environment Agency before the limit was breached in 2010, and this was accepted by the European Commission and implemented from 1st April 2010.

2 Radioactive discharges (aerial and liquid) were generally similar to those in 2009 and, apart from antimony-125, were all well below the authorised limits.

3 The estimated dose in 2010 due to discharges to sea from Sellafield to members of the critical group who consume fish and shellfish from the local area was about 130 μSv. Taking into account doses due to beach occupancy and aerial pathways, the total dose to this group was about 160 μSv, the same as 2009. Doses due to direct radiation from plant on site were estimated as being up to 1.9 μSv to the most exposed members of the public who live nearby, who may, in addition, have received up to 12 μSv from aerial discharge pathways. These doses are summarised in table 1.

4 There was one instance in 2010 of non-compliance with numerical limits in PPC authorisations and the Environmental Permit. This was an exceedance in the volume of discharges from the site's sewage treatment plant, caused by excess water from a burst main entering the site sewage system.


## Operations at Sellafield

5 Sellafield is one of the most complex nuclear sites in the world, home to the Thorp and Magnox reprocessing plants, the Sellafield MOX plant and a wide range of waste management and effluent treatment facilities. As reprocessing runs down the emphasis is shifting to remediation, decommissioning and clean up of the historical legacy.

6 During reprocessing operations, some effluents containing a small fraction of the radioactivity originally present in the used fuel are discharged to the sea and atmosphere, or disposed of as solid wastes to the Low Level Waste Repository (LLWR) near Drigg. Discharges of radioactivity to sea have declined significantly since the 1970s as a result of considerable investments and improvements in effluent treatment plants that have been described in previous reports in this series.

7 Since 1990, a number of plants that encapsulate solid intermediate-level radioactive waste in stainless steel drums have been and continue to be brought on line.

8 Sellafield also operates the Waste Vitrification Plant which converts both historical and current arisings of liquid high-level waste into a form of glass. The molten glass is allowed to solidify inside stainless steel containers, which are then placed in a specially designed, self-cooling storage facility.

9 The Solvent Treatment Plant (STP), which was commissioned in 2002, treats arisings of solvent as well as historical solvent wastes currently stored at Sellafield.

**Table 1.** Summary of critical group doses from operations at Sellafield (μSv)

| Pathway | 2009 | 2010 | Position in text (paragraph no.) |
|---|---|---|---|
| Marine critical group | | | |
| seafood consumption | 130 | 130 | 55, 56 |
| aerial pathways | 2.7 | 2.1 | 56 |
| external radiation from beach occupancy | 32 | 33 | 60 |
| Total dose to marine critical group | 160 | 160 | 55, 56 |
| Terrestrial critical group | | | |
| inhalation (adults) | 0.71 | 0.72 | 64 |
| immersion (adults) | 0.64 | 0.47 | 68 |
| external radiation from beach occupancy (all ages) | 1.1 | 1.3 | 67 |
| terrestrial foodstuff consumption (infants) | 11 | 11 | 63, 64 |
| (of which milk) | 7.8 | 8.5 | 63 |
| marine foodstuff consumption (adults) | 2.0 | 2.2 | 67 |
| All discharge pathways (infants) | 12 | 12 | 69 |
| direct radiation | 1.4 | 1.9 | 70 |
| Total dose to terrestrial critical group (infants) | 13 | 14 | 69, 70 |

10 The Sellafield MOX (Mixed Oxide) Fuel Plant (SMP) manufactures reactor fuel, based upon the recycle of plutonium.

11 Magnox reprocessing throughput in 2010 was lower than in 2009 (317 te compared to 544 te) due to a number of planned outages and reprocessing constraints due to the antimony-125 aerial discharge limit. Decommissioning work on older Magnox plants continued throughout the year.

12 Thorp reprocessing throughput in 2010 was considerably higher than that in 2009 (328 te compared to 196 te).

## Radioactive discharges and disposals

13 Sellafield discharges are regulated by the Environmental Permit for Radioactive Substances (EPR 2010)[1]. The Environmental Permitting Regulations were introduced on 6 April 2010 and repeal the Radioactive Substances Act 1993 in England and Wales. The permit is a multi-media authorisation covering all the discharge and disposal routes under a single Certificate of Authorisation. Additional requirements are specified by the Environment Agency in a supplementary document, the 'Compilation of Environment Agency Requirements' (CEAR). This includes the Statutory Environmental Monitoring Programme and the required format for discharge reports.

14 A review of the Monitoring Programme undertaken in 2005 led to an overall reduction in the types of samples collected and radionuclides analysed. The aim of these changes is to avoid unnecessary duplication with monitoring undertaken by Environment Agency and Food Standards Agency, particularly where limited sample numbers are available. Monitoring of important exposure pathways and indicators has been retained, or in a few instances extended, for reasons of public reassurance.

15 The results of the Sellafield Ltd environmental monitoring programme for 2010 (black text in tables) are presented within this report alongside supplementary data, for foodstuffs and radionuclides pertinent to dose calculations, published by the Food Standards Agency (grey text in tables).

16 A number of inter-site transfer authorisations cover the transfer of radioactive waste between Sellafield and the LLWR.

### Liquid discharges via the pipeline

17 Radioactive liquid effluents arise from fuel reprocessing and storage operations; on-site decommissioning operations, and Sellafield Ltd and UKAEA laboratories. Liquors from the reprocessing plants that contain the highest levels of activity are routed directly to storage pending incorporation into solid glass form in the Waste Vitrification Plant; they are not therefore discharged from the site.

18 Where practicable, the medium active waste streams from reprocessing are routed via the Medium Active Evaporator, or the Salt Evaporator, to interim decay storage pending treatment in the Enhanced Actinide Removal Plant (EARP) prior to discharge. Where this is not possible, the effluents are routed directly to EARP or other plants for treatment prior to discharge.

19 The remaining low-level liquid effluents are discharged to sea, after monitoring, via the Sellafield pipeline. The main sources of such effluents are:

- Storage pond water from the old Magnox decanning plants and the Fuel Handling Plant (FHP). This water is treated in the Site Ion-Exchange Effluent Plant (SIXEP) to remove radioactive contaminants, principally caesium-137 and strontium-90.

- Storage pond water from the oxide fuel reprocessing plant, Thorp.

- EARP Bulk discharges, consisting of treated Magnox effluents and some effluents from Thorp; and 'EARP Concentrate' discharges, consisting of treated batches of effluent from interim storage and other concentrates.

- Thorp dissolver off-gas scrubber liquors following treatment to remove carbon-14 as solid waste.

- Remaining process liquors are routed to the Segregated Effluent Treatment Plant (SETP) where effluent is adjusted for pH and held for confirmation of its composition prior to discharge. Three discharge tanks are in operation, permitting flexible effluent management and the extended retention of effluent if required.

- Minor waste streams, such as surface drainage water and laundry effluent.

20 The authorisation includes Site Limits for liquid effluents with Annual Limits and Quarterly Notification Levels for 'total alpha' and 'total beta' activity as well as for individual radionuclides. In addition, the authorisation has limits on individual plants. For this

*Continued page 18*

**Table 2.** Radioactive discharges to the Irish Sea via the pipeline, 2006 – 2010

| Radionuclide | Annual discharge (TBq) | | | | | Authorised Limit (TBq)[b] |
|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 | |
| Tritium | 1,100 | 600 | 780 | 1,500 | 1,400 | 20,000 |
| Carbon-14 | 11 | 4.7 | 7.2 | 8.2 | 4.4 | 21 |
| Cobalt-60 | 0.14 | 0.05 | 0.07 | 0.08 | 0.10 | 3.6 |
| Zinc-65 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | |
| Strontium-90 | 5.0 | 5.0 | 1.7 | 2.9 | 1.0 | 48 |
| Zirconium-95 | 0.09 | 0.07 | 0.07 | 0.11 | 0.12 | 2.8[c] (Zirconium-95 and Niobium-95 combined) |
| Niobium-95 | 0.07 | 0.05 | 0.05 | 0.08 | 0.11 | |
| Technetium-99 | 6.0 | 4.9 | 2.4 | 3.1 | 1.4 | 10 |
| Ruthenium-106 | 3.5 | 1.5 | 1.4 | 3.2 | 1.2 | 51[c] |
| Antimony-125 | 8.0 | 5.1 | 3.1 | 3.8 | 4.5 | |
| Iodine-129 | 0.20 | 0.10 | 0.20 | 0.25 | 0.27 | 2 |
| Caesium-134 | 0.15 | 0.14 | 0.12 | 0.14 | 0.11 | 1.6 |
| Caesium-137 | 6.0 | 7.0 | 5.1 | 4.3 | 4.8 | 34 |
| Cerium-144 | 0.60 | 0.40 | 0.40 | 0.50 | 0.57 | 4 |
| Europium-152 | 0.11 | 0.13 | 0.11 | 0.07 | 0.03 | |
| Europium-154 | 0.08 | 0.09 | 0.10 | 0.06 | 0.02 | |
| Europium-155 | 0.06 | 0.07 | 0.10 | 0.09 | 0.03 | |
| Neptunium-237 | 0.05 | 0.04 | 0.04 | 0.05 | 0.04 | 0.73[c] |
| Plutonium-alpha | 0.15 | 0.11 | 0.11 | 0.12 | 0.13 | 0.7 |
| Plutonium-241 | 3.6 | 2.8 | 2.4 | 2.9 | 3.2 | 25 |
| Americium-241 | 0.05 | 0.02 | 0.03 | 0.05 | 0.03 | 0.3 |
| Curium-243+244 | 0.002 | 0.003 | 0.003 | 0.005 | 0.003 | 0.05 |
| Total alpha[a] | 0.21 | 0.12 | 0.13 | 0.15 | 0.13 | 1 |
| Total beta[a] | 29 | 25 | 14 | 18 | 11 | 220 |
| Uranium (kg) | 440 | 300 | 280 | 410 | 250 | 2,000 |

*a. 'Total alpha' and 'total beta' are control measures relating to specified analytical determinations. They do not reproduce precisely the contributions from all individual isotopes.*

*b. Current discharge authorisation dates from 01/10/2004*

*c. Limits changed in April 2010.*

**Table 3.** Radioactive discharges to the Irish Sea via the Factory Sewer, 2006 – 2010

| Radionuclide | Annual discharge (GBq) | | | | | Authorised Limit (GBq)[a] |
|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 | |
| Total alpha | 0.06 | 0.06 | 0.08 | 0.05 | 0.04 | 0.30 |
| Total beta | 0.58 | 0.68 | 0.55 | 1.1 | 0.86 | 6.1 |
| Tritium | 21 | 11 | 16 | 9.8 | 8.7 | 68 |

*a. Current discharge authorisation dates from 01/10/2004.*

report, only performance against the Site Limits is considered. To comply with the authorisation, samples from each waste stream are analysed either daily (Thorp Receipt and Storage, SIXEP, laundry, surface drainage water) or prior to discharge (SETP, EARP Bulks and Concentrates, Thorp carbon-14 removal facility) for 'total alpha', 'total beta' and (SETP and EARP only) tributylphosphate. More detailed analyses for a wide range of radionuclides, including all those listed in the schedule to the authorisation, are carried out on fortnightly, monthly or quarterly bulks of daily samples.

21 Trends in liquid effluent discharges from the Sellafield pipeline for radionuclides that contribute to largest proportions of the marine critical group dose are illustrated in figures 1a-e. Table 2 presents data on discharges over the last five years and provides a basis for comparison with current authorised limits. All discharges during 2010 were within those limits.

22 The discharges of the actinides (and hence of 'total alpha') in 2010 were similar to 2009 and remained lower than in 2006-7.

**Liquid discharges via the Factory Sewer**

23 The Factory Sewer discharges into the confluence of the Rivers Calder and Ehen. The primary source of the effluent is treated sewage and surface water drainage from non-radioactive areas of the Sellafield site to the north of the River Calder. This water may contain trace amounts of radioactivity and therefore discharges are included in the Environmental Permit for Radioactive Substances (EPR 2010) for the Sellafield site. Total quantities of radioactivity discharged over the last five years and current authorised limits are shown in table 3.

**Aerial discharges**

24 Aerial effluents are discharged from a number of stacks (chimneys) on the Sellafield site. They mainly consist of ventilation air from the process plants. Their radioactive constituents comprise noble gases (e.g. krypton), other gases and vapours (e.g. hydrogen, water vapour, iodine and carbon dioxide) and suspended particulates. Most release points are monitored continuously and fitted with appropriate abatement equipment, such as high efficiency particulate air filters or scrubbers.

*Continued page 20*

**Figure 1a.** Tc-99 discharge from marine pipeline and concentration in lobster

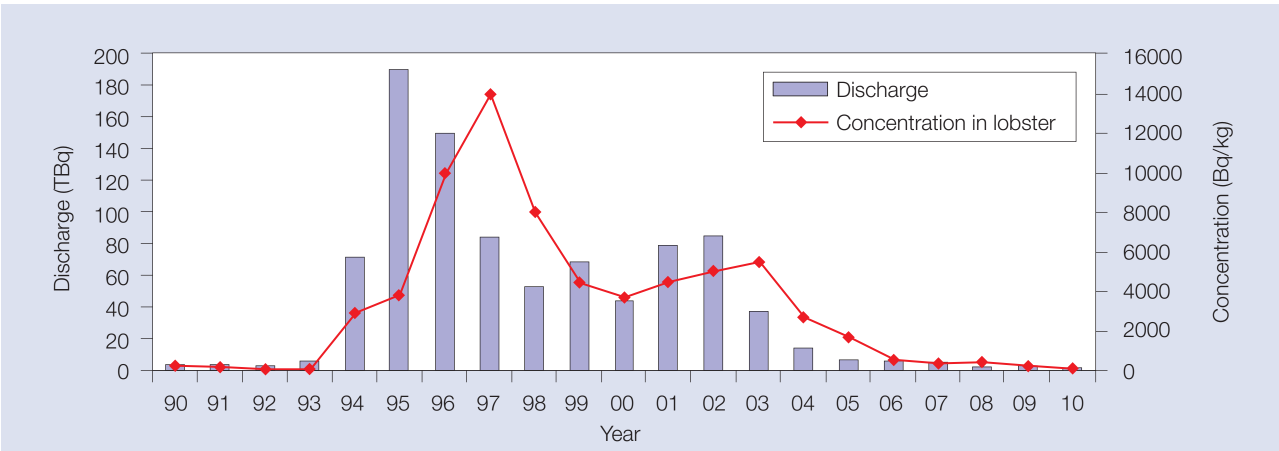



**Figure 1b.** Pu-alpha discharge from marine pipeline and concentration in winkles

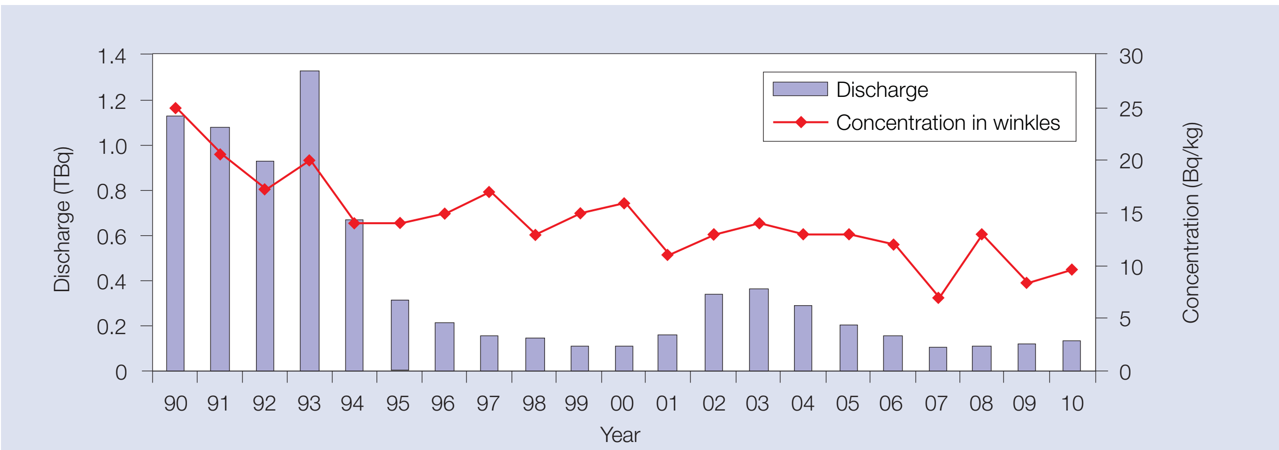


**Figure 1c.** Am-241 discharge from marine pipeline and concentration in winkles

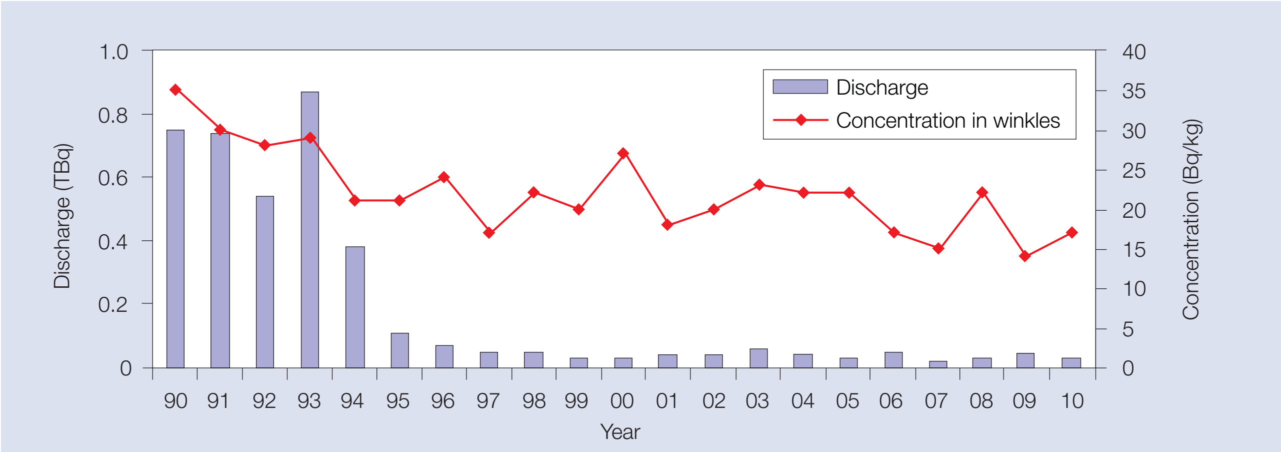



**Figure 1d.** Pu-alpha discharge from marine pipeline and concentration in mussels

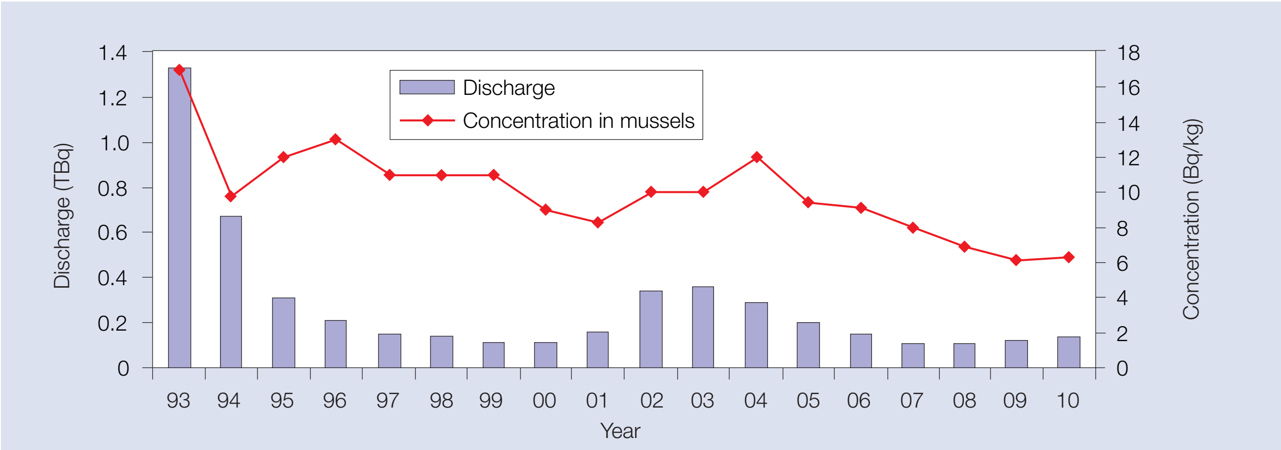
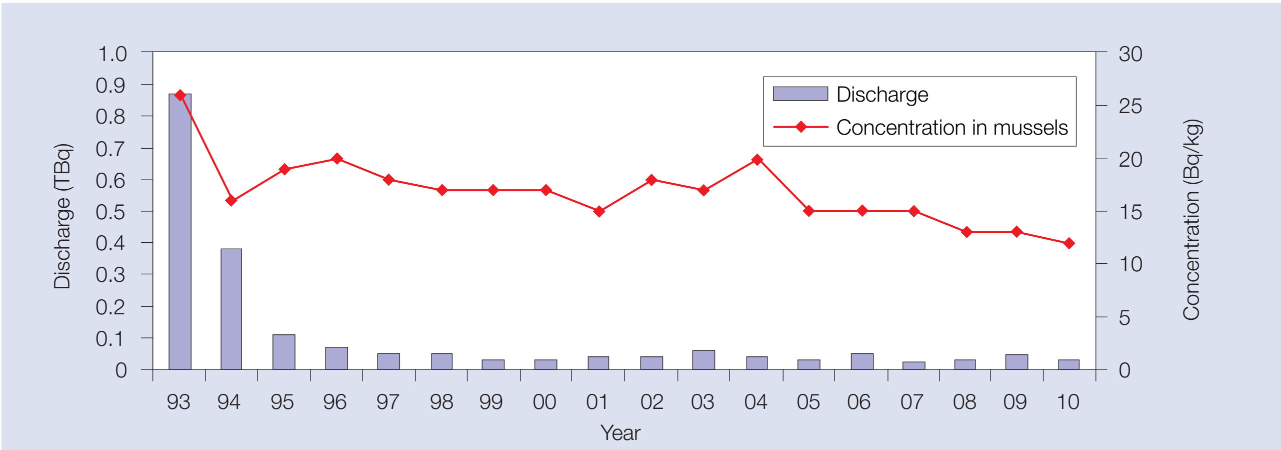



**Figure 1e.** Am-241 discharge from marine pipeline and concentration in mussels



25 The authorisation has annual Site Limits and individual Stack Limits. The individual stack discharges are summed to produce the Site discharge. In this report, only performance against the Site Limits is presented (see table 4).

26 Discharges of radioactivity to the atmosphere also take place from "Other Outlets and Miscellaneous Outlets". These are largely associated with the re-suspension of radioactivity from open fuel storage ponds and other places. As in previous years, releases in 2010 were calculated by a methodology agreed with the Environment Agency using data on activity concentrations in air at the site perimeter.

**Table 4.** **Total airborne radioactive discharges, 2006 - 2010**

| Radionuclide | 2006 | 2007 | 2008 | 2009 | 2010 | Authorised Limit[a] (all sources) |
|---|---|---|---|---|---|---|
| | Annual discharge (TBq) | | | | | |
| Tritium | 200 | 83 | 140 | 190 | 98 | 1,100 |
| Carbon-14 | 0.71 | 0.36 | 0.69 | 0.38 | 0.27 | 3.3 |
| Krypton-85 | 23,000 | 14,000 | 26,000 | 42,000 | 45,000 | 440,000 |
| | Annual discharge (GBq) | | | | | |
| Strontium-90 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.71 |
| Ruthenium-106 | 1.6 | 1.3 | 1.4 | 0.97 | 0.75 | 23[c] |
| Antimony-125 | 1.5 | 0.71 | 3.6 | 11 | 7.4 | 30[d] |
| Iodine-129 | 6.7 | 4.8 | 5.7 | 7.6 | 9.6 | 70 |
| Iodine-131 | 0.66 | 0.56 | 0.63 | 0.69 | 0.38 | 37[e] |
| Caesium-137 | 0.59 | 0.17 | 0.13 | 0.12 | 0.09 | 5.8 |
| Radon-222 | - | - | 32 | 43 | 43 | 500[b] |
| Plutonium alpha | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 | 0.19 |
| Plutonium-241 | 0.22 | 0.28 | 0.26 | 0.36 | 0.22 | 3.0 |
| Americium-241 + Curium-242 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.12 |
| Total alpha[b] | 0.11 | 0.14 | 0.11 | 0.10 | 0.09 | 0.88 |
| Total beta[c] | 2.0 | 2.1 | 1.5 | 1.4 | 1.0 | 42 |

*a. Current discharge authorisation dates from 01/10/2004.*
*b. Site limit introduced in April 2008 as part of Windscale integration.*
*c. Site limit changed in April 2010 to 23GBq.*
*d. Site limit changed in April 2010 to 30GBq.*
*e. Site limit changed in April 2010 to 37GBq.*

**Table 5.** **Disposals of solid radioactive waste to LLWR from Sellafield, 2006 - 2010**

| Radionuclide | Radioactivity disposed (GBq) | | | | | Authorised Limit (GBq)[e] |
|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 | |
| Tritium | 2.1 | 3.4 | 21 | 12 | 4.6 | 1,400 |
| Carbon-14 | 0.30 | 0.15 | 0.20 | 0.27 | 0.64 | 50 |
| Cobalt-60[a] | 11 | 2.3 | 110 | 40 | 13 | 2,000 |
| Iodine-129 | 0.08 | 0.17 | 0.08 | 0.06 | 0.06 | 0.22 |
| Others[b] | 700 | 480 | 590 | 620 | 280 | 15,000 |
| Radium-226 + Thorium-232 | 0.02 | 0.02 | 0.04 | 0.15 | 0.32 | 30 |
| Uranium | 4.6 | 4.5 | 3.9 | 6.3 | 3.5 | 300 |
| Other alpha emitters[c] | 92 | 31 | 30 | 24 | 14 | 300 |
| Volume ($m^3$ $y^{-1}$)[d] | 6,000 | 4,000 | 4,000 | 3,600 | 2,300 | 34,000 |

*a. The cobalt-60 figure is included in 'others' as well as shown separately.*
*b. Defined in the current authorisation as:*
*i. iron-55 and beta emitting radionuclides with half lives greater than three months (excluding carbon-14, iodine-129 and tritium).*
*ii. not more than 2TBq may be cobalt-60.*
*c. Alpha emitting radionuclides with half-lives greater than three months (excluding uranium, radium-226 and thorium-232).*
*d. These volumes represent the volume of waste and its primary containment. Figures are for waste produced by Sellafield Ltd. only. From 1 April 2008 this includes the Windscale site.*
*e. Includes waste consigned by other customers for treatment at Sellafield. Current discharge authorisation dates from 01/10/2004.*

27 Discharges for the years 2006 to 2010 are summarised in table 4. The discharges of tritium and carbon-14 generally reflect the reprocessing throughput (paragraphs 11 and 12). Recorded antimony-125 discharges increased in 2010 as a result of increased reprocessing of fuel with higher burn-up (coupled with relatively low fuel cooling) and changes in the sampling arrangements. Most of the remaining radionuclides are associated with particulate material and their annual discharges are not directly related to annual reprocessing rates. Radon-222 was added to the aerial discharge data set in 2008 following the integration of the Windscale site into Sellafield Ltd.

**Solid wastes**

28 Solid low level radioactive waste arises on the Sellafield site from process operations and decommissioning. Arisings of process wastes have been reduced in recent years to a fairly constant level, so that fluctuations in total arisings now mainly reflect decommissioning operations. The wastes are sent to the LLWR under the terms of an inter-site transfer authorisation which also covers use of the Waste Monitoring and Compaction (WAMAC) facility at Sellafield. This facility reduces the volume of waste being sent for disposal at the LLWR. It also offers a compaction service to other generators of low level radioactive waste across the UK. Therefore, the inter-site transfer authorisation (and Limit) also includes allowances for the transfer of non-Sellafield Ltd waste from WAMAC to the LLWR. The annual radionuclide content of waste produced by Sellafield Ltd only and sent to the LLWR under the terms of the inter-site transfer authorisation are presented in table 5.

29 Contaminated soil arising at Sellafield from construction and excavation is disposed of on-site at two authorised locations. The Calder Floodplain Landfill Extension- Segregated Area received 5,562 $m^3$ in 2010. No waste was consigned to the South Landfill Site in 2010. These disposals are included in the Site's multi-media authorisation (see paragraph 74). The terms include an activity limit of 37 kBq $kg^{-1}$ (dry weight) for total alpha & total beta, above which soil has to be disposed of at the LLWR as low level radioactive waste.

## Monitoring of the environment for radioactivity

30 The main pathways identified by Sellafield Ltd, the Environment Agency and Food Standards Agency as relevant to calculating critical group doses attributable to radioactive discharges from Sellafield are:

- Internal exposure from the high rate consumption of seafoods (particularly crustacea and shellfish) and of local agricultural produce (particularly milk).
- External gamma radiation from exposed intertidal sediments, particularly the silts and muds of estuaries and harbours.
- Inhalation of, and exposure to, airborne radioactivity.

The habits and consumption rates relating to each pathway are kept under regular review[2,7,10].
The Statutory Environmental Monitoring Programme, as supplemented by data from the EA and FSA monitoring programmes, reflects these pathways.
In addition to pathways of radiation exposure, the monitoring programme also includes the analysis of ‘indicators’. These are usually biological materials which accumulate radioactivity and therefore are more likely to produce positive analytical results and provide trends in environmental concentrations; examples are grass and seaweed. Doses from direct radiation, as distinct from discharges, are discussed under a separate heading (Paragraph 52 and 53).

*Continued page 23*

**Table 6.** Radioactivity in fish, 2010

| Species | Location | Mean radionuclide concentration (Bq $kg^{-1}$ wet weight) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $^{14}C^a$ | $^{60}Co$ | $^{99}Tc$ | $^{106}Ru$ | $^{137}Cs$ | Pu(α) | $^{241}Am$ |
| Plaice | Sellafield coastal area | 140 | 0.05 | 6.2 | <0.23 | 4.7 | 0.04 | 0.06 |
| | Sellafield offshore area | 120 | <0.06 | 5.2 | <0.26 | 4.6 | 0.03 | 0.04 |
| | Sellafield area$^b$ | 140 | <0.05 | 6.0 | <0.23 | 4.7 | 0.04 | 0.05 |
| | Whitehaven landed | 150 | 0.04 | 6.4 | <0.27 | 4.8 | 0.01 | 0.02 |
| Cod | Sellafield coastal area | 130 | - | <0.27 | <0.27 | 6.0 | <0.003 | <0.009 |
| | Sellafield offshore area | 83 | - | 0.84 | <0.31 | 5.2 | <0.003 | <0.01 |
| | Sellafield area$^b$ | 110 | - | <0.41 | <0.28 | 5.8 | <0.003 | <0.01 |
| | Whitehaven landed | 140 | - | <0.27 | <0.25 | 4.9 | 0.01 | 0.02 |

*a. $^{14}C$ data includes background.*
*b. Combined average for Sellafield coastal and offshore areas, this is consistent with the St Bees-Selker location reported in previous reports.*

**Table 7a.** Radioactivity in molluscs, 2010

| Species | Location | Mean radionuclide concentration (Bq kg$^{-1}$ wet weight) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total alpha | Total beta | $^{14}C^{a}$ | $^{60}Co$ | $^{90}Sr$ | $^{99}Tc$ | $^{106}Ru$ | $^{110m}Ag$ | $^{125}Sb$ | $^{129}I$ | $^{137}Cs$ | $^{237}Np$ | Pu(α) | $^{238}Pu$ | $^{239+240}Pu$ | $^{241}Pu$ | $^{241}Am$ | Cm(α) | U(α) |
| winkles | Sellafield coastal area (north) | 60 | 140 | - | 2.8 | 7.2 | 47 | 13 | 0.24 | 0.74 | - | 11 | - | - | - | 19 | 100 | 31 | - | 2.1 |
| | Sellafield coastal area (north) | 41 | 94 | - | 1.8 | 1.2 | 16 | 5.4 | 0.22 | 1.5 | - | 6.7 | - | - | - | 9.6 | 49 | 20 | - | 1.5 |
| | Sellafield coastal area (north) | - | - | 120 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Sellafield coastal area (north) | 26 | 91 | - | 1.7 | 1.2 | 11 | 3.1 | 0.20 | 0.97 | - | 4.9 | - | - | - | 7.2 | 34 | 15 | - | 1.2 |
| | Sellafield coastal area (north) | 21 | 84 | - | 1.3 | 0.80 | 37 | 4.0 | - | 1.4 | - | 2.2 | - | - | - | 5.1 | 25 | 8.7 | - | 1.4 |
| | Sellafield coastal area (south) | 63 | 140 | - | 4.1 | 3.0 | 210 | 17 | <0.30 | 1.5 | - | 8.6 | - | - | - | 16 | 88 | 28 | - | 2.2 |
| | Sellafield coastal area (south) | 25 | 110 | - | 3.5 | 1.5 | 150 | 9.7 | 0.26 | 1.4 | - | 4.8 | - | - | - | 10 | 57 | 16 | - | 2.3 |
| | Sellafield coastal area (south) | - | - | 140 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Sellafield coastal area (south) | 14 | 92 | - | 1.9 | 0.81 | 35 | 2.9 | 0.17 | 0.65 | - | 2.0 | - | - | - | 4.1 | 21 | 8.6 | - | 1.6 |
| | Sellafield coastal area (south) | 17 | 90 | - | 1.9 | 1.1 | 120 | 6.4 | 0.21 | 1.8 | - | 3.3 | - | - | - | 5.7 | 30 | 10 | - | 2.3 |
| | **Sellafield coastal area (Average)** | **33** | **110** | **130** | **2.4** | **2.1** | **78** | **7.7** | **0.23** | **1.3** | **-** | **5.4** | **-** | **-** | **-** | **9.6** | **51** | **17** | **-** | **1.8** |
| mussels | Sellafield coastal area (north) | 35 | 83 | - | 1.4 | 0.88 | 100 | 12 | - | 1.4 | - | 2.9 | 0.02 | 1.6 | 7.9 | 9.6 | 59 | 19 | - | 2.2 |
| | Sellafield coastal area (north) | 31 | 53 | - | 1.5 | 0.50 | 83 | 4.7 | - | 1.7 | - | 1.4 | 0.02 | 0.89 | 4.6 | 5.5 | 30 | 11 | - | 1.8 |
| | Sellafield coastal area (north) | - | - | 110 | - | - | - | - | - | - | <0.14 | - | - | - | - | - | - | - | - | - |
| | Sellafield coastal area (north) | 21 | 41 | - | 0.75 | 0.72 | 26 | 3.4 | - | 0.94 | - | 1.6 | 0.01 | 0.79 | 3.8 | 4.6 | 22 | 9.8 | - | 0.78 |
| | Sellafield coastal area (north) | 20 | 56 | - | 0.80 | 0.72 | 30 | 3.5 | - | 1.2 | - | 2.2 | 0.01 | 0.88 | 4.1 | 5.0 | 33 | 9.4 | - | 0.96 |
| | **Sellafield coastal area (north) (Average)** | **27** | **58** | **110** | **1.1** | **0.71** | **60** | **5.9** | **-** | **1.3** | **<0.14** | **2.0** | **0.02** | **1.0** | **5.1** | **6.1** | **36** | **12** | **<0.05** | **1.4** |
| | Sellafield coastal area (south) | 46 | 60 | - | 1.3 | 0.85 | 100 | 13 | - | 1.6 | - | 2.6 | 0.02 | 1.5 | 7.3 | 8.8 | 53 | 15 | - | 1.9 |
| | Sellafield coastal area (south) | 31 | 64 | - | 1.9 | 0.48 | 93 | 5.0 | - | 1.3 | - | 1.4 | 0.02 | 1.3 | 5.7 | 6.9 | 45 | 13 | - | 1.9 |
| | Sellafield coastal area (south) | - | - | 130 | - | - | - | - | - | - | <0.15 | - | - | - | - | - | - | - | - | - |
| | Sellafield coastal area (south) | 32 | 50 | - | 1.0 | 0.47 | 73 | 4.2 | - | 1.1 | - | 1.3 | 0.02 | 0.81 | 3.9 | 4.7 | 23 | 12 | - | 1.4 |
| | Sellafield coastal area (south) | 17 | 49 | - | 0.95 | 0.52 | 47 | 5.0 | - | 1.5 | - | 1.6 | 0.01 | 0.91 | 4.2 | 5.2 | 29 | 8.9 | - | 1.1 |
| | **Sellafield coastal area (south) (Average)** | **32** | **56** | **130** | **1.3** | **0.58** | **78** | **6.9** | **-** | **1.4** | **<0.15** | **1.7** | **0.02** | **1.1** | **5.3** | **6.4** | **38** | **12** | **<0.03** | **1.6** |
| | Sellafield coastal area (Average) | 29 | 57 | 120 | 1.2 | 0.64 | 69 | 6.4 | - | 1.3 | <0.14 | 1.9 | 0.02 | 1.1 | 5.2 | 6.3 | 37 | 12 | <0.04 | 1.5 |
| | Ravenglass Garth Musselbed | 40 | 66 | - | 1.5 | 0.73 | 300 | 8.8 | - | 1.5 | - | 1.9 | 0.03 | 1.5 | 8.0 | 9.6 | 55 | 17 | - | 2.3 |
| | Ravenglass Garth Musselbed | 28 | 70 | - | 1.5 | <0.28 | 440 | 3.8 | - | 1.0 | - | 1.1 | 0.02 | 1.2 | 5.8 | 7.0 | 36 | 12 | - | 2.4 |
| | Ravenglass Garth Musselbed | - | - | 120 | - | - | - | - | - | - | <0.14 | - | - | - | - | - | - | - | - | - |
| | Ravenglass Garth Musselbed | 13 | 44 | - | 0.71 | 0.20 | 43 | 1.8 | - | 0.53 | - | 0.79 | 0.01 | 0.61 | 3.1 | 3.7 | 19 | 7.8 | - | 1.2 |
| | Ravenglass Garth Musselbed | 44 | 94 | - | 1.8 | 0.52 | 230 | 5.6 | - | 1.9 | - | 2.5 | 0.03 | 1.9 | 9.1 | 11 | 64 | 19 | - | 3.6 |
| | **Ravenglass Garth musselbed (Average)** | **31** | **68** | **120** | **1.4** | **0.43** | **250** | **5.0** | **-** | **1.2** | **<0.14** | **1.6** | **0.02** | **1.3** | **6.5** | **7.8** | **44** | **14** | **<0.04** | **2.4** |

*a. $^{14}C$ data includes background.*

Table 7b. Radioactivity in crustaceans, 2010

| Species | Location | Mean radionuclide concentration (Bq kg$^{-1}$ wet weight) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{14}C^{a}$ | $^{60}Co$ | $^{90}Sr$ | $^{110m}Ag$ | $^{125}Sb$ | $^{129}I$ | $^{137}Cs$ | Pu(α) | $^{241}Am$ | U(α) |
| crabs | Sellafield coastal area (north) | 120 | 0.71 | 0.19 | - | 0.28 | - | 0.91 | 0.68 | 1.6 | 0.18 |
| | Sellafield coastal area (north) | 130 | 0.20 | <0.10 | - | - | - | 0.91 | 0.21 | 0.97 | 0.06 |
| | Sellafield coastal area (south) | 100 | 0.24 | 0.14 | - | - | - | 1.0 | 0.26 | 1.0 | 0.14 |
| | Sellafield coastal area (south) | 200 | 0.37 | 0.18 | - | - | - | 1.4 | 0.22 | 1.3 | 0.12 |
| | **Sellafield coastal area (Average)** | **140** | **0.38** | **0.15** | **-** | **0.28** | **-** | **1.0** | **0.34** | **1.2** | **0.12** |
| lobsters | Sellafield coastal area (north) | 200 | 0.34 | - | 0.10 | <0.26 | 3.1 | 1.9 | 0.46 | 5.6 | 0.10 |
| | Sellafield coastal area (north) | 160 | 0.17 | - | - | - | 1.1 | 1.2 | 0.18 | 1.4 | 0.04 |
| | Sellafield coastal area (south) | 130 | 0.14 | - | - | - | <0.29 | 1.4 | 0.31 | 9.5 | 0.11 |
| | Sellafield coastal area (south) | 150 | - | - | - | - | <0.38 | 2.1 | 0.21 | 1.1 | 0.03 |
| | **Sellafield coastal area (Average)** | **160** | **0.22** | **-** | **0.10** | **<0.26** | **<1.2** | **1.6** | **0.29** | **4.4** | **0.07** |
| *Nephrops* | Sellafield coastal area | - | - | - | - | - | - | - | - | 3.0 | - |
| | Sellafield coastal area | - | - | - | - | - | - | - | - | 2.7 | - |
| | **Sellafield coastal area (Average)** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **2.8** | **-** |

*a. $^{14}C$ data includes background.*

Table 8. Radioactivity in seaweed, 2010

| Species | Location | Mean radionuclide concentration (Bq kg$^{-1}$ wet weight) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total alpha | Total beta | $^{14}C^{a}$ | $^{60}Co$ | $^{90}Sr$ | $^{99}Tc$ | $^{106}Ru$ | $^{125}Sb$ | $^{129}I$ | $^{134}Cs$ | $^{137}Cs$ | Pu(α) | $^{241}Am$ | U(α) |
| *Porphyra* | St Bees | 11 | 120 | 44 | 0.20 | 0.94 | 4.5 | 2.8 | 0.35 | <0.58 | <0.08 | 1.8 | 4.5 | 6.2 | 0.30 |
| *umbilicalis* | Braystones | 12 | 190 | 68 | 0.30 | 0.38 | 8.4 | 6.2 | 0.46 | <0.59 | <0.10 | 1.7 | 4.0 | 6.6 | 0.36 |
| | Sellafield | 10 | 150 | 80 | 0.26 | 0.49 | 6.9 | 5.2 | 0.96 | <0.46 | <0.08 | 2.3 | 3.6 | 5.9 | 0.32 |
| | Seascale Neb | 12 | 180 | 50 | 0.32 | 0.61 | 9.6 | 7.9 | 2.6 | <0.94 | <0.07 | 2.0 | 3.9 | 6.1 | 0.31 |
| | St Bees-Selker (Av) | 11 | 160 | 60 | 0.27 | 0.61 | 7.3 | 5.5 | 1.1 | <0.64 | <0.08 | 1.9 | 4.0 | 6.2 | 0.32 |
| *Fucus* | Nethertown | 28 | 310 | 110 | 2.0 | 0.73 | 1,900 | 1.4 | 1.4 | 8.3 | <0.11 | 3.4 | 16 | 4.6 | 3.3 |
| *vesiculosus* | Drigg Barnscar | 36 | 370 | 86 | 2.3 | 0.55 | 2,400 | 2.9 | 2.0 | 15 | <0.11 | 3.4 | 23 | 5.1 | 4.0 |
| | Walney Island | 15 | 190 | 16 | 0.32 | 0.46 | 340 | <0.53 | 0.45 | 2.2 | <0.07 | 2.1 | 3.5 | 1.5 | 2.6 |
| | Isle of Whithorn | 13 | 150 | 15 | 0.09 | 0.50 | 80 | <0.56 | 0.49 | <1.7 | <0.07 | 2.6 | 3.0 | 2.8 | 2.2 |

*a. $^{14}C$ data includes background.*

31 Concentrations of radioactivity in the marine environment reflect discharges from the Sellafield pipelines, whereas radioactivity in the terrestrial environment generally reflects discharges to atmosphere. Some overlap does occur, however, with sea to land transfer processes[3,4] and on tidally inundated pastures[5]. Concentrations of caesium-137, plutonium and americium-241 in most environmental materials are predominantly as a consequence of historical discharges.

### Marine pathways

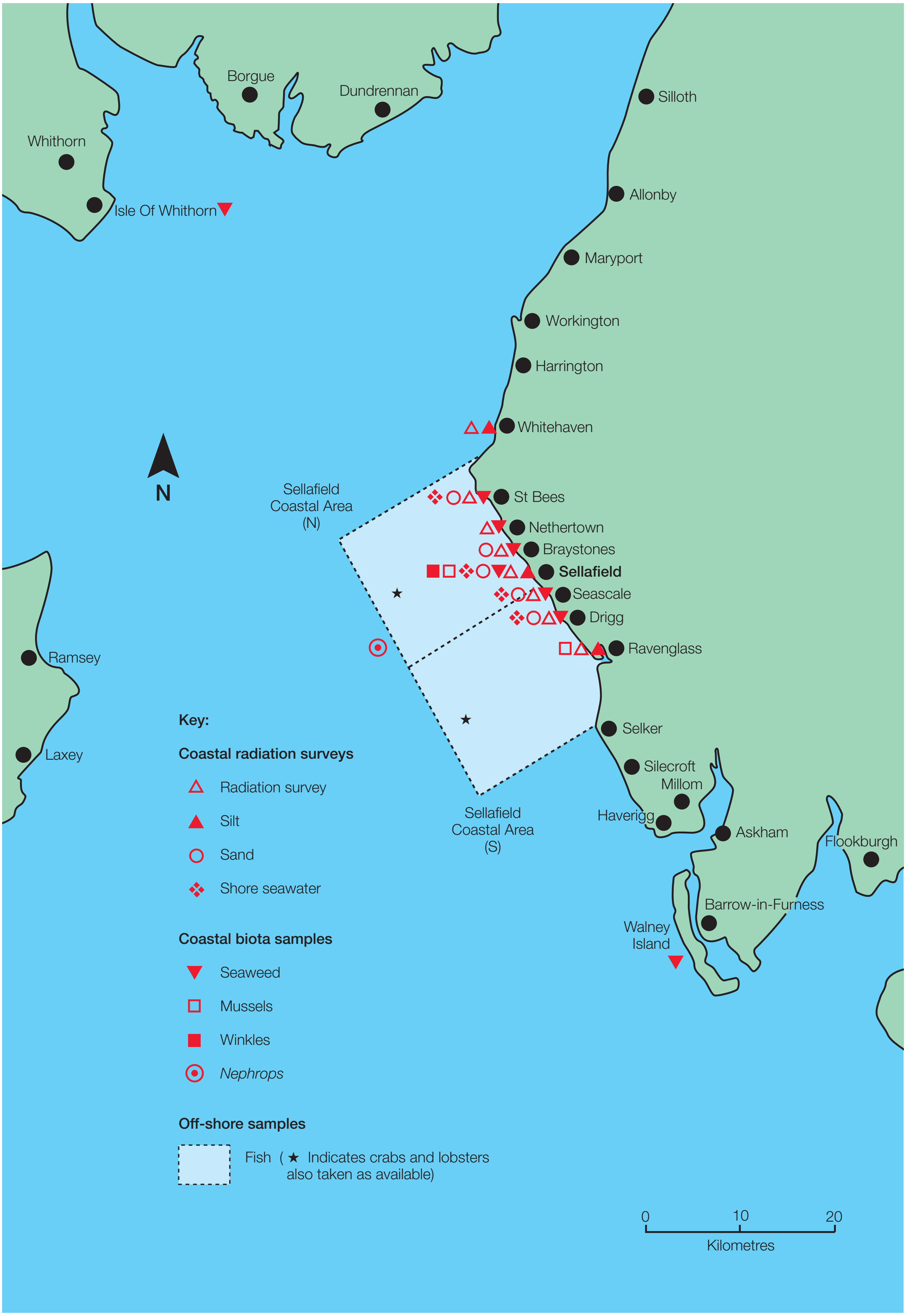
32 The extent of the marine environmental monitoring programme is illustrated in figure 2. Samples are regularly collected from the Cumbrian coast with more limited sampling in south-west Scotland. The precise locations are reviewed periodically. In certain cases, additional samples are obtained through commercial suppliers, representing foodstuffs available for general consumption.

#### Foodstuffs

33 The concentrations of radionuclides in the edible parts of fish, molluscs and crustaceans from the Sellafield area and further afield are presented in tables 6 and 7. Temporal trends are shown in figures 1a-e alongside the discharges from the sea pipeline. Trends in the seafoods generally reflect the annual discharges from the pipeline and as such were generally similar to those in recent years. For lobster caught offshore from Sellafield, there is a lag of up to 2 years between discharges and technetium-99 concentrations, possibly reflecting their diet of smaller molluscs and

*Continued page 25*

Figure 2. Marine environmental monitoring around Sellafield



invertebrates. Pu-alpha concentration in mussels decreased despite an increase in the quantity discharged whereas americium-241 concentration in winkles increased despite a decrease in the amount discharged. There is often a delay between changes in concentration and discharges as molluscs filter feed on marine bacteria and algae that have accumulated radionuclides over several years.

34 Data for carbon-14 presented in tables 6 and 7 are not corrected for the levels which are present naturally[6]. However, background corrected values for carbon-14 in fish, molluscs and crustacea have been used in the assessment of radiation doses to critical groups. For these marine foodstuffs, natural concentrations of carbon-14 have been taken from data published by the Environment Agency and Food Standards Agency[2].

Indicators

35 Seaweeds are useful marine indicators (see paragraph 30). *Fucus vesiculosus* is collected because it accumulates many radionuclides (particularly technetium-99) and is sensitive to fluctuations in their concentrations in seawater. Thus, the reduction in discharges from 2002 onwards was soon reflected in the levels in this species (table 8).

Seawater and sediments

36 Sellafield Ltd routinely collects samples of seawater from the shore at locations close to Sellafield. Concentrations of radioactivity in seawater (table 9) were broadly similar to those of recent years.

*Continued page 27*

**Table 9.** **Radioactivity in coastal samples of seawater from the Irish Sea, 2010**

| Location | | Mean radionuclide concentration (Bq in one litre of seawater) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total alpha | Total beta | $^{3}$H | $^{14}$C | $^{90}$Sr | $^{99}$Tc | $^{129}$I | $^{137}$Cs | $^{237}$Np | Pu(α) | $^{241}$Pu | $^{241}$Am | U(α) |
| St Bees | filtrate | <2.6 | 10 | <6.3 | <0.56 | 0.01 | <0.03 | <0.03 | 0.07 | 0.0006 | 0.005 | 0.06 | <0.001 | 0.11 |
| | solid | 0.23 | <0.21 | - | - | 0.009 | - | - | 0.06 | 0.00008 | 0.05 | 0.27 | 0.09 | 0.003 |
| Sellafield | filtrate | <2.7 | 9.1 | 16 | <0.58 | 0.02 | 0.04 | <0.03 | 0.11 | 0.0005 | 0.005 | 0.06 | <0.002 | 0.10 |
| | solid | 0.27 | 0.18 | - | - | 0.01 | - | - | 0.03 | 0.00008 | 0.06 | 0.31 | 0.10 | 0.003 |
| Seascale | filtrate | <2.8 | 9.6 | <5.0 | <0.57 | 0.02 | <0.03 | <0.03 | 0.09 | 0.0006 | 0.005 | 0.07 | <0.001 | 0.10 |
| | solid | 0.33 | 0.23 | - | - | 0.02 | - | - | 0.04 | 0.0001 | 0.09 | 0.48 | 0.15 | 0.005 |
| Drigg | filtrate | <2.8 | 11 | 6.2 | <0.57 | 0.02 | <0.03 | <0.03 | 0.09 | 0.0006 | 0.005 | 0.04 | <0.001 | 0.10 |
| | solid | 0.21 | <0.16 | - | - | 0.008 | - | - | 0.02 | 0.00007 | 0.05 | 0.24 | 0.08 | 0.003 |

**Table 10.** **Radioactivity in silts and sands from the West Cumbrian Coast, 2010**

| Location | | Mean radionuclide concentration (Bq kg$^{-1}$ dry weight) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total alpha | Total beta | $^{60}$Co | $^{90}$Sr | $^{99}$Tc | $^{106}$Ru | $^{125}$Sb | $^{134}$Cs | $^{137}$Cs | Pu(α) | $^{241}$Am | U(α) |
| *Sand* | St Bees | 640 | 410 | 1.9 | - | - | <11 | - | <1.1 | 56 | - | - | - |
| | Braystones | 470 | 470 | <1.1 | - | - | <8.0 | - | <0.90 | 44 | - | - | - |
| | Sellafield | 480 | 370 | 1.2 | - | - | <7.7 | - | <0.88 | 44 | - | - | - |
| | Seascale Neb | 520 | 400 | <1.2 | - | - | <9.3 | - | <0.99 | 27 | - | - | - |
| | Drigg Barnscar | 420 | 470 | <1.3 | - | - | <9.3 | - | <0.98 | 26 | - | - | - |
| *Silt* | Ravenglass Ford | 1,200 | 580 | 2.4 | 15 | 17 | <11 | - | <1.1 | 80 | 240 | 310 | 36 |
| | Ravenglass Garth | 510 | 500 | 0.97 | 0.87 | 6.1 | <9.0 | - | <0.98 | 31 | 90 | 97 | 24 |
| | Ravenglass Opp Raven Villa | 1,200 | 730 | 3.9 | 14 | 19 | 11 | 3.4 | <0.96 | 92 | 240 | 350 | 40 |
| | Eskmeals, River Esk South Bank Downstream of Viaduct | 1,700 | 1,000 | 4.3 | 52 | 26 | 37 | - | <1.7 | 190 | 380 | 550 | 65 |
| | Eskmeals, Newbiggin Marsh | 1,900 | 1,100 | 5.5 | 150 | 52 | 44 | 7.4 | <1.4 | 280 | 540 | 830 | 65 |
| | River Esk, Muncaster Road Bridge, Downstream | 2,000 | 1,300 | 6.2 | 63 | 45 | 51 | <13 | <1.9 | 410 | 490 | 760 | 53 |
| | Whitehaven Outer harbour (south) | 760 | 470 | <0.83 | 4.8 | 20 | <10 | - | <1.1 | 150 | 130 | 190 | 36 |
| | River Calder | - | - | - | - | - | - | - | - | - | - | - | - |
| | Waberthwaite | 2,400 | 1,500 | 11 | 83 | 49 | 100 | <9.2 | <1.5 | 380 | 600 | 930 | 68 |

**Table 11. Mean gamma dose rates measured in air in intertidal and other coastal areas of Cumbria, 2010**

| Area of survey | Description | Nature of ground | Number of observations | Mean dose rate (µGy $h^{-1}$)[a] |
|---|---|---|---|---|
| Whitehaven Harbour (north) | outer harbour | mud/silt | 12 | 0.13 |
| Whitehaven Harbour (south) | outer harbour | soft mud | 12 | 0.14 |
| St Bees (beach) | beach | sand | 2 | 0.11 |
| St Bees (groynes) | groynes | pebbles/rocks | 2 | 0.15 |
| St Bees | promenade and car park | concrete / grass | 2 | 0.13 |
| St Bees | Seamill Lane car park | car park | 2 | 0.13 |
| Coulderton | grassed areas/beach bungalows | grass banks | 2 | 0.13 |
| Nethertown | beach | pebbles/shingle | 3 | 0.16 |
| Nethertown | car park | concrete / grass | 3 | 0.11 |
| Nethertown | grassed area/beach bungalows | grass banks | 3 | 0.16 |
| Braystones | beach | pebbles/shingle | 2 | 0.16 |
| Braystones | grassed areas/beach bungalows | grass banks | 2 | 0.15 |
| Sellafield beach | beach | | 2 | 0.16 |
| Sellafield | Pipeline 3 | sand | 12 | 0.16 |
| Sellafield | Pipeline 4 | sand | 12 | 0.16 |
| Seascale beach | north of pipeline | sand | 12 | 0.12 |
| Seascale beach | south of pipeline | rocks/sand | 12 | 0.13 |
| Drigg | Barn Scar | mussel beds / silt / rocks | 2 | 0.13 |
| Drigg beach | beach | sand | 2 | 0.12 |
| Ravenglass | Raven Villa | saltmarsh | 2 | 0.18 |
| Ravenglass | River Mite ford | | 2 | 0.14 |
| Ravenglass | small boat area | firm silt / pebbles | 2 | 0.15 |
| Ravenglass | Salmon Garth | mussel beds | 2 | 0.11 |
| Ravenglass | Salmon Garth (saltmarsh) | sand / firm silt | 2 | 0.15 |
| Factory sewer | outfall | rocks / boulders / sand / shingle | 12 | 0.14 |
| Eskmeals Viaduct | saltmarsh | saltmarsh | 2 | 0.14 |
| Newbiggin | saltmarsh | saltmarsh | 12 | 0.22 |
| Muncaster road bridge | riverbank | grass | 2 | 0.15 |
| Hall Waberthwaite | saltmarsh | saltmarsh turf | 2 | 0.17 |

*a. Figures include contributions from natural background, typically 0.05 µGy $h^{-1}$ over sandy areas and 0.07 µGy $h^{-1}$ over silt.*

**Table 12a. Mean gamma dose rates measured in air at Sellafield site perimeter, 2010**

| Area of survey | Number of locations | Mean dose rate (µSv $h^{-1}$)[a] |
|---|---|---|
| North | 4 | 0.005 |
| East | 5 | 0.06 |
| South | 3 | 0.007 |
| West | 4 | 0.05 |
| River Ehen | 2 | 0.002 |
| River Calder | 12 | 0.19 |
| River Calder critical group | 1 | 0.03 |
| Mean annual average | - | 0.10 |

*a. Figures exclude contribution from natural background (approximately 0.06 µSv $h^{-1}$).*

**Table 12b. Mean gamma dose rates measured in air in the vicinity of Sellafield, 2010**

| Location | Mean dose rate (µGy $h^{-1}$)[a] |
|---|---|
| Calderbridge | 0.07 |
| Beckermet | 0.08 |
| Seascale | 0.07 |
| Ravenglass | 0.07 |
| Braystones | 0.08 |
| Whitehaven | 0.08 |
| Gosforth | 0.07 |

*a. Figures exclude contribution from natural background (approximately 0.07 µGy $h^{-1}$).*

37 Concentrations of radioactivity in sediments (table 10) were generally similar to those of recent years but with slight variation in actinides and strontium-90 at some sites. Redistribution of sub-surface sediments may have led to small fluctuations in radionuclide concentrations.

### External pathways

38 Gamma dose rate surveys are carried out in the areas most often frequented by members of the public (table 11). Particular attention is paid to areas where silt or mud accumulates, such as in harbours or estuaries, where dose rates tend to be higher because of the presence of finely-divided sediments. Several measurements are made in each area allowing temporal and geographical trends to be observed. Gamma dose rate surveys are also conducted around the site perimeter and the surrounding district (see tables 12a and b and paragraph 52-53). Dose rates fell steadily until 1993/1994 and have subsequently stayed fairly constant.

39 Beta-gamma ground level monitoring is undertaken just above the surface on local beaches to ascertain the general levels of contamination and to remove items of higher than normal activity if necessary. In addition to the routine monitoring programme, extra monitoring is carried out in the event of exceptionally high tides or severe storms. During 2010, 110 man-hours of effort were spent monitoring 217 km of coastline. Monitoring was concentrated on recent tide-lines and wind-blown debris in near-shore areas. No items were found with higher than normal activity.

### Beach monitoring

40 In 2003, a radioactive particle containing strontium-90 activity was found during a routine beach monitoring survey. The unusual nature of the particle prompted a review of beach monitoring and, as a result, trials of a large area monitoring technique were agreed with the Environment Agency (EA). The trial was undertaken by a contractor on behalf of Sellafield Ltd (SL) using their Groundhog™ monitoring system and proved successful in finding a number of radioactive items on Sellafield and Braystones beach. Following the trial, SL and the EA agreed a programme of large area beach monitoring. This was specified as a reporting requirement by the EA in their “Compilation of Environment Agency Requirements” (CEAR) document.

41 The CEAR required SL to monitor 250 hectares of beach in 2009/10 and 2010/11. Tables 13a and b show which beaches were monitored during the 2009 and 2010 calendar year in addition to the number of finds recovered and associated find rates.

**Table 13a.** Large area beach monitoring coverage and finds summary 2009

| Monitoring area | Area covered (ha) | Finds Recovered | | Find Rate (finds per hectare) | |
|---|---|---|---|---|---|
| | | Particles | Stones | Particles | Stones |
| St Bees | 58.67 | 4 | 0 | 0.068 | 0 |
| Braystones | 46.70 | 31 | 0 | 0.664 | 0 |
| Sellafield | 69.18 | 78 | 53 | 1.127 | 0.766 |
| Seascale | 87.06 | 12 | 0 | 0.138 | 0 |
| Drigg | 9.28 | 0 | 0 | 0 | 0 |
| Silecroft | 13.91 | 0 | 0 | 0 | 0 |
| All | 284.81 | 125 | 53 | 0.439 | 0.186 |

**Table 13b.** Large area beach monitoring coverage and finds summary 2010

| Monitoring area | Area covered (ha) | Finds Recovered | | Find Rate (finds per hectare) | |
|---|---|---|---|---|---|
| | | Particles | Stones | Particles | Stones |
| Allonby | 10.44 | 0 | 0 | 0 | 0 |
| Harrington | 3.90 | 2 | 0 | 0.513 | 0 |
| Parton | 4.14 | 0 | 0 | 0 | 0 |
| Whitehaven | 7.19 | 9 | 0 | 1.251 | 0 |
| St Bees | 45.02 | 47 | 0 | 1.044 | 0 |
| Nethertown | 7.28 | 0 | 0 | 0 | 0 |
| Braystones | 75.80 | 144 | 0 | 1.900 | 0 |
| Sellafield | 70.26 | 160 | 41 | 2.277 | 0.584 |
| Seascale | 43.64 | 14 | 0 | 0.321 | 0 |
| Drigg | 68.57 | 10 | 0 | 0.146 | 0 |
| Total | 336.24 | 386 | 41 | 1.148 | 0.122 |

42 The current monitoring programme is determined by taking account of the find rates (both particles and stones) and the occupancy information for each beach. The programme is reviewed annually and its scope and extent are agreed with the Environment Agency. Stakeholder views are also considered during the review process. Since the introduction of the Groundhog™ Synergy detection system in August 2009 particle find rates have increased and this trend was apparent throughout 2010. The number of beach finds classified as stones continued to decrease.

43 The Health Protection Agency has advised the Environment Agency on the particle risks associated with using the beaches around Sellafield. The current advice is reproduced below.

The HPA confirm that the advice provided in 2009, that "no special precautionary actions are required at this time to limit access to or use of beaches" remains valid.

**Airborne and terrestrial pathways**

44 The extent of the terrestrial environmental monitoring programme is illustrated in figure 3.

Airborne

45 High flow rate air sampling equipment, located close to the site perimeter (table 14a) and in nearby centres of population (table 14b), is used to sample airborne particulates for radiochemical analysis. Levels off-site were generally below the limit of detection, with most positive values reflecting sea to land transfer from marine discharges.

46 Atmospheric krypton-85 measured fortnightly at the Met station on the edge of Sellafield site ranged from 1.9 to 116 Bq $m^{-3}$ and averaged 40.5 Bq $m^{-3}$. This is equivalent to an immersion dose of <1 µSv $a^{-1}$ for all age groups (table 29). Significant variation in

*Continued page 30*

**Table 14a.** Radioactivity in air in the vicinity of Sellafield, 2010: Site perimeter locations

| Radionuclide | Mean radionuclide concentration (mBq $m^{-3}$) | | | | |
|---|---|---|---|---|---|
| | Calder Gate | Met Station | North Gate | West Ring Road | South Side |
| Total alpha | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| Total beta | 0.21 | 0.25 | 0.22 | 0.18 | 0.19 |
| Strontium-90 | 0.002 | 0.005 | 0.005 | 0.002 | 0.002 |
| Ruthenium-106 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 |
| Antimony-125 | <0.02 | <0.02 | <0.02 | <0.02 | <0.03 |
| Caesium-134 | <0.005 | <0.004 | <0.004 | <0.004 | <0.005 |
| Caesium-137 | 0.02 | 0.05 | 0.04 | 0.01 | <0.006 |
| Plutonium alpha | 0.0004 | 0.0006 | 0.002 | 0.0005 | 0.0004 |
| Plutonium-241 | <0.02 | <0.02 | <0.03 | <0.02 | <0.02 |
| Americium-241 | 0.0003 | 0.0006 | 0.0008 | 0.0004 | 0.0003 |
| Uranium-234 | <0.0005 | 0.001 | <0.0004 | 0.001 | 0.0008 |
| Uranium-235 | <0.00003 | 0.00005 | <0.00003 | 0.00005 | 0.00004 |
| Uranium-236 | <0.0002 | <0.0002 | <0.0001 | <0.0002 | <0.0001 |
| Uranium-238 | 0.0005 | 0.001 | 0.0006 | 0.001 | 0.0009 |

**Table 14b.** Radioactivity in air in the vicinity of Sellafield, 2010: Residential locations

| Radionuclide | Mean radionuclide concentration (mBq $m^{-3}$) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Beckermet | Braystones | Calderbridge | Gosforth | Ravenglass | Seascale | Whitehaven |
| Strontium-90 | 0.0008 | 0.0009 | 0.0007 | <0.0004 | <0.0006 | <0.0005 | <0.0005 |
| Antimony-125 | <0.01 | <0.01 | <0.02 | <0.01 | <0.01 | <0.02 | <0.01 |
| Caesium-134 | <0.005 | <0.004 | <0.004 | <0.004 | <0.005 | <0.004 | <0.004 |
| Caesium-137 | <0.006 | <0.004 | <0.004 | <0.004 | <0.005 | <0.004 | <0.004 |
| Plutonium alpha | <0.0003 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | 0.001 | 0.0003 |
| Plutonium-241 | <0.02 | <0.03 | <0.02 | <0.02 | <0.03 | <0.03 | <0.03 |
| Americium-241 | 0.0001 | 0.0002 | <0.0001 | <0.00008 | <0.0001 | 0.002 | 0.0006 |
| Uranium-234 | <0.0004 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0003 | <0.0003 |
| Uranium-235 | <0.00002 | <0.00002 | <0.00002 | <0.00002 | <0.00002 | <0.00004 | <0.00004 |
| Uranium-236 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0002 | <0.0002 |
| Uranium-238 | 0.0003 | 0.0001 | 0.00009 | 0.0001 | 0.00008 | 0.0002 | 0.0003 |

Figure 3. Terrestrial environmental monitoring around Sellafield

atmospheric krypton-85 was observed due to discontinuities in reprocessing operations on Sellafield site combined with the variability in meteorological conditions.

### Foodstuffs and water

47 Milk consumption remains the main contributor to the critical group dose from terrestrial foodstuffs. Locations sampled include local farms (in the range 0 to 4 km from the Sellafield site). The average concentrations of radioactivity in milk are summarised in table 15. The figures include the residual effects of weapons testing and the 1986 Chernobyl reactor accident. Data for carbon-14 includes the contribution from natural background. However, estimates of effective dose (paragraph 63) have been made by subtracting natural background levels of carbon-14. For milk and other terrestrial foodstuffs, vegetation and soil, a background level of 240 Bq carbon-14 per kg carbon is used. The milk results for 2010 are broadly similar to those observed for previous years, with many analyses at the limit of detection.

48 For terrestrial foodstuffs, other than milk, the results of the Sellafield environmental monitoring programme for 2010 are presented in tables 16 and 17 (black text) alongside supplementary data published by the Foods Standards Agency (grey text). The Sellafield Ltd samples were mainly collected from within 4 km of the Sellafield site as they became available throughout the year. Direct comparison with the results of earlier years is difficult due to the relatively small numbers of samples and their locations. Data for carbon-14 are presented as total and net (background subtracted) values. For terrestrial foodstuffs no longer monitored by Sellafield Ltd, natural carbon-14 background concentrations have been taken from data published by the Environment Agency and Food Standards Agency[2].

49 Water samples are collected from the River Calder and River Ehen, lakes and domestic supplies. The results (table 18) are all very low and rarely above the limits of detection except for strontium-90 which is generally present in rain water and surface water at levels typical of those throughout the UK[2].

*Continued page 32*

**Table 15.** **Radioactivity in milk from farms near Sellafield, 2010**

| Location[c] | Mean radionuclide concentration (Bq l$^{-1}$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total alpha | Total beta | $^{3}$H | $^{14}$C$_{Total}$[a] | $^{14}$C$_{Net}$[b] | $^{90}$Sr | $^{106}$Ru | $^{125}$Sb | $^{129}$I | $^{131}$I | $^{137}$Cs |
| Farm A[d] | <0.15 | 40 | <3.0 | 16 | <0.60 | 0.06 | <0.38 | <0.10 | <0.01 | <0.04 | 0.10 |
| Farm B[d] | <0.15 | 38 | <2.9 | 15 | <0.53 | 0.11 | <0.37 | <0.09 | <0.01 | <0.04 | 0.19 |
| Farm C[d] | <0.17 | 32 | <3.4 | 20 | 1.2 | 0.13 | <0.39 | <0.10 | <0.01 | <0.04 | 0.13 |
| Farm D[c] | <0.15 | 39 | <3.2 | 16 | <0.60 | 0.17 | <0.37 | <0.10 | <0.01 | <0.04 | 0.51 |
| Farm E[d] | <0.39 | 40 | <3.1 | 13 | <0.50 | 0.04 | <0.39 | <0.10 | <0.01 | <0.04 | 0.08 |

*a. Including natural background.*
*b. Excluding natural background.*
*c. Milk from farm D has been used in the radiological assessment.*
*d. Milk samples for less than 12 months.*

**Table 16.** **Radioactivity in animal produce from farms near Sellafield, 2010**

| Species (Average) | Mean radionuclide concentration (Bq kg$^{-1}$ wet weight)[c] | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{3}$H | $^{14}$C$_{Total}$[a] | $^{14}$C$_{Net}$[b] | $^{60}$Co | $^{90}$Sr | $^{99}$Tc | $^{106}$Ru | $^{125}$Sb | $^{129}$I | $^{137}$Cs[d] | $^{238}$Pu | $^{239+240}$Pu | $^{241}$Pu | $^{241}$Am |
| Bovine Muscle | 8.0 | 29 | - | <0.20 | 0.01 | - | <1.2 | <0.30 | <0.04 | 0.70 | <0.0002 | <0.0004 | <0.05 | 0.0003 |
| Bovine Kidney | <9.0 | 19 | - | <0.30 | 0.41 | - | <1.8 | <0.60 | <0.05 | 0.53 | - | - | - | - |
| Bovine Liver | <8.0 | 25 | - | <0.20 | 0.27 | - | <1.3 | <0.30 | <0.04 | 0.39 | <0.0002 | <0.0004 | <0.05 | 0.0006 |
| Eggs - General | 7.0 | 31 | - | <0.20 | 0.04 | - | <0.90 | <0.50 | <0.03 | 0.13 | <0.0001 | 0.0003 | <0.05 | 0.0004 |
| Ovine Muscle | - | - | - | <0.20 | 0.03 | - | <0.85 | <0.35 | <0.03 | 0.78 | - | - | - | - |
| Ovine Kidney/Liver | - | - | - | <0.20 | 0.14 | - | <1.1 | <0.25 | <0.03 | 0.33 | - | - | - | - |
| Duck[e] | <7.0 | 97 | 25 | <0.10 | 0.03 | - | <0.90 | <0.40 | <0.03 | 0.31 | <0.0001 | 0.0003 | - | 0.0003 |
| Pheasants | 9.0 | 25 | - | <0.20 | 0.05 | - | <0.70 | <0.30 | - | 0.44 | - | - | - | - |
| Deer Muscle | 14 | 16 | - | <0.20 | 0.01 | - | <0.60 | <0.40 | - | 0.25 | - | - | - | - |
| Rabbit | <7.0 | 12 | - | <0.20 | 0.05 | <0.03 | <1.3 | <0.40 | <0.04 | 1.6 | - | - | | 0.04 |

*a. Including natural background.*
*b. Excluding natural background (values taken from RIFE-15). Measured concentrations that are smaller than background value are indicated by a hyphen.*
*c. Values shown in grey are from measurements performed by the Food Standards Agency.*
*d. Cs-Total reported by the FSA has been assumed to be dominated by $^{137}$Cs, hence dose factors for that radionuclide have been used in the radiological exposure assessment.*
*e. Data from 2007.*

**Table 17.** **Radioactivity in fruit and vegetable produce collected near Sellafield, 2010**

| Species | Mean radionuclide concentration (Bq kg$^{-1}$ wet weight)[c] | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{3}H$ | $^{14}C_{Total}$[a] | $^{14}C_{Net}$[b] | $^{60}Co$ | $^{90}Sr$ | $^{99}Tc$ | $^{106}Ru$ | $^{125}Sb$ | $^{129}I$ | $^{137}Cs$[d] | $^{238}Pu$ | $^{239+240}Pu$ | $^{241}Pu$ | $^{241}Am$ |
| Potatoes | <2.5 | 20 | <0.70 | <0.15 | 0.04 | <0.55 | <0.31 | <0.37 | <0.08 | 0.17 | - | - | - | - |
| Cabbage | - | - | - | <0.07 | 0.33 | 1.0 | <0.94 | <0.15 | <0.02 | 0.08 | - | - | - | <0.08 |
| Sprouts | <5.0 | <3.0 | - | <0.20 | 0.17 | - | <0.90 | <0.30 | - | 0.36 | - | - | - | 0.11 |
| Broccoli | <5.0 | <3.0 | - | <0.30 | 0.04 | - | <1.6 | <0.40 | <0.03 | 0.16 | <0.0001 | <0.0002 | <0.04 | 0.0004 |
| Carrots | <3.0 | 5.0 | - | <0.20 | 0.19 | <0.02 | <1.5 | <0.60 | <0.03 | 0.07 | - | - | - | - |
| Swede | <5.0 | <4.0 | - | <0.20 | 0.21 | - | <1.8 | <0.50 | <0.05 | 0.11 | - | - | - | - |
| Onions | - | - | - | <0.11 | 0.04 | <0.11 | <0.60 | <0.19 | <0.02 | <0.06 | - | - | - | <0.08 |
| Beans, Runner | - | - | - | <0.13 | 0.17 | <0.12 | <0.92 | <0.32 | <0.02 | <0.06 | - | - | - | <0.08 |
| Mushrooms | <6.0 | <6.0 | <1 | <0.20 | 0.64 | - | <1.4 | <0.30 | <0.02 | 0.48 | - | - | - | 0.0005 |
| Honey[e] | <7.0 | 48 | - | <0.10 | 0.05 | - | <0.70 | <0.40 | <0.01 | 0.09 | <0.0002 | <0.0003 | 0.09 | 0.0003 |
| Blackcurrants[f] | <4.0 | 24 | 14 | <0.20 | 0.11 | - | <1.4 | <0.30 | <0.06 | 0.10 | 0.0001 | 0.0007 | <0.05 | 0.002 |
| Apples | - | - | - | <0.10 | 0.17 | - | <1.1 | <0.40 | <0.02 | 0.70 | - | - | - | - |
| Strawberries | 4.0 | - | - | <0.10 | 0.08 | - | <1.1 | <0.20 | - | 0.07 | <0.0002 | 0.0004 | <0.05 | 0.0003 |
| Blackberries | - | - | - | <0.15 | 0.96 | - | <1.1 | <0.35 | <0.03 | 0.37 | - | - | - | - |
| Elderberries | - | - | - | <0.20 | 0.35 | - | <0.90 | <0.40 | <0.03 | 0.64 | - | - | - | - |

a. *Including natural background.*
b. *Excluding natural background (values taken from RIFE-15). Measured concentrations that are smaller than background values are indicated by a hyphen.*
c. *Values shown in grey are from measurements performed by the Food Standards Agency.*
d. *Cs-Total reported by the FSA has been assumed to be dominated by $^{137}Cs$, hence dose factors for that radionuclide have been used in the radiological exposure assessment.*
e. *2008 data.*
f. *2009 data.*

**Table 18.** **Radioactivity in local waters, 2010**

| Location | | Mean radionuclide concentration (Bq l$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total alpha | Total beta | $^{3}H$ | $^{90}Sr$ | $^{99}Tc$ | $^{137}Cs$ | Pu($\alpha$) | Am+ Cm |
| River water: | River Calder at Sellafield | <0.02 | 0.14 | <3.4 | 0.02 | <0.03 | <0.005 | <0.0004 | <0.0005 |
| | River Calder at Calderbridge | <0.02 | <0.11 | <3.1 | 0.005 | <0.03 | <0.005 | <0.0001 | <0.0008 |
| | River Ehen upstream of of factory sewer outfall | <0.03 | 0.20 | <4.6 | 0.004 | <0.04 | <0.006 | <0.0007 | <0.0009 |
| | River Ehen at Sellafield station | <0.02 | 0.18 | <3.5 | 0.004 | <0.03 | <0.005 | <0.0001 | <0.0006 |
| Lake water: | Ennerdale water | <0.02 | 0.11 | <2.7 | 0.005 | - | <0.006 | <0.001 | <0.001 |
| | Wastwater | <0.03 | <0.07 | <2.7 | 0.007 | - | <0.005 | <0.001 | <0.001 |
| Tap water: | Tap water - Calderbridge | <0.02 | <0.07 | <3.3 | 0.004 | - | <0.005 | <0.0004 | <0.0001 |
| | Tap water - Sellafield Site | <0.02 | <0.07 | <2.7 | 0.003 | - | <0.005 | <0.0001 | <0.0003 |
| | Tap water - Ravenglass | <0.02 | <0.07 | <2.7 | 0.004 | - | <0.005 | <0.0005 | <0.0001 |
| | Tap water - Seascale | <0.02 | <0.09 | <3.3 | 0.003 | - | <0.005 | <0.0003 | <0.0003 |
| | Tap water - Whitehaven | <0.02 | <0.08 | <2.7 | 0.003 | - | <0.005 | <0.0003 | <0.0004 |
| Spring water: | Sellafield beach (South)[a] | - | 5.8 | 880 | 0.13 | 4.4 | 0.70 | 0.04 | 0.18 |
| | Sellafield beach[a] | - | - | 80 | - | 0.08 | - | - | - |

a *Results corrected for seawater content.*

### Indicators

50 Grass and soil sampling are included in the monitoring programme as they provide time trend data on environmental concentrations of radioactivity. Grass samples (table 19) are collected quarterly from five locations on the Sellafield site and from one at the Ravenglass Estuary. Soil samples (5 cm cores) are collected annually from the same locations (table 20).

### Groundwater

51 The statutory monitoring programme includes the routine monitoring of groundwater from 15 boreholes around the perimeter of the site so that any significant migration of radioactivity in groundwater will be detected. These boreholes are shown in figure 4. The routine results in 2010 (table 21) were similar to those reported in recent years. Most other results were closer to or below limits of detection, except for tritium and technetium-99 in borehole 6986P1 which is in the vicinity of the main gate at the southwest of the site. Old waste disposal trenches, which were used before disposal operations commenced at the LLWR, are believed to be the source of the tritium in this borehole and also of that monitored in groundwater up-welling on the Sellafield beach. A redundant sea discharge storage tank is believed to be the source of the technetium-99. These concentrations are in line with groundwater modelling that predicted peak concentrations of 0.1 MBq $m^{-3}$ technetium-99 between 2000 and 2010. More detailed information on groundwater monitoring at the Sellafield sites can be found at www.sellafieldsites.com/land.

### Direct radiation

52 Some of the older Magnox buildings, including the Calder reactors, have lower levels of radiation shielding than the modern buildings, such as Thorp. Consequently, it is possible to measure radiation dose rates above natural background at the site perimeter fence. These dose rates were largely due to direct radiation from the unshielded heat exchangers on the Calder reactors and therefore dependent upon the amount of power being produced by the reactors (until they were shut down in March 2003). The perimeter radiation levels are still affected by radiation from contamination within the heat exchangers but at a much lower level.

53 Gamma dose rates are monitored continuously and analysed quarterly using thermoluminescent detectors (TLDs) at 30 locations around the site perimeter (table 12a) and at a further 7 locations in the surrounding district (table 12b). The number of district monitoring locations has been reduced to 7 in 2010 (there were 10 in 2009) because it provides sufficient background data for the purpose of public reassurance. Dose rates at the site perimeter averaged 0.16 µSv $h^{-1}$, significantly lower than when the Calder Hall reactors were fully operational. Dose rates in the surrounding district averaged 0.07 µSv $h^{-1}$. These are total dose rates, which include contributions from natural terrestrial background and cosmic rays. For dose assessment purposes the natural contributions are deducted.

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**Table 19.** Radioactivity in grass at Sellafield, 2010

| Location | Mean radionuclide concentration (Bq $kg^{-1}$ wet weight) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total alpha | Total beta | $^{3}H$ | $^{14}C_{Total}$ [a] | $^{14}C_{Net}$ [b] | $^{90}Sr$ | $^{99}Tc$ | $^{106}Ru$ | $^{125}Sb$ | $^{129}I$ | $^{134}Cs$ | $^{137}Cs$ | U(α) | Pu(α) | $^{241}Am$ |
| Calder Gate | 2.3 | 94 | 7.6 | 34 | 3.4 | 2.3 | 2.0 | <1.1 | 1.4 | <0.46 | <0.13 | 3.5 | 0.13 | 0.17 | 0.18 |
| Met Station | 2.6 | 130 | 13 | 29 | <1.1 | 12 | 1.3 | <0.86 | 0.46 | <0.41 | <0.10 | 6.6 | 0.14 | 0.69 | 0.41 |
| North Gate | 6.1 | 160 | 40 | 33 | 2.2 | 22 | 2.8 | <1.4 | 0.91 | <0.56 | <0.14 | 50 | 0.23 | 1.1 | 0.36 |
| South Side | 3.5 | 130 | 3.5 | 31 | <1.1 | 1.2 | 1.9 | <1.1 | 1.2 | <0.54 | <0.13 | 1.1 | 0.32 | 0.10 | 0.12 |
| West Ring Road | 9.0 | 130 | 6.0 | 25 | <0.93 | 1.8 | 0.75 | <0.84 | <0.46 | <0.44 | <0.10 | 3.0 | 0.73 | 0.92 | 0.57 |
| Ravenglass | 2.0 | 110 | 3.5 | 30 | <1.1 | 0.44 | 3.4 | <0.85 | <0.23 | <0.56 | <0.10 | 0.71 | 0.03 | 0.12 | 0.16 |

*a. $^{14}C$ data includes background.*
*b. Excluding natural background calculated assuming 240 Bq natural $^{14}C$ per kg carbon.*

**Table 20.** Radioactivity in soil at Sellafield, 2010

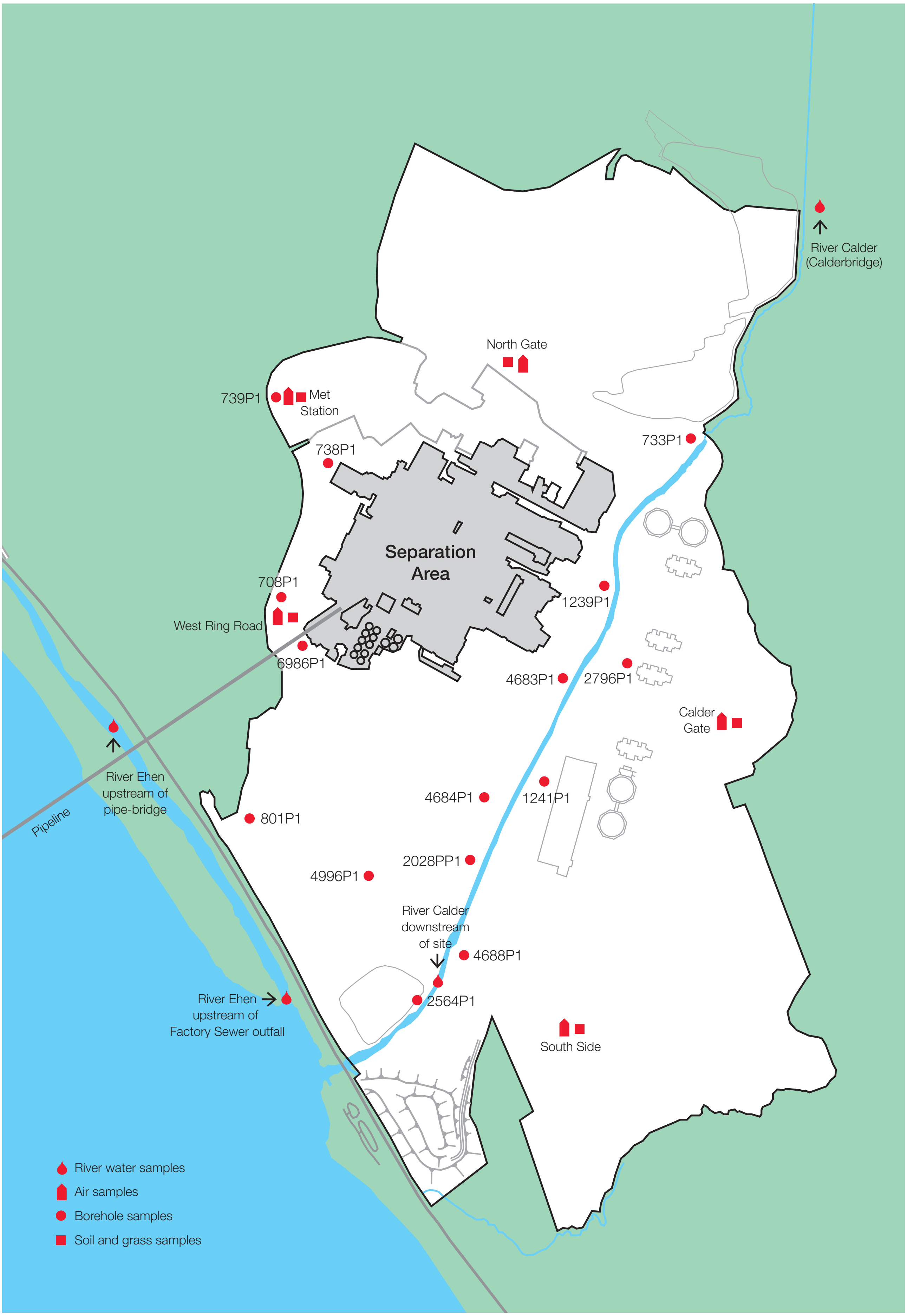
| Location | Mean radionuclide concentration (Bq $kg^{-1}$ wet weight) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total alpha | Total beta | $^{3}H$ | $^{14}C_{Total}$ [a] | $^{14}C_{Net}$ [b] | $^{90}Sr$ | $^{99}Tc$ | $^{106}Ru$ | $^{125}Sb$ | $^{129}I$ | $^{134}Cs$ | $^{137}Cs$ | Pu(α) | $^{241}Am$ | U(α) |
| Calder Gate | 530 | 650 | 2.8 | 6.8 | 2.4 | 4.8 | <2.2 | <22 | <5.5 | <29 | <2.1 | 98 | 46 | 9.7 | 54 |
| Met Station | 610 | 690 | 3.7 | 7.0 | 0.70 | 19 | <2.2 | <21 | <5.9 | <31 | <2.2 | 300 | 110 | 31 | 58 |
| North Gate | 910 | 750 | 9.7 | 7.2 | 2.7 | 33 | <2.2 | <16 | <4.8 | <34 | <1.5 | 420 | 250 | 32 | 60 |
| South Side | 600 | 500 | 3.1 | 9.1 | <0.50 | 9.9 | <2.2 | <21 | <4.8 | <27 | <2.1 | 70 | 13 | 4.1 | 65 |
| West Ring Road | 620 | 730 | 3.2 | 4.3 | 0.50 | 7.0 | <2.2 | <23 | <5.6 | <23 | <2.1 | 93 | 43 | 19 | 53 |
| Ravenglass | 630 | 600 | <1.5 | 13 | <2.6 | 1.5 | 95 | <16 | <4.9 | <32 | <1.4 | 570 | 130 | 180 | 52 |

*a. $^{14}C$ data includes background.*
*b. Excluding natural background calculated assuming 240 Bq natural $^{14}C$ per kg carbon.*

**Table 21.** Radioactivity in groundwater at Sellafield, 2010

| Borehole number | Mean radionuclide concentration (Bq $m^{-3}$) | | | | | |
|---|---|---|---|---|---|---|
| | Total alpha | Total beta | $^{3}H$ | $^{90}Sr$ | $^{99}Tc$ | $^{137}Cs$ |
| 708P1 | <22 | <260 | <5,200 | <110 | <35 | <67 |
| 733P1 | <15 | 610 | <4,900 | 220 | <96 | - |
| 1239P1 | <11 | <240 | <4,400 | - | - | - |
| 2028PP1 | <14 | 350 | <4,700 | <110 | <79 | - |
| 2564P1 | <23 | <260 | <4,700 | <100 | <66 | - |
| 738P1 | 37 | 780 | 6,900 | 200 | <43 | <82 |
| 739P1 | <26 | <320 | 6,200 | 110 | 41 | <96 |
| 4683P1 | <16 | <250 | <5,000 | - | - | - |
| 4684P1 | <35 | <270 | 7,100 | - | - | - |
| 2796P1 | <8.7 | <250 | <4,700 | - | - | - |
| 801P1 | <20 | <250 | <4,900 | <88 | 2,200 | <22 |
| 1241P1 | 20 | <250 | 6,500 | - | - | - |
| 4688P1 | <21 | <240 | 15,000 | <94 | 42 | <46 |
| 4996P1 | <20 | <300 | 8,800 | 250 | 280 | <83 |
| 6986P1 | <45 | 370 | 1,900,000 | 130 | 4,400 | <21 |

Figure 4. Groundwater and radiological environmental monitoring at Sellafield



## Radiological impact of operations at Sellafield

### Critical group doses

54 Critical group doses have been calculated following the Principles for Total Retrospective Dose Assessment[8], which is consistent with last year's report. In 2005 several changes were made to the dose calculation methodology in order to make the Sellafield Ltd. dose calculations more consistent with these principles, the methodology for which is presented in the National Dose Assessment Working Group (NDAWG) Paper 11-03[9]. These changes in methodology include:

- Milk dose is based on the mean concentration at a nearby farm with the highest individual result (paragraph 63).
- The age groups considered for terrestrial critical group dose now includes pre-natal (foetal) dose, which has been calculated as an extension to the adult dose assessment using relevant dose coefficients.
- Dose per unit intake factors for ingestion and inhalation have been taken from the latest values published by the Environment Agency and Food Standards Agency. These factors differ from those used in previous reports because they include the presence of short-lived daughter radionuclides assumed to be in equilibrium with their parent at the time of ingestion, inhalation etc. Furthermore, the Environment Agency and Food Standards Agency methodology does not use a Cumbrian specific dose per unit intake factor for technetium-99 in lobster, which was used in previous assessments.
- Doses from inhaled and ingested tritium have been assessed using the more conservative dose factor for organically bound tritium, rather than that for tritiated water, which was used in previous reports.

Marine pathways

55 Using habits surveys, the Food Standards Agency has identified the marine critical group for seafood consumption as a small number of people in the Cumbrian coastal community who are high-rate consumers of fish and shellfish obtained from the Sellafield area between St Bees and Selker. Consumption and occupancy rates are kept under regular review and are published annually[2]. In this report, the consumption and occupancy rates used by Sellafield Ltd for dose assessment purposes (table 22) are taken from the most recent data provided by Food Standards Agency for the five years 2006-2010[7] with updated consumption rates for crustaceans and molluscs and occupancy rates from 2007. In reports published prior to 2005 the consumption of 'other molluscs' was equally divided between limpets, mussels and cockles. Since 2005, for consistency with the Food Standards Agency, they are all ascribed to mussels[2]. For the dose assessment, "Other fish" reported by the FSA are assumed to be plaice.

56 Table 23 shows dose to the critical group of consumers of seafood (caught locally between St Bees and Selker). The estimated critical group dose was about 130 µSv which is the same as 2009. The group may also receive doses from other pathways, such as inhalation and consumption of agricultural produce. An assessment has shown that these would increase the dose by only about 2 µSv. The doses from the consumption of molluscs are likely to be overestimated because no account has been

*Continued page 38*

**Table 22.** Seafood consumption rates for people associated with marine discharges (2006-2010 average data)

| Seafood | Consumption rates (kg $y^{-1}$) | | |
|---|---|---|---|
| | Critical group (Sellafield fishing community)[a] | Consumers associated with Whitehaven fishery[b] | Typical fish eating public (Whitehaven)[b] |
| Fish: | | | |
| cod | 15.8 | 20 | 7.5 |
| plaice | 24.6 | 20 | 7.5 |
| Crustaceans: | | | |
| crabs | 9.6 | - | - |
| lobsters | 5.6 | - | - |
| *Nephrops* | 3.9 | 9.7 | - |
| Molluscs: | | | |
| winkles | 14.8 | - | - |
| mussels | 15.2 | - | - |

*a. CEFAS, 2011. Radiological Habits Survey: Sellafield Review, 2010.*
*b. RIFE-15.*

**Table 23.** Summary of doses associated with marine discharges in 2010 (µSv): Critical group consumers of seafoods[a] (Sellafield fishing community)

| Radionuclide | Cod | Plaice | Lobster | Crab | *Nephrops* | Winkles | Mussels | Total for radionuclide |
|---|---|---|---|---|---|---|---|---|
| Carbon-14[b] | 0.80 | 1.7 | 0.43 | 0.63 | - | 0.92 | 0.86 | 5.3 |
| Cobalt-60 | - | 0.004 | 0.004 | 0.01 | - | 0.12 | 0.06 | 0.20 |
| Strontium-90 | - | - | - | 0.04 | - | 0.96 | 0.30 | 1.3 |
| Technetium-99 | 0.004 | 0.09 | 0.68 | 0.03 | 0.22 | 0.76 | 0.68 | 2.5 |
| Ruthenium-106 | 0.03 | 0.04 | - | 0.06 | - | 0.83 | 0.64 | 1.6 |
| Silver-110m | - | - | 0.002 | - | - | 0.01 | - | 0.01 |
| Antimony-125 | - | - | 0.002 | 0.003 | - | 0.02 | 0.02 | 0.05 |
| Iodine-129 | - | - | 0.75 | - | - | - | 0.23 | 0.98 |
| Caesium-137 | 1.2 | 1.5 | 0.12 | 0.12 | - | 1.0 | 0.38 | 4.3 |
| Curium-alpha | - | - | - | - | - | - | 0.09 | 0.09 |
| Neptunium-237 | - | - | - | - | - | - | 0.03 | 0.03 |
| Plutonium-alpha | 0.01 | 0.25 | 0.41 | 0.82 | - | 14 | 24 | 39 |
| Plutonium-241 | - | - | - | - | - | 1.4 | 2.7 | 4.1 |
| Americium-241 | 0.03 | 0.25 | 4.9 | 2.3 | 2.2 | 20 | 36 | 66 |
| Total for species | 2.1 | 3.8 | 7.3 | 4.0 | 2.4 | 40 | 66 | 126 |
| Total for group | | | | 126 | | | | |

*a. Based on Sellafield area data for fish (table 6) and Sellafield coastal area data for crustaceans and molluscs (Table 7a and 7b).*
*b. Calculated using background corrected activity concentrations.*

**Figure 5a.** Dose to marine critical group from Tc-99 in lobster and consumption rate

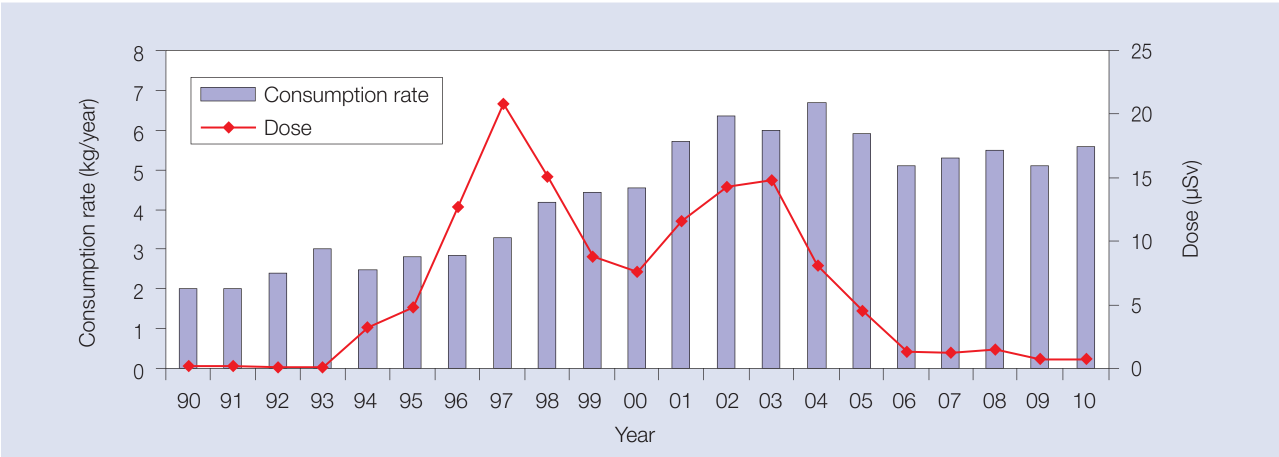



**Figure 5b.** Dose to marine critical group from Pu-alpha in winkles and consumption rate

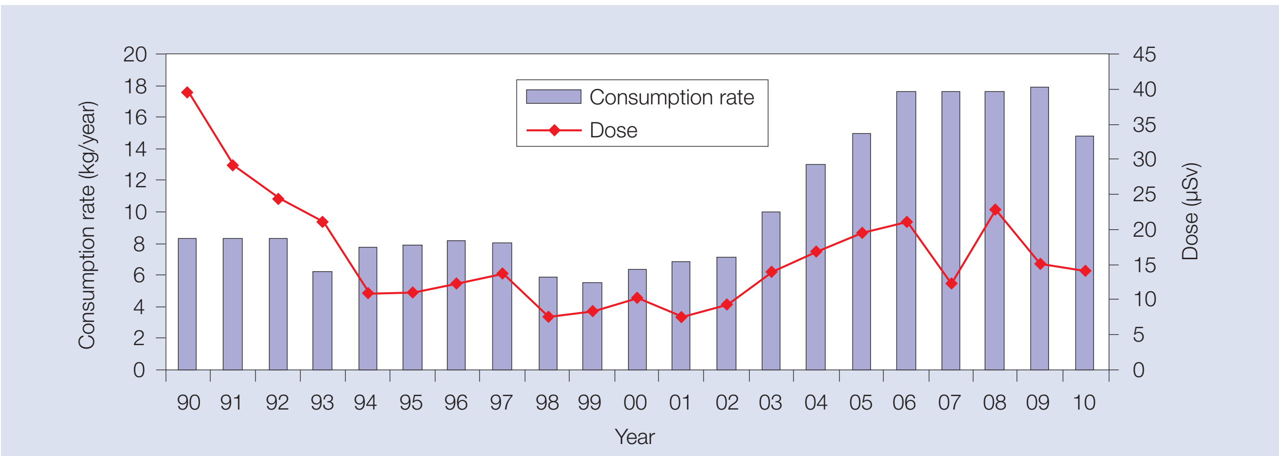


**Figure 5c.** Dose to marine critical group from Am-241 in winkles and consumption rate

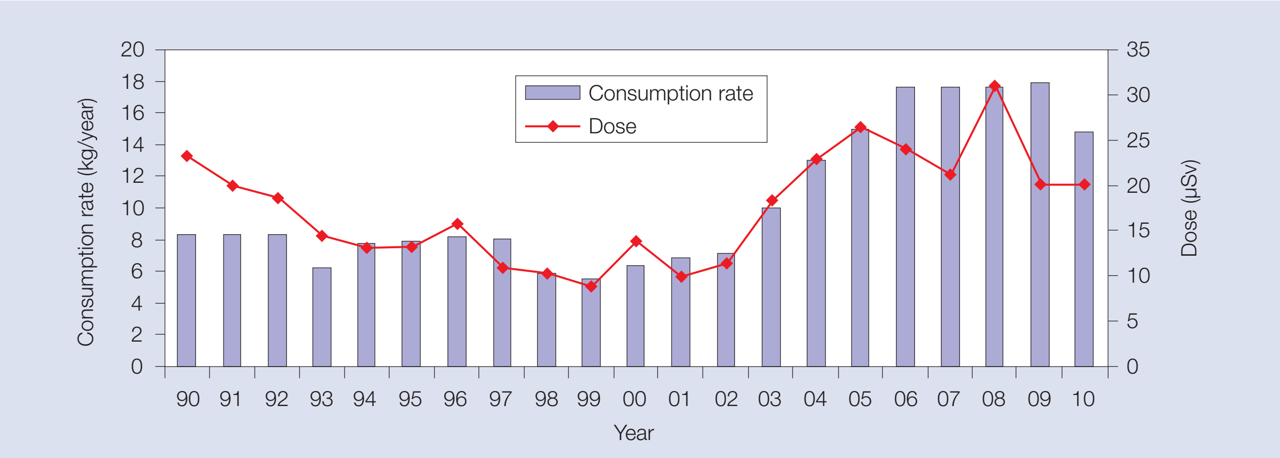



**Figure 5d.** Dose to marine critical group from Pu-alpha in mussels and consumption rate

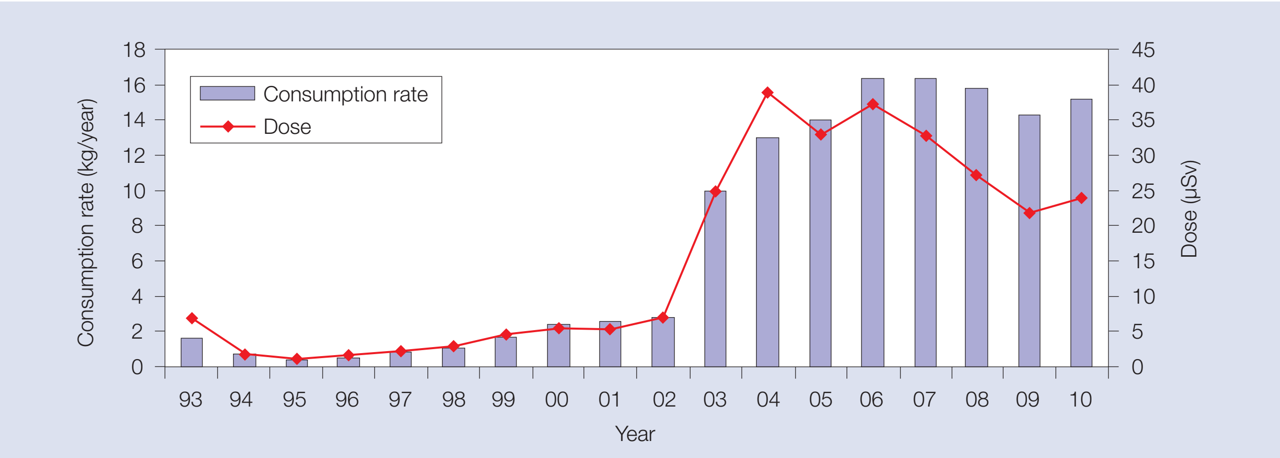



**Figure 5e.** Dose to marine critical group from Am-241 in mussels and consumption rate

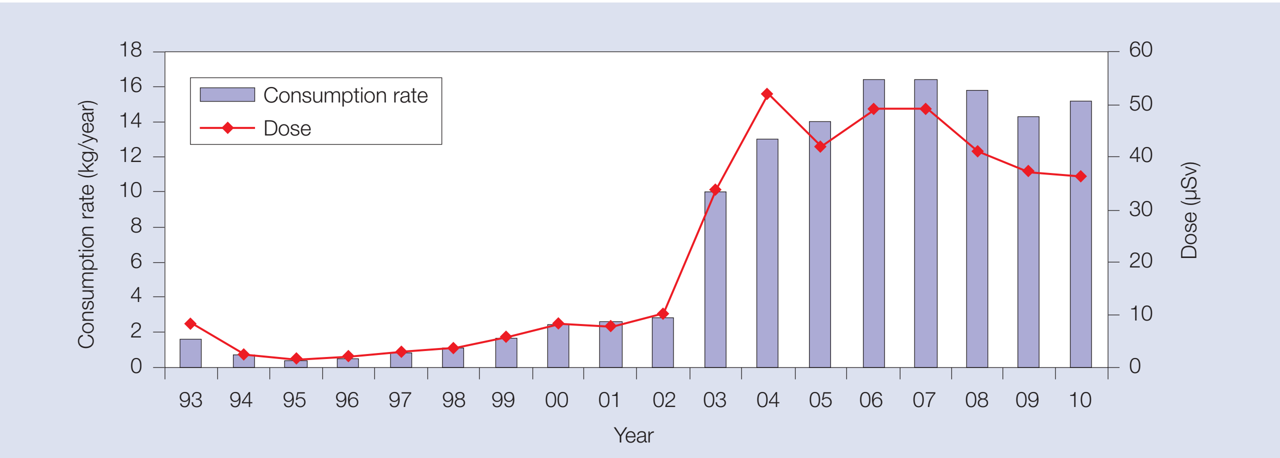


**Figure 6.** Marine Critical Group Dose (Adult) (Consumption pathways) by Nuclide

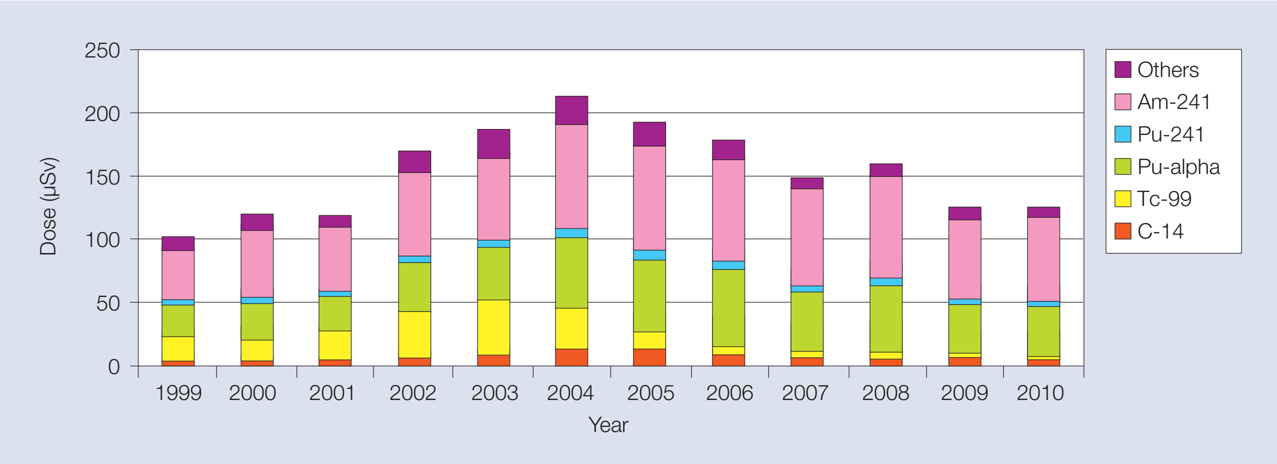
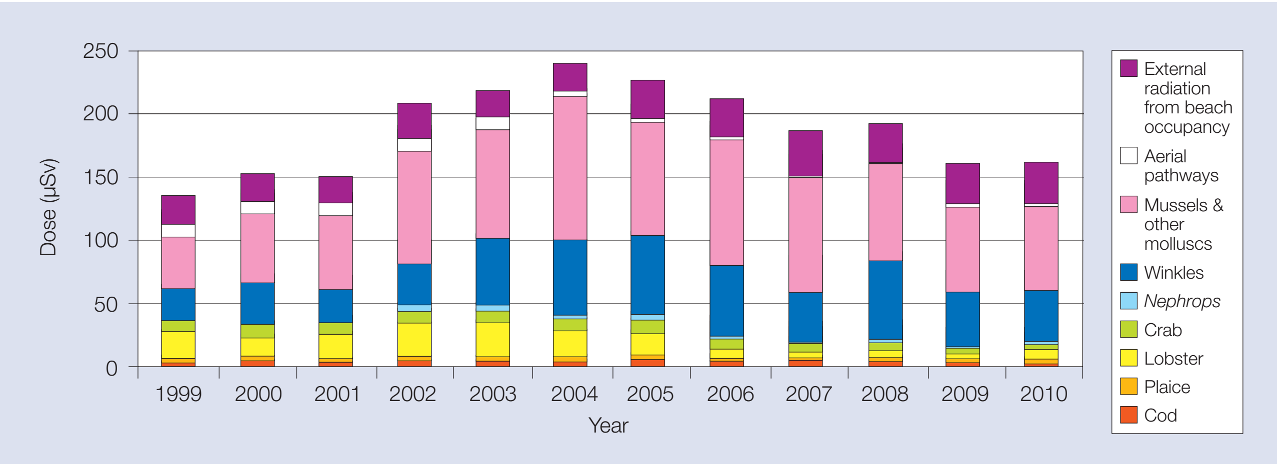



**Figure 7.** Marine Critical Group Dose (Adult) by Pathways




taken of the effects of food preparation procedures, such as the soaking of winkles to eliminate their gut contents which contain most of the actinide radioactivity (adsorbed onto silt particles). Doses to typical fish-eating members of the public were as usual very low (2.4 µSv). Doses to consumers associated with the Whitehaven fishery remained similar to last year (6.4 µSv).

57 Figure 5 shows doses to the marine critical group from seafoods (for nuclides contributing the highest proportions of dose) against the consumption rate of these foods. Consumption of lobster has steadily risen during the last two decades. Dose from technetium-99 has generally declined since 1997, despite this increased consumption because discharges, and hence concentrations in lobster, have declined. Consumption of winkles has increased steadily since 2000. This has resulted in an increased dose from plutonium-alpha and americium-241, despite stable discharges of these radionuclides and concentrations in winkles. Consumption of mussels has increased steadily since the mid-1990s. This has resulted in an increased dose up to 2006 from plutonium-alpha and americium-241, despite stable discharges and concentrations of these radionuclides in mussels. Since 2006/7 the dose has fallen sharply due to a combination of reduced consumption and reduced plutonium-alpha concentration in mussels.

58 Figure 6 shows the contribution of individual nuclides to the marine critical group's dose. Over the last 15 years the main contributors to marine dose have been americium-241, plutonium-alpha and technetium-99. The decrease in dose in the last 5 years has largely been caused by a reduction in technetium-99 dose resulting from decreased technetium-99 discharges.

59 Figure 7 shows the contribution of individual foodstuffs to the marine critical group's dose. Over the last 15 years the main contributors to marine dose have been from mussels, winkles and lobster. Variations in the proportion of dose from each food reflect changes in both consumption rate and radionuclide concentrations.

60 The Food Standards Agency and the Environment Agency[7] continue to keep under review the amount of time spent by members of the public on inter-tidal areas of the coastline bordering the north-east Irish Sea and more inland locations. In particular, it was considered that members of the critical group received an external contribution to their radiation exposure from spending up to 834 hours each year on local beaches (i.e. Parton to Eskmeals). This additional dose was estimated to be 33 µSv using averaged habit data for 2005-2009.

61 The Health Protection Agency[18] (HPA) continues to keep under review the numbers and radionuclide content of particles that are detected by monitoring on beaches near the Sellafield site. However, acting on the information supplied by the EA during 2010, the HPA considered no special precautionary actions to be necessary regarding access to, or use of, these beaches.

### Airborne and terrestrial pathways

62 For some years Sellafield Ltd has used consumption rates obtained from the approach used by the Health Protection Agency (HPA)[11], whereby several dose assessments are carried out to establish which foodstuffs contribute the maximum dose at higher critical group consumption rates. Using this process, the two food groups identified as making the highest contribution to dose are assigned critical group (higher) consumption rates (milk and green vegetables in 2007; milk and apples in 2008, milk and domestic fruit in 2009 and 2010). The remainder are assigned national mean consumption rates. The consumption rates used for 2010 are summarised in table 24.
In addition to changes in food consumption rates, Sellafield Ltd has adopted the generic advice of the HPA on parameters relating to external radiation pathways (table 25)[12,13]. In previous years the dose from terrestrial foodstuffs has been based only on the foods sampled by Sellafield Ltd and Foods Standards Agency in that year. In the dose assessment reported here, where 2010 data was not collected, the most recent data available was used (e.g. 2008 honey).

63 Milk dose is based on the mean concentration at a nearby farm with the highest individual result.
This accounts for the possibility that any farm close to a site can act as the sole source of supply of milk to high-rate consumers. Based on the average concentrations of radioactivity in milk from farm D reported in table 15 (excluding ruthenium-106 and iodine-131), the estimated annual dose to infants who drink milk obtained only from local farms would have been 8.5 µSv and the corresponding doses to adults, children and foetus about 3.3, 4.6 and 2.9 µSv respectively (table 26). The doses from ruthenium-106 in all terrestrial foodstuffs and iodine-131 in milk,

**Table 24.** **Consumption rates of critical group consumers associated with aerial discharges**

| Foodstuff[a] | Consumption rate (kg $y^{-1}$)[i, j] | | |
|---|---|---|---|
| | Adult | Child | Infant |
| milk | 240 | 240 | 320 |
| beef | 15 | 15 | 3 |
| beef liver | 2.75 | 1.5 | 0.5 |
| mutton | 8 | 4 | 0.8 |
| poultry[b] | 10 | 5.5 | 2 |
| game[c] | 6 | 4 | 0.8 |
| fish (cod + plaice) | 15 | 3 | 0.75 |
| leafy vegetables[d] | 15 | 6 | 3.5 |
| potatoes | 50 | 45 | 10 |
| root vegetables[e] | 10 | 6 | 5 |
| legumes[f] | 20 | 8 | 3 |
| domestic fruit[g] | 75 | 50 | 35 |
| wild fruit[h] | 7 | 3 | 1 |
| mushrooms | 3 | 1.5 | 0.6 |
| honey | 2.5 | 2 | 2 |
| eggs | 8.5 | 6.5 | 5 |

*a. Based on HPA/FSA recommendations.*
*b. Duck from 2007.*
*c. Rabbits, pheasants and venison.*
*d. Cabbage, cauliflower and broccoli.*
*e. Carrots, swede and onions.*
*f. Runner beans.*
*g. Apples, blackcurrants and strawberries.*
*h. Blackberries and elderberries.*
*i. Consumption rates for foetal exposure taken to be same as those of adults.*
*j. Milk and domestic fruit as high rate consumers.*

**Table 25.** **Parameters for calculation of plume immersion and inhalation doses**[a]

| | Adult | Child | Infant |
|---|---|---|---|
| Occupancy (%) | 100 | 100 | 100 |
| Time indoors (%) | 50 | 90 | 90 |
| Building shielding factor | 0.2 | 0.2 | 0.2 |
| Breathing rate ($m^3$ $a^{-1}$) | 9860 | 5600 | 1900 |

*a. Foetal dose is calculated from the adult dose multiplied by the ratio of the foetus to the adult dose conversion factors (following NRPB, 2005).*

shown in table 26, are assessed using standard modelling techniques[12,14,15] (as used by the Health Protection Agency and others) which are based on knowledge of the transfer of these radionuclides through the food chain. This is considered to be more realistic than using the limits of detection from the radiochemical analysis.

64 Based on the average concentrations reported in tables 14a, 14b, 16 and 17 for radioactivity in air, and in terrestrial foodstuffs other than milk, infants would have received an estimated dose of 2.9 µSv (4.0, 3.7 and 2.9 µSv for adults, children and foetus) from these other foodstuffs and from inhalation. Detailed data are provided in tables 26 and 27. Doses assessed as being less than 0.001 microSv have been presented as "<0.001".

**Figure 8.** Terrestrial Critical Group Dose (Infant) (Consumption pathways) by Nuclide

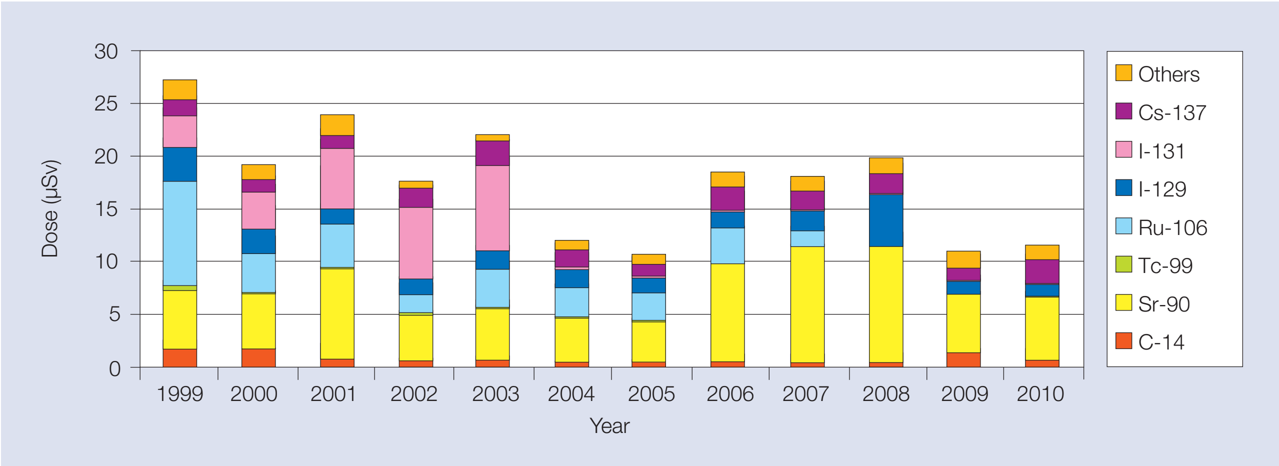
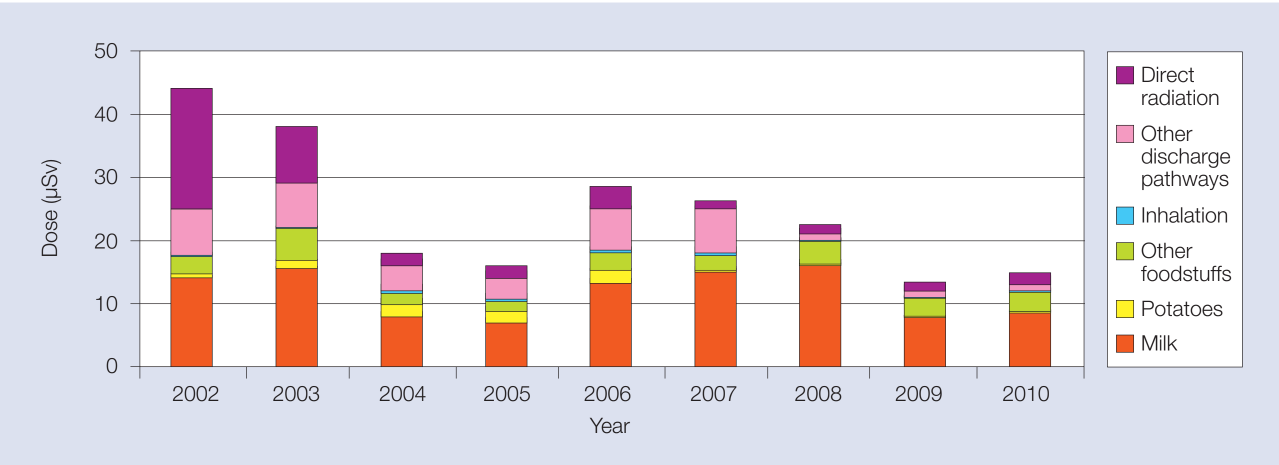



**Figure 9.** Terrestrial Critical Group Dose (Infant) by Pathways




65 Table 27 and figure 8 show that over the last 15 years, the main radionuclides contributing to doses from consumption and inhalation are strontium-90, ruthenium-106, iodine-129, iodine-131 and caesium-137 (all dominated by consumption). Doses from strontium-90 and caesium-137 are dominated by pre-1980 discharges, the testing of nuclear weapons in the 1960s and (for caesium-137) the Chernobyl accident in 1986. The relative proportions of nuclides in recent years can largely be explained by changes in reprocessing rates and improvements in the analytical limits of detection achievable.

66 Figure 9 shows the contribution of individual foodstuffs to the terrestrial critical group's dose. Over the last 15 years terrestrial dose has been dominated by milk and potato consumption.

67 Members of the terrestrial critical group also received a dose of up to 3.5 µSv, arising from seafood consumption. This dose contained an external component (1.3 µSv) from radioactivity deposited on local beaches, based on data published by the Environment Agency and Food Standards Agency, and an internal component (2.2, 0.48, 0.22 and 1.9, µSv respectively to adults, children, infants and foetuses) from an assumed consumption of locally caught fish (table 28).

68 In addition to exposure from the consumption of local produce, the critical group also receives exposure from immersion in a plume containing krypton-85 discharged from the reprocessing plants. The doses in 2010 to adults, children, infants and foetuses living near to Sellafield would have been respectively 0.47, 0.33, 0.33 and 0.47 µSv using modelling and dosimetry published by the EU and the ICRP[14,15] (table 29).

69 The doses to the terrestrial critical group are summarised in table 29. If all the above pathways are considered to be additive, the highest dose to infants in 2010 was about 12 µSv. The dose to adults was also about 12 µSv but dose to children and foetuses was slightly lower. The changes to the dose assessment methodology (paragraph 54), and the inclusion of an external dose that is quoted as a less

*Continued page 44*

**Table 26.** Summary of doses to the terrestrial critical group from terrestrial foodstuffs and inhalation in 2010 (µSv)[a]

| Radionuclide | Milk | | | | Beef | | | | Beef offal | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus |
| Total tritium | 0.03 | 0.04 | 0.12 | 0.05 | 0.005 | 0.007 | 0.003 | 0.008 | <0.001 | <0.001 | <0.001 | 0.001 |
| Carbon-14[b] | 0.08 | 0.12 | 0.31 | 0.12 | - | - | - | - | - | - | - | - |
| Cobalt-60 | - | - | - | - | 0.01 | 0.03 | 0.02 | 0.006 | 0.002 | 0.004 | 0.003 | 0.001 |
| Strontium-90 | 1.3 | 2.7 | 5.1 | 1.9 | 0.005 | 0.01 | 0.003 | 0.007 | 0.03 | 0.03 | 0.02 | 0.04 |
| Technetium-99 | - | - | - | - | - | - | - | - | - | - | - | - |
| Ruthenium-106[c] | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Antimony-125 | 0.03 | 0.05 | 0.20 | 0.01 | 0.005 | 0.009 | 0.005 | 0.002 | 0.001 | 0.001 | 0.001 | <0.001 |
| Iodine-129 | 0.26 | 0.46 | 0.70 | 0.11 | 0.07 | 0.11 | 0.03 | 0.03 | 0.01 | 0.01 | 0.005 | 0.005 |
| Iodine-131[c] | 0.004 | 0.008 | 0.04 | 0.004 | - | - | - | - | - | - | - | - |
| Caesium-134 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-137 | 1.6 | 1.2 | 2.0 | 0.70 | 0.14 | 0.11 | 0.03 | 0.06 | 0.02 | 0.007 | 0.003 | 0.007 |
| Plutonium alpha | - | - | - | - | 0.002 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Plutonium-241 | - | - | - | - | 0.004 | 0.004 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Americium-241 | - | - | - | - | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Total | 3.3 | 4.6 | 8.5 | 2.9 | 0.24 | 0.28 | 0.10 | 0.12 | 0.07 | 0.06 | 0.04 | 0.06 |

| Radionuclide | Mutton | | | | Poultry | | | | Eggs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus |
| Total tritium | - | - | - | - | - | - | - | - | 0.003 | 0.002 | 0.002 | 0.004 |
| Carbon-14[b] | - | - | - | - | - | - | - | - | 0.15 | 0.11 | 0.08 | 0.20 |
| Cobalt-60 | 0.005 | 0.009 | 0.004 | 0.003 | 0.002 | 0.003 | 0.003 | 0.001 | 0.003 | 0.006 | 0.005 | 0.002 |
| Strontium-90 | 0.007 | 0.008 | 0.002 | 0.01 | 0.01 | 0.01 | 0.007 | 0.02 | 0.009 | 0.01 | 0.006 | 0.01 |
| Technetium-99 | - | - | - | - | - | - | - | - | - | - | - | - |
| Ruthenium-106[c] | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Antimony-125 | 0.003 | 0.003 | 0.002 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.004 | 0.005 | 0.005 | 0.002 |
| Iodine-129 | 0.03 | 0.02 | 0.005 | 0.01 | 0.009 | 0.009 | 0.003 | 0.004 | 0.03 | 0.03 | 0.01 | 0.01 |
| Iodine-131 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-134 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-137 | 0.08 | 0.03 | 0.007 | 0.04 | 0.01 | 0.005 | 0.002 | 0.005 | 0.04 | 0.02 | 0.007 | 0.02 |
| Plutonium alpha | - | - | - | - | - | - | - | - | <0.001 | <0.001 | <0.001 | <0.001 |
| Plutonium-241 | - | - | - | - | - | - | - | - | - | - | - | - |
| Americium-241 | - | - | - | - | - | - | - | - | <0.001 | <0.001 | <0.001 | <0.001 |
| Total | 0.13 | 0.07 | 0.02 | 0.07 | 0.03 | 0.03 | 0.02 | 0.03 | 0.24 | 0.19 | 0.12 | 0.25 |

| Radionuclide | Game | | | | Honey | | | | Potatoes | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus |
| Total tritium | 0.002 | 0.003 | 0.004 | 0.004 | 0.003 | 0.002 | <0.001 | 0.004 | <0.001 | <0.001 | 0.002 | 0.001 |
| Carbon-14[b] | - | - | - | - | - | - | - | - | - | - | - | - |
| Cobalt-60 | 0.006 | 0.01 | 0.03 | 0.003 | 0.004 | 0.009 | 0.004 | 0.002 | <0.001 | 0.002 | 0.005 | <0.001 |
| Strontium-90 | 0.01 | 0.02 | 0.02 | 0.02 | 0.007 | 0.01 | 0.003 | 0.01 | 0.004 | 0.007 | 0.009 | 0.006 |
| Technetium-99 | - | - | - | - | <0.001 | <0.001 | <0.001 | <0.001 | - | - | - | - |
| Ruthenium-106[c] | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Antimony-125 | 0.005 | 0.007 | 0.02 | 0.002 | 0.002 | 0.003 | 0.002 | 0.001 | 0.001 | 0.002 | 0.005 | <0.001 |
| Iodine-129 | 0.03 | 0.04 | 0.03 | 0.01 | 0.009 | 0.01 | 0.002 | 0.004 | 0.003 | 0.004 | 0.004 | 0.001 |
| Iodine-131 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-134 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-137 | 0.01 | 0.008 | 0.008 | 0.006 | 0.05 | 0.03 | 0.007 | 0.02 | 0.003 | 0.002 | 0.002 | 0.001 |
| Plutonium alpha | <0.001 | <0.001 | <0.001 | <0.001 | - | - | - | - | <0.001 | <0.001 | <0.001 | <0.001 |
| Plutonium-241 | 0.002 | 0.002 | 0.001 | <0.001 | - | - | - | - | 0.001 | <0.001 | 0.001 | <0.001 |
| Americium-241 | <0.001 | <0.001 | <0.001 | <0.001 | 0.02 | 0.01 | 0.004 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Total | 0.07 | 0.09 | 0.12 | 0.05 | 0.10 | 0.08 | 0.03 | 0.04 | 0.02 | 0.02 | 0.03 | 0.02 |

*a. Values in grey have been calculated using FSA monitoring data*
*b. Calculated using background corrected activity concentrations (see paragraph 47).*
*c. Derived from standard modelling techniques.*

**Table 26.** continued

| Radionuclide | Root Vegetables | | | | Green Vegetables | | | | Legumes | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus |
| Total tritium | <0.001 | <0.001 | <0.001 | 0.001 | 0.005 | 0.006 | 0.003 | 0.008 | 0.001 | <0.001 | 0.002 | 0.002 |
| Carbon-14[b] | 0.002 | 0.001 | <0.001 | 0.002 | 0.02 | 0.03 | 0.01 | 0.03 | - | - | - | - |
| Cobalt-60 | 0.002 | 0.003 | 0.003 | 0.001 | 0.03 | 0.07 | 0.04 | 0.01 | 0.006 | 0.01 | 0.02 | 0.003 |
| Strontium-90 | 0.06 | 0.06 | 0.04 | 0.09 | 0.06 | 0.12 | 0.04 | 0.09 | 0.05 | 0.06 | 0.07 | 0.07 |
| Technetium-99 | - | - | - | - | 0.02 | 0.03 | 0.03 | 0.01 | <0.001 | <0.001 | 0.001 | <0.001 |
| Ruthenium-106[c] | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Antimony-125 | <0.001 | <0.001 | 0.001 | <0.001 | 0.02 | 0.03 | 0.02 | 0.009 | 0.005 | 0.005 | 0.01 | 0.002 |
| Iodine-129 | 0.007 | 0.006 | 0.003 | 0.003 | 0.17 | 0.26 | 0.07 | 0.07 | 0.04 | 0.04 | 0.04 | 0.01 |
| Iodine-131 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-134 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-137 | 0.02 | 0.007 | 0.003 | 0.008 | 0.11 | 0.07 | 0.020 | 0.05 | 0.01 | 0.005 | 0.005 | 0.005 |
| Plutonium alpha | - | - | - | - | - | - | - | - | - | - | - | - |
| Plutonium-241 | - | - | - | - | - | - | - | - | - | - | - | - |
| Americium-241 | <0.001 | <0.001 | <0.001 | <0.001 | - | - | - | - | 0.05 | 0.04 | 0.05 | <0.001 |
| Total | 0.10 | 0.08 | 0.05 | 0.11 | 0.44 | 0.62 | 0.23 | 0.28 | 0.16 | 0.16 | 0.20 | 0.10 |

| Radionuclide | Mushrooms | | | | Domestic Fruit | | | | Wild Fruit | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus |
| Total tritium | 0.002 | 0.001 | 0.001 | 0.003 | 0.008 | 0.008 | 0.01 | 0.01 | - | - | - | - |
| Carbon-14[b] | - | - | - | - | 0.20 | 0.19 | 0.26 | 0.28 | - | - | - | - |
| Cobalt-60 | 0.01 | 0.01 | 0.02 | 0.005 | 0.03 | 0.07 | 0.13 | 0.02 | 0.004 | 0.006 | 0.005 | 0.002 |
| Strontium-90 | 0.08 | 0.07 | 0.06 | 0.12 | 0.28 | 0.40 | 0.39 | 0.41 | 0.14 | 0.13 | 0.06 | 0.21 |
| Technetium-99 | 0.003 | 0.003 | 0.006 | 0.002 | - | - | - | - | - | - | - | - |
| Ruthenium-106[c] | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Antimony-125 | 0.005 | 0.004 | 0.006 | 0.002 | 0.02 | 0.03 | 0.06 | 0.01 | 0.003 | 0.002 | 0.002 | 0.001 |
| Iodine-129 | 0.03 | 0.02 | 0.01 | 0.01 | 0.22 | 0.25 | 0.21 | 0.09 | 0.02 | 0.02 | 0.007 | 0.009 |
| Iodine-131 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-134 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-137 | 0.04 | 0.01 | 0.008 | 0.02 | 0.28 | 0.15 | 0.12 | 0.12 | 0.05 | 0.02 | 0.006 | 0.02 |
| Plutonium alpha | <0.001 | <0.001 | <0.001 | <0.001 | 0.009 | 0.006 | 0.007 | <0.001 | - | - | - | - |
| Plutonium-241 | <0.001 | <0.001 | <0.001 | <0.001 | 0.01 | 0.009 | 0.007 | <0.001 | - | - | - | - |
| Americium-241 | 0.19 | 0.08 | 0.08 | 0.003 | 0.01 | 0.008 | 0.01 | <0.001 | - | - | - | - |
| Total | 0.36 | 0.20 | 0.19 | 0.17 | 1.1 | 1.1 | 1.2 | 0.94 | 0.22 | 0.18 | 0.08 | 0.24 |

| Radionuclide | Drinking water | | | | Drinking water (1) | | | | Inhalation (1) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus | Adult | Child | Infant | Foetus |
| Total tritium | - | - | - | - | 0.07 | 0.06 | 0.09 | 0.11 | - | - | - | - |
| Carbon-14[b] | - | - | - | - | - | - | - | - | - | - | - | - |
| Cobalt-60 | 0.009 | 0.01 | 0.01 | 0.005 | - | - | - | - | - | - | - | - |
| Strontium-90 | 0.11 | 0.09 | 0.05 | 0.16 | 0.07 | 0.08 | 0.09 | 0.10 | 0.001 | <0.001 | <0.001 | <0.001 |
| Technetium-99 | 0.002 | 0.001 | 0.002 | 0.001 | - | - | - | - | - | - | - | - |
| Ruthenium-106 | <0.001 | <0.001 | <0.001 | <0.001 | - | - | - | - | 0.01 | 0.009 | 0.008 | <0.001 |
| Antimony-125 | 0.007 | 0.005 | 0.006 | 0.003 | - | - | - | - | <0.001 | <0.001 | <0.001 | <0.001 |
| Iodine-129 | 0.04 | 0.03 | 0.01 | 0.02 | - | - | - | - | - | - | - | - |
| Iodine-131 | - | - | - | - | - | - | - | - | - | - | - | - |
| Caesium-134 | - | - | - | - | - | - | - | - | <0.001 | <0.001 | <0.001 | <0.001 |
| Caesium-137 | 0.02 | 0.005 | 0.002 | 0.007 | 0.04 | 0.02 | 0.02 | 0.02 | <0.001 | <0.001 | <0.001 | <0.001 |
| Plutonium alpha | - | - | - | - | 0.05 | 0.03 | 0.04 | 0.002 | 0.35 | 0.19 | 0.10 | 0.007 |
| Plutonium-241 | - | - | - | - | - | - | - | - | 0.19 | 0.10 | 0.04 | 0.002 |
| Americium-241 | 0.320 | 0.140 | 0.090 | 0.0040 | 0.03 | 0.02 | 0.02 | <0.001 | 0.17 | 0.09 | 0.05 | 0.001 |
| Total | 0.51 | 0.28 | 0.17 | 0.20 | 0.26 | 0.21 | 0.26 | 0.23 | 0.72 | 0.39 | 0.20 | 0.02 |

*a. Values in grey have been calculated using FSA monitoring data.*
*b. Calculated using background corrected activity concentrations.*
*c. Derived from standard modelling techniques.*

**Table 27. Summary of doses by radionuclide to the critical group from terrestrial foodstuffs and from inhalation in 2010**

| Radionuclide | Total dose per radionuclide (μSv) | | | |
|---|---|---|---|---|
| | Adult | Child | Infant | Foetus |
| Tritium | 0.13 | 0.13 | 0.24 | 0.21 |
| Carbon-14[a] | 0.45 | 0.45 | 0.66 | 0.63 |
| Cobalt-60 | 0.12 | 0.25 | 0.30 | 0.07 |
| Strontium-90 | 2.2 | 3.8 | 6.0 | 3.3 |
| Technetium-99 | 0.03 | 0.04 | 0.04 | 0.02 |
| Ruthenium-106 | 0.03 | 0.03 | 0.02 | 0.02 |
| Antimony-125 | 0.11 | 0.16 | 0.35 | 0.05 |
| Iodine-129 | 0.98 | 1.3 | 1.1 | 0.40 |
| Iodine-131 | 0.004 | 0.008 | 0.04 | 0.004 |
| Caesium-134 | 0.001 | 0.001 | 0.001 | 0.001 |
| Caesium-137 | 2.5 | 1.7 | 2.3 | 1.1 |
| Plutonium alpha | 0.42 | 0.23 | 0.15 | 0.02 |
| Plutonium-241 | 0.21 | 0.12 | 0.05 | 0.008 |
| Americium-241 | 0.80 | 0.39 | 0.31 | 0.02 |
| Total overall dose | 8.0 | 8.6 | 12 | 5.8 |
| Inhalation | 0.72 | 0.39 | 0.20 | 0.02 |
| All foodstuffs | 7.3 | 8.3 | 11 | 5.8 |
| Milk | 3.3 | 4.6 | 8.5 | 2.9 |
| Foodstuffs other than milk | 4.0 | 3.7 | 2.9 | 2.9 |

*a. Calculated using background corrected activity concentrations.*

**Table 28. Summary of doses to the terrestrial critical group from seafood consumption in 2010**

| Radionuclide | Dose in 2010 (μSv) | | | |
|---|---|---|---|---|
| | Adult | Child | Infant | Foetus |
| Carbon-14[a] | 1.1 | 0.29 | 0.15 | 1.5 |
| Cobalt-60 | 0.001 | 0.001 | 0.001 | 0.001 |
| Technetium-99 | 0.03 | 0.01 | 0.01 | 0.02 |
| Ruthenium-106 | 0.02 | 0.01 | 0.01 | 0.002 |
| Caesium-137 | 0.95 | 0.14 | 0.04 | 0.42 |
| Plutonium alpha | 0.04 | 0.008 | 0.004 | 0.002 |
| Americium-241 | 0.06 | 0.01 | 0.006 | 0.002 |
| Total | 2.2 | 0.48 | 0.22 | 1.9 |

*a. Calculated using background corrected activity concentrations.*

**Table 29. Summary of doses to the terrestrial critical group in 2010**

| Pathway | Dose in 2010 (μSv) | | | |
|---|---|---|---|---|
| | Adult | Child | Infant | Foetus |
| Food consumption: | | | | |
| terrestrial foods | 7.3 | 8.3 | 11 | 5.8 |
| marine foods | 2.2 | 0.48 | 0.22 | 1.9 |
| Inhalation | 0.72 | 0.39 | 0.20 | 0.02 |
| Immersion: | | | | |
| krypton-85 | 0.47 | 0.33 | 0.33 | 0.47 |
| External[a] | 1.3 | 0.67 | 0.04 | 1.3 |
| Total | 12 | 10 | 12 | 9.5 |

*a. Taken from RIFE-15, Data from 2010 Total Dose assessment. Infant taken from Doses - gaseous. Adult and Child calculated from Child ratios. Foetus set equal to adult.*

than value by the Food Standards Agency, are the reason that these doses are higher than those reported before 2006. These doses are however considerably lower than in earlier years when the Calder Hall reactors were operational. Conservatively, it is assumed that members of this critical group are also exposed to direct radiation (see next paragraph and table 1).

### Direct radiation

70 Due to the closure of Calder Hall in March 2003 (paragraph 52), direct radiation doses to local residents have reduced significantly. Based on survey work conducted in 2008 the upper bound of the dose range to residents living closest to the site is about 1.4 µSv.

### Collective doses

71 Collective doses resulting from the effects of discharges from Sellafield in 2009, summed over 500 years, have been calculated in accordance with paragraphs 26-29 and 36 of the Introduction (amplified in the Appendix). The results (table 30) give collective dose commitments (combined aerial and marine) of about 2.0 manSv to the UK population, 7 manSv to the European population (including the UK) and 49 manSv to the world population. These are significantly lower than the values reported in 2009 due to a decrease in carbon-14 and krypton-85 discharges reflecting reduced Magnox reprocessing throughput (paragraph 11).

72 Most of the collective dose commitment from Sellafield discharges results from carbon-14 because of its long radioactive half-life (5730 years) and its incorporation into the global carbon cycle. However, concentrations of carbon-14 in the atmosphere which are attributable to Sellafield are indistinguishable from naturally occurring background concentrations at distances exceeding 100 km. The natural background results in collective doses that are many orders of magnitude higher than the doses resulting from Sellafield's discharges of carbon-14. This reflects the fact that natural sources of radiation constitute the largest source of public radiation exposure on a national or global scale[16].

**Table 30.** Collective doses from Sellafield's discharges in 2010

| Radionuclide | Collective dose (man Sv) from discharges in 2010 | | | | | |
|---|---|---|---|---|---|---|
| | Aerial discharges | | | Marine discharges | | |
| | UK | Europe | World | UK | Europe | World |
| Tritium | 0.06 | 0.12 | 0.15 | 0.0006 | 0.003 | 0.05 |
| Carbon-14 | 0.06 | 0.28 | 3.4 | 0.88 | 2.9 | 30 |
| Krypton-85 | 0.20 | 0.67 | 12 | - | - | - |
| Technetium-99 | - | - | - | 0.004 | 0.01 | 0.01 |
| Iodine-129 | 0.43 | 2.0 | 2.8 | 0.005 | 0.02 | 0.06 |
| Caesium-137 | 0.002 | 0.005 | 0.005 | 0.08 | 0.20 | 0.35 |
| Plutonium Alpha | 0.01 | 0.02 | 0.02 | 0.04 | 0.11 | 0.13 |
| Americium-241 | 0.002 | 0.003 | 0.003 | 0.04 | 0.10 | 0.11 |
| Other nuclides | 0.002 | 0.003 | 0.003 | 0.11 | 0.33 | 0.37 |
| Total | 0.77 | 3.1 | 18 | 1.2 | 3.7 | 31 |

## Non-radioactive discharges and disposals

73 Non-radioactive discharges and disposals from the Sellafield site are made in accordance with the requirements of appropriate permits, consents and licences. Liquid effluent discharges are summarised in table 31 and include all discharges for which annual mass limits are specified. Aerial discharges are summarised in table 32.

### Disposals made under the terms of Waste Disposal or Waste Management Licences

74 There are five licensed landfill sites at Sellafield although three are effectively closed. The South Landfill Site and the Calder Floodplain Landfill Extension are operational and are permitted to take a range of inert, non-radioactive wastes and are also authorised to take radioactive soil (see paragraph 29). In recent years, these two sites have been reserved almost exclusively for radioactive soil, as the only alternative site is the LLWR. Non-radioactive soil and other non-radioactive wastes are usually sent for off-site disposal.

### Ozone depleting substances and fluorinated greenhouse gases

75 The Company is committed to minimising the use of ozone depleting substances and replacing equipment containing ozone depleting substances and fluorinated greenhouse gases. Routine releases are estimated from the amounts of refrigerants used to top up systems on site. Site releases of ozone depleting substances are summarised in table 33.

### Carbon dioxide and other greenhouse gases

76 Sellafield's discharges of carbon dioxide and methane are mainly from Fellside combined heat and power plant (CHP), which is managed and operated by Sellafield Ltd, and its emissions controlled by the Sellafield Environmental Permit and an Emissions Trading Permit. Carbon dioxide may also be emitted from standby generators on Sellafield site which also have an Emissions Trading Permit. In addition, small amounts of carbon dioxide are released from the process plants (table 32). Discharges of carbon dioxide and methane in 2010 were similar to those in 2009.

**Table 31.** Non-radioactive liquid effluent discharges in 2010[a]

| Substance | Release points | Discharge (te) | Annual Limit (te) |
|---|---|---|---|
| Mercury | SETP, SIXEP, EARP, Laundry, Inactive Tank Farm Neutralising Pit, Thorp-C14 removal plant, Water Treatment Plant | 0.002 | 0.01 |
| Chromium | SETP, SIXEP, EARP | 0.09 | 1.2 |
| N as $NO_2$ and $NO_3$ | SETP, EARP | 960 | 4,100 |
| N as $NO_2$ and $NO_3$ | Thorp-C14 removal plant | 2.8 | 27 |
| Glycol | SETP, SIXEP, EARP | 1.5 | 12 |

*a. Annual mass limits reported under the Environmental Permit.*

**Table 32.** Non-radioactive aerial effluent discharges in 2010

| Substance | Discharge (te) | Annual Limit (te)[a] |
|---|---|---|
| Oxides of nitrogen (as $NO_2$) | 0.02 | 1.00 |
| Oxides of nitrogen (as $NO_2$) | 0.01 | 0.50 |
| Particulate matter | 0.5 | N/A |
| Volatile organic compounds (VOCs) | 60 | N/A |
| Carbon dioxide | 420,000 | N/A |
| Carbon monoxide | 25 | N/A |
| Methane | 11 | N/A |
| Sulphur hexafluoride | 0.0001 | N/A |

*a. Annual mass limits reported under the Environmental Permit.*

77 Sulphur hexafluoride is used periodically in small quantities for testing the effectiveness of stack and duct sampling systems (table 32). Discharges were about 140 g in 2010 compared to about 20 g in 2009. This increase is the result of more vent testing in 2010.

### Off-site disposals of solid waste

78 Non-radioactive controlled wastes consisting of office, canteen, workshop or general waste (mainly solid but including some sludges and liquids) are disposed of off-site via a specialist waste disposal contractor. Wherever possible, waste is recycled but if this is not practicable, it is disposed of to a licensed landfill. Waste that is particularly hazardous may have to be considered as special waste and disposed of to specially licensed disposal facilities after pre-notifying the Environment Agency. In order to reduce the amount of low-level radioactive waste sent for disposal at the LLWR, which is a national resource with limited capacity, some wastes arising in process areas of the site are carefully monitored to confirm that they are not radioactive before they too are sent for disposal off-site with other controlled wastes. It should be noted that radioactive special waste is also included in the LLWR disposal figures.

## Non-radiological monitoring of the environment

79 The Environmental Permitting Regulations (2010) permit includes a monitoring programme (see figure 4). Compared to the radiological environmental monitoring programme, its scope is limited and comprises local air sampling on the Sellafield site, water sampling from the Rivers Calder and Ehen, and seawater sampling from local beaches. A more comprehensive summary of non-radioactive releases to air, controlled waters, land and off-site transfers of waste is given in the Pollution Inventory supplied to the Environment Agency each year and available from their website.

### Air sampling

80 Measurements of nitrogen dioxide concentrations in air are made at five locations on the Sellafield site: West Ring Road, Meteorological Station, North Group roundabout, Calder Gate and South Side. Measurements are made using passive diffusion tubes which are exposed for one month before being analysed. Air sampling results are summarised in table 34.

**Table 33.** Discharges of ozone depleting substances and fluorinated greenhouse gases in 2010

| Substance[a] | Discharge (te) |
|---|---|
| 22 HCFC | 0.13 |
| R407c HFC | 0.08 |
| R134A HFC | 0.05 |

*a. HCFCs are ozone depleting substances and HFCs are fluorinated greenhouse gases. Note: The range of substances discharged varies each year depending on which equipment is topped up with refrigerants.*

**Table 34.** Non-radioactive monitoring of air in 2010

| | Mean concentration in air (µg $m^{-3}$) $NO_X$ |
|---|---|
| North Gate | 12 |
| Meteorological Station | 10 |
| Calder Gate | 10 |
| West Ring Road | 15 |
| South Side | 11 |
| Calder Farm[b] | 12 |
| NAQS objective[a] | 40 |

*a. National Air Quality Standard (annual mean)[16].*
*b. Calder Farm sampling ceased on 31/03/2010.*

**Table 35a.** Non-radioactive monitoring of river waters in 2010

| Location | pH | mg per litre $NO_3^-$ |
|---|---|---|
| River Calder - downstream of site | 7.8 | 1.1 |
| River Calder - upstream of site | 7.4 | 0.69 |
| River Ehen - downstream of pipebridge | 8.3 | 1.2 |
| River Ehen - upstream of Factory Sewer outfall | 8.1 | 1.2 |
| EQS[a] | 6.0 - 9.0 | N/A |

*a. National Environmental Quality Standard.*

**Table 35b.** Non-radioactive monitoring of coastal waters in 2010

| Location | milligrammes per litre | | |
|---|---|---|---|
| | $NO_3^-$ as N | $NO_2^-$ as N | Boron |
| Drigg | 0.07 | <0.04 | 4.1 |
| Seascale | 0.21 | <0.04 | 4.1 |
| Sellafield | 0.11 | <0.04 | 3.7 |
| St. Bees | 0.14 | <0.04 | 4.2 |

**Water sampling**

81 Water samples are obtained from the Rivers Calder and Ehen at locations both upstream and downstream of the site (table 35a). The downstream samples are taken above the confluence of the two rivers, and at times which minimise contamination with seawater. As a result of the review of the Monitoring Programme (paragraph 14), seawater samples are now obtained from the shoreline areas given in table 35b rather than from offshore sites as performed up to 2006.

**Monitoring of Sellafield's landfill sites**

82 The Waste Management Licences for the North Landfill Site and Calder Floodplain Landfill Extensions require that environmental monitoring be carried out in the vicinity of the two sites. Although not a requirement of its Waste Management Licence, environmental monitoring is also carried out in the vicinity of the South Landfill Site. The monitoring comprises water sampling from the River Calder and New Mill Beck upstream and downstream of the tips and gas monitoring over their surfaces. The river water is sampled monthly and gas monitoring carried out monthly. The results are summarised in tables 36a and b.

**Environmental impact of non-radioactive discharges**

83 In this report, the impact of aerial discharges has been addressed (table 34) by comparing the measured environmental concentrations with the most stringent (annual mean) national air quality objectives[17] for nitrogen dioxide. The interpretation of these results is not straightforward since discharges are made not only from Sellafield but also from other industrial sites in West Cumbria and from natural sources. The data in table 34 show that the measured concentrations in air on the Sellafield site were all below the guideline value.

84 The results in table 35a and 35b confirm that the liquid discharges from Sellafield are not causing the Environmental Quality Standards (EQS) and Environmental Assessment Levels (EAL)[17] to be exceeded. Continuous concentrations at the EQS or EAL should not produce any significant detriment.

85 Environmental monitoring results (table 36) confirm that the impact of Sellafield's landfill sites remains negligible. No significant concentrations of carbon dioxide or methane have been measured at these sites.

**Table 36a.** Non-radioactive monitoring of surface water and gases on Sellafield's landfill sites in 2010

| Surface water analysis | pH | Temperature (°C) | Conductivity (mS cm$^{-1}$) | Dissolved $O_2$ (ppm) | $NH_3N$ (4g l$^{-1}$) | $Cl^-$ (ppm) | COD (mg l$^{-1}$) | Total suspended solids (mg l$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| North Landfill Site Extension | | | | | | | | |
| Stream to north | 7.5 | 4.0 | 0.32 | 9.8 | 0.02 | 36 | 25 | 53 |
| River Calder upstream | 7.5 | 3.4 | 0.10 | 11 | 0.005 | 10 | 5.4 | 1.9 |
| River Calder downstream | 7.6 | 3.6 | 0.12 | 11 | 0.006 | 12 | 9.7 | 14 |
| Calder Floodplain Landfill Extension | | | | | | | | |
| New Mill Beck upstream | 7.9 | 4.2 | 0.26 | 11 | 0.09 | 30 | 26 | 5.8 |
| River Calder downstream | - | - | - | - | - | - | - | - |
| South Landfill Site | | | | | | | | |
| River Calder upstream | 7.8 | 3.5 | 0.11 | 11 | 0.006 | 12 | 6.0 | 3.3 |
| River Calder downstream | - | - | - | - | - | - | - | - |

**Table 36b.** Non-radioactive monitoring of gases on Sellafield's landfill sites in 2010

| Gas spike probe monitoring | $CH_4$ (ppm) | $CO_2$ (%) | $O_2$ (%) |
|---|---|---|---|
| North Landfill Site Extension | 0.09 | 1.8 | 20 |
| North Landfill Site | 0.06 | 2.5 | 18 |
| Calder Floodplain Landfill | 0.05 | 1.1 | 18 |
| Calder Floodplain Landfill Extension | 0.05 | 1.0 | 20 |
| South Landfill Site | 0.05 | 1.9 | 20 |

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# Capenhurst

## Discharges and Monitoring in the United Kingdom

## Annual Report 2010

## Summary

1 At no time during 2010 have discharges and disposals of radioactive or non radioactive waste through authorised and scheduled outlets at Capenhurst exceeded numerical limits in any of the authorisations. The annual radiation doses to the critical groups from liquid and aerial discharges are shown in table 1. The value continued to be less than 1 μSv and was therefore radiologically insignificant.

**Table 1.** Critical dose

| Pathway | Liquid discharges | | | Aerial discharges | | |
|---|---|---|---|---|---|---|
| | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 |
| Rivacre Brook: child playing | 0.017 | 0.017 | 0.016 | - | - | - |
| Milk consumption: infant | - | - | | N/A* | N/A* | N/A* |

** Off site sampling ceased September 2007.*

## Operations at Capenhurst

2 The Capenhurst Works, situated near Ellesmere Port is operated by two separate companies each holding a Nuclear Site Licence. These are Sellafield Ltd and Urenco UK Ltd. Sellafield Ltd undertakes decommissioning operations related to the redundant gaseous diffusion plant and storage of uranic material (as either oxide powders or fluoride compounds). Urenco UK Ltd own and operate principally enrichment plants. For future reference throughout this chapter, Capenhurst relates to the site run by Sellafield Ltd. Urenco UK Ltd will be referred to as appropriate. The main activities undertaken during 2010 at Capenhurst were the continued decommissioning of the gaseous diffusion plant and associated facilities. Capenhurst continued to provide a uranic storage service to the nuclear industry.

## Radioactive discharges and disposals

3 In April 2010, the Environmental Permitting Regulations Part 2 were issued by the Environment Agency. These regulations replaced the Radioactive Substances Act 1993; therefore, Capenhurst now has an Environmental Permit to cover radioactive discharges relating to solid, aqueous and aerial media. The permit itself will not be issued to replace the current authorisation unless the Environment Agency decide that it would be appropriate or there is a variation which prompts re-issue of documentation.

### Liquid discharges into the Rivacre Brook

4 Liquid wastes principally arise from decommissioning operations. These wastes, together with those from Urenco UK Ltd, are all discharged into the Rivacre Brook by means of a partly culverted ditch.

5 Collectively, the Permit includes quarterly limits for a number of individual radionuclides. Discharges of 'total alpha' activity are subject to daily (24 hour) limits. In order to demonstrate compliance with the terms of the authorisation, samples from each waste stream are analysed daily or prior to discharge (e.g. decommissioning effluent delay tanks) along with daily sampling and analysis of the site outlet.

6 Table 2 presents data on discharges for the past five years and provides a basis for comparison with the authorised limits. Variations in these small discharge levels reflect the various phasing of decommissioning operations.

### Aerial discharges

7 Radioactive effluents are discharged to atmosphere via stacks on the Capenhurst site. These discharges consist principally of incinerator gases and ventilation air from decommissioning operations in the legacy diffusion plant and the hexafluoride bottle washing facility. *Note: The incinerator is not currently operational and is a state of care and maintenance; therefore, no emissions are generated.*

8 The radioactive content of discharges from release points on site consist predominantly of uranium accompanied by an approximately equal beta activity from uranium daughters and lesser activities of Technetium-99. The Permit includes the quantitative limits on airborne radioactive discharges.

9 Discharges of uranium over the past five years are shown in table 3. Variations in these small discharge levels reflect various phasing of decommissioning operations.

### Solid wastes

10 Solid waste disposals at Clifton Marsh are shown in table 4. The waste consists of scrap metal and other non-combustible materials, such as glassware and building rubble. It can also include waste transferred from Urenco UK Ltd under the terms of the inter-site transfer Permit. The alpha radioactivity in the solid waste, due almost entirely to uranium is accompanied by an approximately equal amount of beta activity from uranium daughters. Annual activity limits are part of the Permit.

**Table 2.** Radioactive discharges to the Rivacre Brook (includes UUK transfers)

| Radionuclide | Mean radionuclide concentration | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pre Sep 2007 Limit (GBq)* | 2006 | 2007 | Post Sep 2007 Limit (GBq)* | 2008 | 2009 | 2010 |
| Total alpha (Bq $l^{-1}$) | 100 | <5 | <5 | N/A | <5 | <5 | <3 |
| Tritium (Bq $ml^{-1}$) | 111 | 0.05 | 0.05 | N/A | N/A | N/A | |
| | Annual discharge (GBq) | | | | | | |
| Total uranium alpha activity | 20 | 0.10 | 0.09 | 0.75 | 0.14 | 0.08 | 0.006 |
| Uranium daughters | 20 | 0.18 | 0.07 | 1.36 | 0.01 | 0.01 | 0.006 |
| Non-uranic alpha emitters (mostly neptunium-237) | 3 | 0.02 | 0.03 | 0.22 | 0.02 | 0.02 | 0.02 |
| Technetium-99 | 100 | 0.08 | 0.04 | 1.00 | 0.02 | 0.01 | 0.002 |

** Where authorised limits are specified for periods of three consecutive calendar months, annual equivalents have been derived by multiplying these limits by four.*
*N/A = Not applicable.*

**Table 3.** Airborne radioactive waste discharges

| Radionuclide | Annual discharge | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pre Sep 2007 Limit (GBq) | 2006 | 2007 | Post Sep 2007 Limit (GBq) | 2008 | 2009 | 2010 |
| Uranium | N/A | <0.001 | <0.001 | 0.0025 | <0.001 | <0.001 | <0.001 |

**Table 4.** Disposals of solid waste to Clifton Marsh from Capenhurst

| Radionuclide | Annual discharge | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pre Sep 2007 Limit (GBq) | 2006 | 2007 | Post Sep 2007 Limit (GBq) | 2008 | 2009 | 2010 |
| Bulk weight (tonnes) | N/A | 1055 | 475 | NA | 6080 | 202 | 172.02 |
| Uranium alpha content (GBq) | N/A | 614 | 1.38 | 36 | 31.60 | 35.79 | 20.1 |
| Technetium-99 (GBq) | N/A | 7.9 | 2.99 | 68 | 66.23 | 14.14 | 41.21 |

**Table 5.** Disposals of solid radioactive waste to LLWR from Capenhurst

| Radionuclide | Annual discharge | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pre Sep 2007 Limit (GBq) | 2006 | 2007 | Post Sep 2007 Limit (GBq) | 2008 | 2009 | 2010 |
| Volume (m3) | 6000 | 98 | 0 | 6000 | 208 | 442 | 78 |
| Uranium (GBq) | 250 | 17.6 | 0 | 250 | 3.3 | 20.78 | 2.03 |
| Other alpha emitters (GBq) | 15 | 0.11 | 0 | 50 | 0.5 | 0.93 | 0.13 |
| Others (GBq) | 3000 | 62 | 0 | 4000 | 56.0 | 223.24 | 2.78 |

11 Solid waste which does not conform to the requirements of the Clifton Marsh Condition of Acceptance is disposed of at the LLWR. Solid waste disposals at LLWR are shown in table 5. Generally the Capenhurst waste is consigned to Clifton Marsh in preference to the LLWR.

## Monitoring of the environment for radioactivity

12 During the many years of site operations the principal exposure pathways for radioactivity discharged from the Capenhurst site, as identified by environmental monitoring and habits surveys, have been the ingestion of milk produced at local farms and the external radiation to, and potential inadvertent ingestion of, water and silt by children playing in the Rivacre Brook. These pathways are covered by the site's Statutory Environmental and Monitoring Programme and the Food Standards Agency's monitoring programme[1]. The monitoring of milk and bovine faeces ceased as part of the Statutory Programme in 2007. The low direct radiation dose rates from the site are also routinely monitored.

### Aquatic pathways

13 There is a requirement under the Statutory Environmental Monitoring Programme to analyse samples from the Rivacre Brook of water, silt and the water weed *Cladophora* (table 6). The levels of radioactivity are similar to those in the previous year as they arise from ongoing decommissioning activities on the site. Levels of activity at the plant outlet (Point A), which is within the boundary of the licensed site, are significantly higher than downstream (Point B) due to accumulation of radioactivity in silt. The silt is periodically removed from the outlet and disposed of to a local landfill site or to the LLWR, depending on the radioactive content. Measurements have also been carried out by the regulatory bodies for many years.

### Airborne and terrestrial pathways

14 The discharges to atmosphere are radiologically insignificant. However, Sellafield Ltd collects samples of grass from two on-site locations and analyse them for technetium-99 and uranium on a fresh mass basis. The results for grass were all below the limit of detection

15 The Food Standards Agency undertakes a monitoring programme for uranium in samples of milk. Recent results show that mean uranium concentrations in milk samples collected from a local farm were below the limits of detection (0.0032 Bq $l^{-1}$). Milk samples are not taken by Sellafield Ltd.

### Direct radiation

16 The monitoring programme includes measurements to account for line of sight and shine effects. The site has recently been asked by the regulatory bodies to investigate and understand an apparent increase in neutron does around site. Currently the site is investigating if this effect is due to natural variations in background that affect the method of calculation or if atmosphere effects are influencing the results. No direct link has been established with site operators.

## Radiological impact of operations at Capenhurst

### Critical group doses

Aquatic pathways

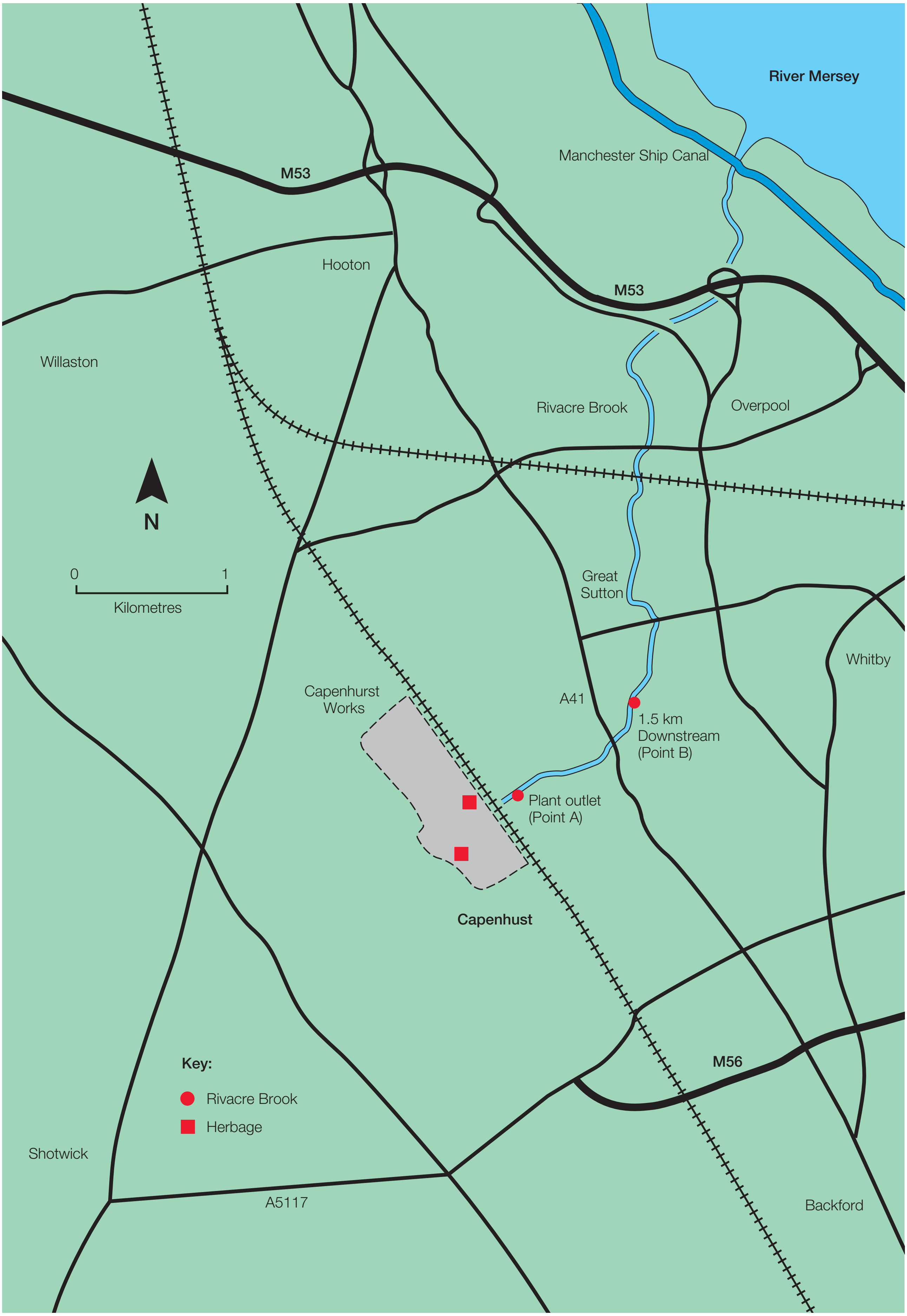
17 The critical group pathway[2] for liquid discharges is considered to be children playing on or near Rivacre Brook. The estimated dose from inadvertent ingestion of water and silt is less than 1 μSv per year from all site discharges (table 1). Potential doses (3 μSv) from external radiation over the banks of the brook could be attributable to variations in natural background dose rates. The number of hours children play on or

**Table 6.** Environmental Sampling

| Location/sample | Number of samples | Mean radionuclide concentration (Bq $kg^{-1}$ wet weight for *Cladophora,* Bq $kg^{-1}$ dry weight for silt) | | |
|---|---|---|---|---|
| | | Uranium | Technetium-99 | Neptunium-237 |
| Point A - Water | 4 | 0.18 | 0.2 | 0.015 |
| Algae | Nil* | Nil | Nil | Nil |
| Silt | 4 | 955 | 1325 | 7.25 |
| Point B - Water | 4 | 0.1 | 0.20 | 0.015 |
| Algae | 2 | 27.5 | 37 | 2 |
| Silt | 4 | 123.5 | 170.25 | 5.0 |

* *No algae present to take sample.*

Figure 1. Environmental monitoring around Capenhurst



near the Rivacre Brook and any potential water and silt ingestion rates are those recommended by the Health Protection Agency[3] for generic use where no habit survey has been carried out[3], and previously used by the Environment Agency. This data is more realistic for the critical group pathway applicable to Capenhurst, than the pessimistic assumptions used by the Food Standards Agency and the Environment Agency.

Airborne and terrestrial pathways

18 The radiotoxicity of uranium is low compared with its chemical toxicity. Based upon the previous sampling regime that included bovine faeces, the uranium concentrations in that material have been historically equivalent to about 0.1% of the concentration estimated to begin to affect the health of cattle and are within the range of concentrations observed naturally. Hence, there are no radiological or toxicological implications for food safety.

19 Sampling of milk consumption for the most exposed member of the public i.e. a one year old infant, ceased in 2007 as values were less than 1 μSv (table 1).

**Direct radiation**

20 Dose rates at the site perimeter and other locations are measured annually[4]. Any increase above the background level of about 0.1 μGy $h^{-1}$ is attributable to direct radiation from the plant rather than waste discharges. Background does rates used to calculate the maximum potential annual effective dose to a member of the public arising from external radiation measures at approximately 0.28 mSv; slightly higher than in 2009 recorded figure (above background) but is still significantly lower than the public dose limit of 1 mSv. The overall uncertainties associated with this measurement are of the order of +/- 100%.

21 Members of the public spend very little time in the immediate vicinity of the perimeter of the combined sites and so radiation levels are of very little significance in terms of public radiation exposure. Detailed HPA studies into the direct radiation exposure to the general public in the vicinity of the site have been carried out on an annual basis[3]. A combination of dose rate measurements and theoretical extrapolation to locations occupied by the public has given a maximum potential dose range of 15 - 160 μSv (based on pessimistic assumptions) for local residences and up to 470 μSv for adjacent industrial premises. An estimated dose of 1mSv has been calculated for locations immediately adjacent to the site perimeter and based upon 100% occupancy over the year. Based upon more realistic assumptions of occupancy actual doses are likely to be much lower.

**Table 7.** Collective Dose

| Discharge route | Collective dose (man Sv) | | |
|---|---|---|---|
| | UK | Europe | World |
| Aerial | 4.94E-05 | 5.77E-05 | 5.77E-05 |
| Liquid | 8.59E-07 | 2.16E-06 | 2.33E-06 |

**Collective doses**

22 Collective doses from discharges from Capenhurst were calculated and are presented in table 7. Until 2000, over 99% of the collective dose arose predominantly from aerial discharges of tritium.

## Non-radioactive discharges and disposals

23 Discharges to the Rivacre Brook are made in accordance with the Water Resources Act consent (also now issued under Environmental Permitting Regulations 2010). There were no non-compliances with discharge limits and conditions. Off-site disposals of solid waste were made in accordance with Duty of Care requirements and the Hazardous Waste Regulations.

**Discharges made under the terms of Prescribed Process authorisations**

24 The incinerator was not operational during 2010 and hence there were no discharges made during the year. However, when operational, an EA Pollution Prevention Control (PPC) authorisation regulates the discharge of gaseous effluents from the incinerator stack. Concentration limits are specified for certain off-gases generated as a result of the high temperature combustion process. When necessary, compliance checking is completed by passing the flue gases through bubbler trains, filters and by direct spectrometry. The resultant solutions and used filters are sampled and analysed by UKAS accredited methods. Radioactive combustible waste which is necessarily generated is currently transferred to Clifton Marsh for disposal.

**Discharges made under terms of consents**

25 Non-radioactive liquid wastes arise principally from decommissioning operations on the Capenhurst site. These wastes, together with those transferred to Capenhurst from the Urenco UK Ltd site, those from neighbouring companies (e.g. Capenhurst Technology Centre, EA Technology, Sutton Nurseries) and certain local domestic properties, are all discharged into the Rivacre Brook by means of the partly culverted culvert used for radioactive effluents.

26 The discharges from Capenhurst are made under the terms of a consent relating to treated sewage effluent and a delay tank. From 2002, compliance with the consent has been checked by regular and periodic sampling at the authorised point of discharge from the on-site Rivacre Brook culvert. Non-radioactive wastes, together with those from neighbouring companies, pass through a sewage plant. Consequently, site discharges are assumed to originate predominantly from the sewage farm and Urenco UK Ltd rather than at the site outlet where non-radioactive results can be affected by events unrelated to Capenhurst or Urenco UK Ltd operations

### Ozone depleting substances

27 Use of ozone depleting substances is limited to those which are necessarily contained within domestic refrigeration units. Wherever practicable, the use of these substances will be phased out as equipment is replaced due to age and through to implementation of environmentally sound substitutes.

### Off-site disposals of solid waste

28 If they cannot be directly recycled, controlled wastes from offices, workshops and other sources are disposed of via specialist waste contractor where 87% of the waste is recycled or reused. The waste disposal contractor operates a rigorous process of segregation of wastes once collected to increase the proportion of material recycled. Furthermore, they utilise a second stage of recycle and reuse that aims to retrieve further recyclable material that has been cross-contaminated with food waste and is this not suitable for the initial sort process. Non-recyclable material from that process is subsequently converted into replacement fuels to maximise the reuse of the material.

29 Hazardous wastes are sent for recycling or to licensed disposal facilities. Hazardous wastes, which are also radioactive, are included in the LLWR disposal figures. The total amounts of non-radioactive wastes disposed of or recycled in 2010 are categorised and summarised in table 8.

**Table 8.** Disposal of Controlled Wastes (non-radioactive)

| Waste type | Quantity (te) |
|---|---|
| Inert | 0 |
| Non-hazardous | 499 |
| Hazardous | 10.6 |

## References


1 Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency (2010). **Radioactivity in food and the environment, 2009. RIFE-15**.

2 Environment Agency (2002); Radioactivity in the Environment. **A summary and radiological assessment of the Environment Agency's monitoring programmes**. Report for 2001.

3 National Radiological Protection Board (2003); **Generalised habit data for radiological assessments**. NRPB-W-41.

4 Health Protection Agency, **Radiation Protection Adviser Visit Report**; November 2010.

# Appendix

## Discharges and Monitoring in the United Kingdom

## Annual Report 2010

## Values for individual dose per unit intake and collective dose per unit discharge

### Individual doses

1 Radionuclides taken into the body, either by ingestion or by inhalation, cause exposure both to the local tissue and to the whole body. For the purposes of dosimetry, monitoring and control, it is the whole-body exposure which is often of prime concern. The actual exposure will depend on many factors, such as the solubility of the radionuclide and its characteristic retention time in the body.

2 The dose coefficients in tables 1 and 2 reflect the most recent advice of the International Commission on Radiological Protection (ICRP)[1]. They represent the committed effective dose (CED) that would be incurred by an individual up to the age of 70 years following the uptake of a unit amount of a radionuclide. Since biokinetic behaviour (and hence dose incurred) may change with age, differing values are presented depending on the age of the individual at the time of intake. The methods and parameter values used for the radiological assessments generally follow the values and relationships given in Annexes II and III to the Council Directive 96/29/Euratom of 13 May 1996.

3 In determining the dose arising from ingestion of material containing radioactivity, it is necessary to consider the fraction of the radioactivity which is likely to be absorbed across the wall of the gastro-intestinal tract. Such absorption is referred to as the gut uptake factor ($f_1$) and varies with the physical and chemical form of the radionuclide and with the metabolism and physiology of the individual. In general, young infants absorb some molecular species more readily than older children or adults and $f_1$ values tend to be correspondingly larger for infants in a number of cases. In general, more soluble elements, such as caesium or tritium, tend to be absorbed more readily than less soluble elements, such as plutonium, across all age ranges.

4 With respect to intakes of radionuclides by ingestion, a number of studies[2,3,4] have established more appropriate gut uptake values for the actinides present in winkles and other molluscs in the Sellafield area, for use in critical group studies. For winkles, these values have been endorsed by the Health Protection Agency[5] and supported by other studies[6]. These values are presented here and are used in this report to estimate doses arising from consuming winkles from the West Cumbrian coast. For seafoods other than winkles close to Sellafield, the Health Protection Agency considers that using a gut transfer factor of 0.0005 for both plutonium and americium will not lead to underestimates of critical group doses[4,7]. These approaches are consistent with the dose assessments performed within RIFE-15[8].

5 Dose per unit intake values for the inhalation of radionuclides are derived from the most recent recommendations of ICRP[1,9]. The dose following intake of radionuclides by inhalation depends upon a number of factors in addition to the radioactive properties of the nuclide(s) involved - in particular, on the particle size of the inhaled material (which influences the extent and distribution of deposition within the respiratory tract) and the rate at which deposited material can be absorbed into body fluids within the respiratory tract, and subsequently enter general systemic circulation. A significant proportion of particulate material deposited in the respiratory tract is cleared directly via the gastro-intestinal tract in swallowed mucus, so the proportion of this swallowed material which is absorbed across the gut wall also influences the dose. Regarding particle size, ICRP recommends the calculation of doses to members of the public assuming an activity median aerodynamic diameter of 1 micron ($10^{-6}$ m) for the inhaled material[9]. For most nuclides, this maximises the resulting dose by maximising deposition in the alveolar region of the respiratory tract.

6 ICRP has derived a standard classification for inhaled material (the 'lung absorption type') based on the rate of absorption of different chemical forms of radionuclides into body fluids. These absorption types are denoted as V, F, M and S with type V being the most rapidly absorbed and type S the slowest. For each absorption type ICRP recommends an appropriate factor (the '$f_1$ value') for the fraction of swallowed material which is absorbed through the gut wall.

7 ICRP has provided calculated values for the committed effective dose to members of the public of different ages, for inhalation of airborne particles with a median diameter of 1 micron, for all the radionuclides of relevance to this report[9]. Several values are generally cited for each radionuclide, reflecting the range of absorption types which may be encountered. However, for most radionuclides, ICRP recommends a default absorption type which may be assumed in the absence of specific information about absorption behaviour; in most cases the dose per unit intake values corresponding to those default absorption types are used in the dose assessments in this report. For some radionuclides, ICRP does not specify a default absorption type and in these instances the absorption type producing the highest value of dose per unit intake is assumed for dose assessments. Finally, for some discharges of uranium

*Continued page 59*

Table 1. Committed effective doses per unit intake for ingestion

| Radionuclide | $f_1$[a] | Dose per unit intake (Sv $Bq^{-1}$) | | | |
|---|---|---|---|---|---|
| | | Foetus | 1y | 10y | Adult |
| H-3 oxide | 1E+00 | 3.1E-11 | 4.8E-11 | 2.3E-11 | 1.8E-11 |
| H-3 organic | 1E+00 | 6.3E-11 | 1.2E-10 | 5.7E-11 | 4.2E-11 |
| C-14 | 1E+00 | 8.0E-10 | 1.6E-09 | 8.0E-10 | 5.8E-10 |
| S-35 organic | 1E+00 | 1.6E-09 | 5.4E-09 | 1.6E-09 | 7.7E-10 |
| Mn-54 | 1E-01 | 7.1E-10 | 3.1E-09 | 1.3E-09 | 7.1E-10 |
| Fe-55 | 1E-01 | 8.1E-11 | 2.4E-09 | 1.1E-09 | 3.3E-10 |
| Co-60 | 1E-01 | 1.9E-09 | 2.7E-08 | 1.1E-08 | 3.4E-09 |
| Zn-65 | 5E-01 | 4.1E-09 | 1.6E-08 | 6.4E-09 | 3.9E-09 |
| Sr-90 | 3E-01 | 4.6E-08 | 9.3E-08 | 6.6E-08 | 3.1E-08 |
| Zr-95 | 1E-02 | 7.6E-10 | 8.8E-09 | 3.0E-09 | 1.5E-09 |
| Nb-95 | 1E-02 | 3.7E-10 | 3.2E-09 | 1.1E-09 | 5.8E-10 |
| Tc-99 | 5E-01 | 4.6E-10 | 4.8E-09 | 1.3E-09 | 6.4E-10 |
| Ru-103 | 5E-02 | 2.7E-10 | 4.6E-09 | 1.5E-09 | 7.3E-10 |
| Ru-106 | 5E-02 | 3.8E-10 | 4.9E-08 | 1.5E-08 | 7.0E-09 |
| Ag-110m | 5E-02 | 2.1E-09 | 1.4E-08 | 5.2E-09 | 2.8E-09 |
| Sb-125 | 1E-01 | 4.7E-10 | 6.1E-09 | 2.1E-09 | 1.1E-09 |
| I-129 | 1E+00 | 4.4E-08 | 2.2E-07 | 1.9E-07 | 1.1E-07 |
| I-131 | 1E+00 | 2.3E-08 | 1.8E-07 | 5.2E-08 | 2.2E-08 |
| Cs-134 | 1E+00 | 8.7E-09 | 1.6E-08 | 1.4E-08 | 1.9E-08 |
| Cs-137 | 1E+00 | 5.7E-09 | 1.2E-08 | 1.0E-08 | 1.3E-08 |
| Ce-144 | 5E-04 | 3.1E-11 | 3.9E-08 | 1.1E-08 | 5.2E-09 |
| Pm-147 | 5E-04 | 2.6E-10 | 1.9E-09 | 5.7E-10 | 2.6E-10 |
| Eu-154 | 5E-04 | 2.0E-09 | 1.2E-08 | 4.1E-09 | 2.0E-09 |
| Eu-155 | 5E-04 | 3.2E-10 | 2.2E-09 | 6.8E-10 | 3.2E-10 |
| Ra-226 | 2E-01 | 3.2E-07 | 9.6E-07 | 8.0E-07 | 2.8E-07 |
| Th-228 | 5E-04 | 2.4E-07 | 1.1E-06 | 4.3E-07 | 1.4E-07 |
| Th-230 | 5E-04 | 8.6E-09 | 4.1E-07 | 2.4E-07 | 2.1E-07 |
| Th-232 | 5E-04 | 9.4E-09 | 4.5E-07 | 2.9E-07 | 2.3E-07 |
| Th-234 | 5E-04 | 1.5E-11 | 2.5E-08 | 7.4E-09 | 3.4E-09 |
| U-234 | 2E-02 | 1.5E-08 | 1.3E-07 | 7.4E-08 | 4.9E-08 |
| U-235 | 2E-02 | 1.4E-08 | 1.3E-07 | 7.1E-08 | 4.7E-08 |
| U-238 | 2E-02 | 1.3E-08 | 1.5E-07 | 7.5E-08 | 4.8E-08 |
| Np-237 | 5E-04 | 3.6E-09 | 2.1E-07 | 1.1E-07 | 1.1E-07 |
| Pu-238 | 5E-04 | 9.0E-09 | 4.0E-07 | 2.4E-07 | 2.3E-07 |
| Pu-239 | 5E-04 | 9.5E-09 | 4.2E-07 | 2.7E-07 | 2.5E-07 |
| Pu-240 | 5E-04 | 9.5E-09 | 4.2E-07 | 2.7E-07 | 2.5E-07 |
| Pu-241 | 5E-04 | 1.1E-10 | 5.7E-09 | 5.1E-09 | 4.8E-09 |
| Am-241 | 5E-04 | 2.7E-09 | 3.7E-07 | 2.2E-07 | 2.0E-07 |
| Cm-242 | 5E-04 | 4.7E-10 | 7.6E-08 | 2.4E-08 | 1.2E-08 |
| Cm-243 | 5E-04 | 1.5E-07 | 3.3E-07 | 1.6E-07 | 1.5E-07 |
| Cm-244 | 5E-04 | 2.2E-09 | 2.9E-07 | 1.4E-07 | 1.2E-07 |
| Plutonium and americium values for application to the consumption of Cumbrian winkles | | | | | |
| Pu-238 | 2E-04 | 3.6E-09 | 1.6E-07 | 9.6E-08 | 9.2E-08 |
| Pu-239 | 2E-04 | 3.8E-09 | 1.7E-07 | 1.1E-07 | 1.0E-07 |
| Pu-240 | 2E-04 | 3.8E-09 | 1.7E-07 | 1.1E-07 | 1.0E-07 |
| Pu-241 | 2E-04 | 4.4E-11 | 2.3E-09 | 2.0E-09 | 1.9E-09 |
| Am-241 | 2E-04 | 1.1E-09 | 1.5E-07 | 8.8E-08 | 8.0E-08 |

*a. The gastro-intestinal absorption fraction does not apply to neonates or infants aged below about one year.*

Table 2. Committed effective doses per unit intake by inhalation

| Radionuclide | Lung absorption type | $f_1$[a] | Dose per unit intake, Sv $Bq^{-1}$ | | | | Basis for choice of lung absorption type |
|---|---|---|---|---|---|---|---|
| | | | Foetus | 1y | 10y | Adult | |
| H-3 oxide | V | 1E+00 | 2.6E-12 | 2.7E-10 | 8.2E-11 | 4.5E-11 | Water vapour |
| H-3 organic | V | 1E+00 | 6.3E-11 | 1.1E-10 | 5.5E-11 | 4.1E-11 | Organically bound tritium |
| C-14 | M | 1E-01 | 6.6E-11 | 6.6E-09 | 2.8E-09 | 2.0E-09 | ICRP recommended default |
| S-35 | M | 1E-01 | 1.5E-11 | 4.5E-09 | 2.0E-09 | 1.4E-09 | ICRP recommended default |
| Mn-54 | M | 1E-01 | 1.5E-09 | 6.2E-09 | 2.4E-09 | 1.5E-09 | ICRP recommended default |
| Co-60 | M | 1E-01 | 1.2E-09 | 3.4E-08 | 1.5E-08 | 1.0E-08 | ICRP recommended default |
| Zn-65 | M | 1E-01 | 7.4E-10 | 6.5E-09 | 2.4E-09 | 1.6E-09 | ICRP recommended default |
| Sr-90 | M | 1E-01 | 1.0E-08 | 1.2E-07 | 5.4E-08 | 3.8E-08 | ICRP recommended default |
| Zr-95 | M | 2E-03 | 4.6E-10 | 2.1E-08 | 9.0E-09 | 6.3E-09 | ICRP recommended default |
| Nb-95 | M | 1E-02 | 1.6E-10 | 5.2E-09 | 2.2E-09 | 1.5E-09 | ICRP recommended default |
| Tc-99 | M | 1E-01 | 8.3E-11 | 1.3E-08 | 5.7E-09 | 4.0E-09 | ICRP recommended default |
| Ru-103 | M | 5E-02 | 1.1E-10 | 8.4E-09 | 3.5E-09 | 2.4E-09 | ICRP recommended default |
| Ru-106 | M | 5E-02 | 4.1E-10 | 1.1E-07 | 4.1E-08 | 2.8E-08 | ICRP recommended default |
| Ag-110m | M | 5E-02 | 1.5E-09 | 2.8E-08 | 1.2E-08 | 7.6E-09 | ICRP recommended default |
| Sb-125 | M | 1E-02 | 2.6E-10 | 1.6E-08 | 6.8E-08 | 4.8E-08 | ICRP recommended default |
| I-129 | F | 1E+00 | 1.5E-08 | 8.6E-08 | 6.7E-08 | 3.6E-08 | ICRP recommended default |
| I-131 | F | 1E+00 | 8.1E-09 | 7.2E-08 | 1.9E-08 | 7.4E-09 | ICRP recommended default |
| Cs-134 | F | 1E+00 | 3.0E-09 | 7.3E-09 | 5.3E-09 | 6.6E-09 | ICRP recommended default |
| Cs-137 | F | 1E+00 | 2.0E-09 | 5.4E-09 | 3.7E-09 | 4.6E-09 | ICRP recommended default |
| Ce-144 | M | 5E-04 | 4.2E-10 | 1.6E-07 | 5.5E-08 | 3.6E-08 | ICRP recommended default |
| Pm-147 | M | 5E-04 | 5.0E-09 | 1.8E-08 | 7.0E-09 | 5.0E-09 | Most restrictive[b] |
| Eu-154 | M | 5E-04 | 5.3E-08 | 1.5E-07 | 6.5E-08 | 5.3E-08 | Most restrictive[b] |
| Eu-155 | M | 5E-04 | 6.9E-09 | 2.3E-08 | 9.2E-09 | 6.9E-09 | Most restrictive[b] |
| Ra-226 | M | 1E-01 | 9.9E-08 | 1.1E-05 | 4.9E-06 | 3.5E-06 | ICRP recommended default |
| Th-228 | S | 5E-04 | 2.5E-07 | 1.4E-04 | 5.9E-05 | 4.3E-05 | ICRP recommended default |
| Th-230 | S | 5E-04 | 2.6E-08 | 3.5E-05 | 1.6E-05 | 1.4E-05 | ICRP recommended default |
| Th-232 | S | 5E-04 | 2.8E-08 | 5.0E-05 | 2.6E-05 | 2.5E-05 | ICRP recommended default |
| U-234 | M | 2E-02 | 4.9E-08 | 1.1E-05 | 4.8E-06 | 3.5E-06 | ICRP recommended default |
| U-235 | M | 2E-02 | 4.5E-08 | 1.0E-05 | 4.3E-06 | 3.1E-06 | ICRP recommended default |
| U-238 | M | 2E-02 | 4.4E-08 | 9.4E-06 | 4.0E-06 | 2.9E-06 | ICRP recommended default |
| Np-237 | M | 5E-04 | 4.3E-07 | 4.0E-05 | 2.2E-05 | 2.3E-05 | ICRP recommended default |
| Pu-238 | M | 5E-04 | 1.1E-06 | 7.4E-05 | 4.4E-05 | 4.6E-05 | ICRP recommended default |
| Pu-239 | M | 5E-04 | 1.2E-06 | 7.7E-05 | 4.8E-05 | 5.0E-05 | ICRP recommended default |
| Pu-240 | M | 5E-04 | 1.2E-06 | 7.7E-05 | 4.8E-05 | 5.0E-05 | ICRP recommended default |
| Pu-241 | M | 5E-04 | 1.4E-08 | 9.7E-07 | 8.3E-07 | 9.0E-07 | ICRP recommended default |
| Am-241 | M | 5E-04 | 3.2E-07 | 6.9E-05 | 4.0E-05 | 4.2E-05 | ICRP recommended default |
| Cm-242 | M | 5E-04 | 5.1E-08 | 1.8E-05 | 7.3E-06 | 5.2E-06 | ICRP recommended default |
| Cm-243 | M | 5E-04 | 3.1E-05 | 6.1E-05 | 3.1E-05 | 3.1E-05 | ICRP recommended default |
| Cm-244 | M | 5E-04 | 2.6E-07 | 5.7E-05 | 2.7E-05 | 2.7E-05 | ICRP recommended default |

*a. The gastro-intestinal absorption fraction does not apply to neonates or infants aged below about one year.*
*b. No default inhalation class recommended - most restrictive value cited by ICRP used.*

to atmosphere from Capenhurst, specific information on chemical composition and lung absorption type is available. In these instances, the dose per unit intake corresponding to the actual lung absorption type is used for dose assessment.

8 Sellafield Ltd have considered the information in ICRP Publication 88[10], which provides dose coefficients for the embryo and foetus after intakes of radionuclides by the mother, but does not advise on dose limitation or dose constraints for the embryo[11]. A report produced by the Health Protection Agency[12] provides guidance on the use of the ICRP dose coefficients and advice regarding the situations for which the assessment of foetal dose is required. In consulting this document, the foetal dose has been calculated by multiplying the adult dose by the ratio of the foetus to adult dose conversion factors[12].

9 Only radionuclides which are known to be present in Sellafield Ltd discharges from Sellafield and Capenhurst and are listed in the discharge authorisations, are included here. In the case of krypton-85, which is present in aerial discharges, no dose per unit intake value is presented since exposure for this nuclide is determined by external rather than internal dosimetry.

## Collective doses

10 The collective committed effective dose estimates resulting from discharges from Sellafield have been calculated using the 2008 upgrade of the Health Protection Agency model PC CREAM[13], which is based on a methodology for assessing the radiological consequences of routine releases to the environment published by the European Commission[14].

11 Generally, the PC CREAM default dose per unit intake values have been applied. Where required, the pulmonary retention classes for nuclides have been modified on a site-specific basis. For example, -site-specific ratios of the chemical forms of uranium in aerial discharges from the Capenhurst site have been used to identify the most appropriate pulmonary retention half times. The dose per unit discharge factors have been derived accordingly.

12 The collective effective dose has units of man Sieverts (man Sv) and can be defined as the sum of all the exposures from a given source to a defined group of people.

**Table 3. Collective dose commitment from Sellafield Ltd sites (man Sv per Bq discharged, integrated to 500 years): atmospheric discharges**

| Radionuclide | Sellafield | | | Capenhurst[b] | | |
|---|---|---|---|---|---|---|
| | UK | EU[a] | World | UK | EU[a] | World |
| H-3 | 6.7E-16 | 1.2E-15 | 1.5E-15 | 2.4E-15 | 3.7E-15 | 4.0E-15 |
| C-14 | 2.0E-13 | 1.0E-12 | 1.3E-11 | | | |
| Kr-85 | 4.3E-18 | 1.5E-17 | 2.6E-16 | | | |
| Sr-90 | 1.9E-12 | 8.8E-12 | 8.8E-12 | | | |
| Ru-106 | 3.1E-13 | 4.2E-13 | 4.2E-13 | | | |
| Sb-125 | 1.2E-13 | 1.7E-13 | 1.7E-13 | | | |
| I-129 | 4.5E-11 | 2.1E-10 | 2.9E-10 | | | |
| I-131 | 7.8E-13 | 4.8E-13 | 4.8E-13 | | | |
| Cs-137 | 1.8E-12 | 6.1E-12 | 6.1E-12 | | | |
| U-234 | | | | 1.3E-10 | 1.5E-10 | 1.5E-10 |
| U-235 | | | | 1.2E-10 | 1.4E-10 | 1.4E-10 |
| U-238 | | | | 1.1E-10 | 1.3E-10 | 1.3E-10 |
| Pu-239 / Pu-240 | 1.7E-10 | 2.4E-10 | 2.4E-10 | | | |
| Pu-241 | 3.0E-12 | 4.4E-12 | 4.4E-12 | | | |
| Am-241 | 1.4E-10 | 2.0E-10 | 2.0E-10 | | | |

*a. EU is defined as the population of the member states of the European Union, including the UK.*
*b. Data reflect actual chemical compounds discharged by Capenhurst.*

13 For this report, the collective committed dose follows the current Health Protection Agency advice[15,16] of a 500 year integration period and the doses are calculated to the populations of the UK, Europe and the world. Europe is defined as the population of the member states of the European Union, including the UK. The EU population chosen is for 12 countries to allow a consistent presentation between the aerial and marine model results.

14 The values presented in tables 3 and 4 for Sellafield and Capenhurst are site specific and are given as man Sieverts per Becquerel discharged. Only radionuclides which are known to be present in Sellafield Ltd discharges from Sellafield and Capenhurst and are listed in the discharge authorisations, are included here.

**Table 4. Collective dose commitment from Sellafield Ltd sites (man Sv per Bq discharged, integrated to 500 years): liquid discharges[a]**

| Radionuclide | Sellafield | | | Capenhurst | | |
|---|---|---|---|---|---|---|
| | UK | EU[b] | World | UK | EU[b] | World |
| H-3 | 4.6E-19 | 1.9E-18 | 3.5E-17 | 5.2E-19 | 2.2E-18 | 4.4E-17 |
| C-14 | 2.0E-13 | 6.6E-13 | 6.8E-12 | | | |
| Co-60 | 6.7E-14 | 1.9E-13 | 2.4E-13 | | | |
| Sr-90 | 7.0E-16 | 1.8E-15 | 3.0E-15 | | | |
| Zr-95 | 7.3E-17 | 1.5E-16 | 1.6E-16 | | | |
| Nb-95 | 1.7E-17 | 3.5E-17 | 3.8E-17 | | | |
| Tc-99 | 2.5E-15 | 7.6E-15 | 9.5E-15 | 2.5E-15 | 6.1E-15 | 6.5E-15 |
| Ru-106 | 1.9E-14 | 5.1E-14 | 5.6E-14 | | | |
| I-129 | 1.9E-14 | 5.7E-14 | 2.2E-13 | | | |
| Cs-134 | 1.3E-14 | 3.0E-14 | 4.6E-14 | | | |
| Cs-137 | 1.6E-14 | 4.1E-14 | 7.1E-14 | | | |
| Ce-144 | 6.9E-17 | 1.8E-16 | 2.0E-16 | | | |
| Th-230 | | | | 6.6E-15 | 1.5E-14 | 1.6E-14 |
| Th-234 | | | | 1.6E-16 | 1.9E-16 | 1.9E-16 |
| U-234 | | | | 3.5E-15 | 9.2E-15 | 1.0E-14 |
| U-235 | | | | 3.6E-15 | 9.0E-15 | 9.9E-15 |
| U-238 | | | | 3.2E-15 | 8.3E-15 | 8.9E-15 |
| Np-237 | | | | 6.5E-14 | 1.6E-13 | 1.7E-13 |
| Pu-239, Pu-240 | 3.0E-13 | 8.4E-13 | 9.8E-13 | | | |
| Pu-241 | 2.5E-14 | 7.1E-14 | 7.9E-14 | | | |
| Am-241 | 1.3E-12 | 3.6E-12 | 3.9E-12 | | | |
| Cm-242 | 2.3E-15 | 6.1E-15 | 6.8E-15 | | | |
| Cm-243, Cm-244 | 4.3E-14 | 1.1E-13 | 1.2E-13 | | | |

*a. The collective dose factors include the contribution from the first decay product where appropriate.*
*b. EU is defined as the population of the member states of the European Union, including the UK.*

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# Glossary

## Discharges and Monitoring in the United Kingdom

## Annual Report 2010

## Glossary of terms and abbreviations

**Absorbed radiation dose** Quantity of energy imparted by ionising radiation to unit mass of matter such as tissue. The unit is the Gray (Gy). 1 Gy = 1 joule per kilogram.

**Activation products** Radionuclides produced by the interaction of neutrons with stable nuclides.

**Activity** See ***radioactivity***.

**Alpha activity** Radionuclides that decay by emitting an alpha particle. The latter consists of two protons and two neutrons.

**ALARA (As Low as Reasonably Achievable)** Radiation doses from a source of exposure are ALARA when they are consistent with the relevant dose or target standard and have been reduced to a level that represents a balance between radiological and other factors, including social and economic factors. The level of protection may then be said to be optimised.

**Authorisation** Permission given by regulatory authority under the ***Radioactive Substances Act*** or ***Environmental Protection Act*** to dispose of respectively radioactive and non-radioactive waste, subject to conditions.

**Basic Safety Standards Directive (BSS)** European Community Directive 80/836/Euratom, Basic Safety Standards for the Health Protection of the General public and Workers against the Dangers of Ionising Radiation. These standards were adopted as European Law in 1980. A revised Directive 96/29/Euratom was adopted in May 1996 for implementation in Member States by May 2000. The Radioactive Substances (Basic Safety Standards) Direction 2000 is the means by which the BSS Directive has been implemented in England and Wales, and in Scotland, with respect to the ***Radioactive Substances Act 1993***. Other provisions of the BSS Directive were implemented through the ***Ionising Radiation Regulations 1999.***

**Becquerel** The SI unit of ***radioactivity*** equal to one transformation per second.

**BAT (Best Available Technique)** ***"Best"*** – means the most effective techniques for achieving a high level of protection of the environment as a whole. ***"Available"*** – means techniques developed on a scale which allows them to be used in the relevant industrial sector, under economically and technically viable conditions, taking into account of the costs and advantages. ***"Techniques"*** – includes both the technology and the way the installation is designed, built, maintained, operated and decommissioned. Application of BAT is central to PPC compliance and guidance on what constitutes BAT is provided by the EA.

**BATNEEC (Best Available Technique Not Entailing Excessive Costs)** The best available technique (BAT) is the most effective process in preventing, minimising or rendering harmless polluting emissions taking into account availability and whether the costs are not out of proportion to the benefit. (see ***IPC***.)

**BPEO (Best Practicable Environmental Option)** A concept developed by the Royal commission on Environmental Pollution. It implies that decisions on waste management have been based on an assessment of alternative options evaluated on the basis of factors such as the occupational and environmental impacts, the costs and social implications. ( See ***IPC***.)

**BPM (Best Practicable Means)** Within a particular waste management option, the BPM is that level of management and engineering control that minimises as far as practicable, the release of radioactivity to the environment whilst taking account of a wider range of factors including cost-effectiveness, technological status, operational safety, and social and environmental factors.

**Beta activity** Radionuclides that decay by emitting a beta particle (an electron with high energy).

**CEFAS** The Centre for Environment, Fisheries and Aquaculture Science is a scientific research and advisory centre for fisheries management and environmental protection. It is an Agency of the UK Government's ***Department for Environment, Food and Rural Affairs (defra)***. It was formed in 1997 from the Fisheries Research Laboratory of MAFF and its Lowestoft laboratory carries out habit surveys and monitoring of radioactivity in the environment on behalf of the ***Food Standards Agency***.

**Collective dose** See ***dose***.

**Committed effective dose** See ***dose***.

**Consent** Discharges to controlled waters of sewage or trade effluent, from processes not subject to Environmental Protection Act authorisations, are regulated through consents under the Water Resources Act (1991) or the Water Industries Act 1991 (in England and Wales) and Control of Pollution Act 1974 or Sewerage Scotland Act 1968 (in Scotland).

**Critical group** A group of members of the public whose radiation exposure is reasonably homogeneous and is typical of the people receiving the highest dose from a radiation source. The critical group dose is calculated as the mean effective dose to members of the group.

**Defra (Department for Environment, Food and Rural Affairs)** Formed in 2001 from ***MAFF*** and the environmental section of the Department of Environment, Transport and the Regions (DETR). It is the sponsoring department for the EA, and is responsible inter alia for environmental policy in England, including that for the management and disposal of radioactive wastes.

**Direct radiation** Term used to refer to radiation direct from a nuclear site as distinct from the radiation emitted from discharged radioactive wastes.

**Dose** A measure of radiation received, which may be quantified in several different ways. The dose quantities most commonly referred to are defined below. In this document it is used primarily to mean the 'effective dose' received by members of critical groups.

**Absorbed dose** The mean energy imparted by ionising radiation to matter in a given volume divided by the mass of the matter. Normally used in the context of the dose averaged over an organ or tissue. The unit is the Gray (Gy) (see inside front cover).

**Equivalent dose** The ***absorbed dose*** in a tissue or organ weighted by the radiation weighting factor (e.g. alpha particles = 20, beta particles = 1, gamma rays = 1) which allows for the different effectiveness of various types of ionising radiations in causing harm to tissues. The unit is the Sievert (Sv) (see inside front cover).

**Effective dose** The sum of the ***equivalent doses*** in all tissues and organs of the body from internal and external radiation multiplied by the tissue weighting factor (e.g. skin = 0.01, thyroid = 0.05, red bone marrow = 0.12, gonads = 0.20). It allows the various equivalent doses in the body to be represented by a single number giving a broad indication of the detriment to the health of an individual from exposure to ionising radiation, regardless of the energy and type of radiation. For comparison with dose limits, the term takes on a specific meaning (see below).

**Committed effective dose** The time integral of the ***effective dose*** from ingested and inhaled radioactivity delivered over 50 years (adults, who are cautiously assumed to be 20 years old at the time of intake) or to age 70 years (children). For a particular radionuclide it is a function of the distribution within, and clearance from, the body and also the radioactive ***half-life***. For radionuclides which are cleared quickly from the body (e.g. caesium-137) or which have a short ***half-life*** (e.g. sulphur-35), most of the committed effective dose is delivered in the year in which the intake of activity took place. (e.g.caesium-137), most of the committed effective dose is delivered in the year in which the intake of ***activity*** took place. For others, such as plutonium, the committed dose is delivered over the remaining lifetime of the individual and so the dose in the year of intake is much lower than the committed dose.

**Effective dose (definition used for calculation of critical group doses and for comparison with dose limits)** The overall annual effective dose is the sum of ***committed effective doses*** from intakes of radionuclides in a given year and the effective dose from external irradiation in that year. It is this quantity that should be compared with the annual limit on effective dose ***(dose limit)***.

**Collective dose** The summation of individual effective doses received by the population of a defined geographical area over a defined period of time. A 500 year integration period is used in this report (see paragraph 29 of the Introduction). The unit is the man sievert (man Sv).

**Dose constraint** A restriction on annual dose to an individual from a single source, applied at the design and planning stage of any activity in order to ensure that when aggregated with doses from all sources, excluding natural background and medical procedures, the dose limit is not exceeded.

**Dose limit** For the purpose of discharge authorisations, the UK has (since 1986) applied a dose limit of 1 mSv (1000 μSv) per annum to members of the public from all man-made sources of radiation (other than medical exposure). This limit is now incorporated into UK law (see ***Basic Safety Standards Directive***).

**EA (Environment Agency)** The leading public body for protecting and improving the environment in England and Wales. (see ***defra***).

**Effective dose** See ***dose***.

**Environment Act 1995** The legislation giving the EA its powers, aims and objectives.

**Environmental Permitting (England and Wales) Regulations (2010)** The Environmental Permitting (England and Wales) Regulations 2010 extend the permitting regime introduced in 2008 (which provided a unified system for permitting waste operations, mining waste operations, mobile plant and installations) to include water discharge consents, groundwater permits and radioactive substances regulations. The new Regulations also introduce the new waste exemptions regime which was consulted upon in 2008 and 2009.

**Environmental Protection Act 1990** See ***IPC***.

**Equivalent dose** See ***dose***.

**Fission products** Nuclear fission is the splitting of a heavy atomic nucleus such as uranium into (usually) two nuclei, either spontaneously or under the impact of another particle, with resulting increase of energy. The two nuclei are called fission products.

**Fluorinated Greenhouse Gases** Fluorinated greenhouse gases are powerful greenhouse gases that trap heat in the atmosphere and contribute to global warming. The most commonly used fluorinated greenhouse gases belong to a class of chemicals known as hydrofluorocarbons (HFCs) and are being used to replace ozone depleting substances, in, for example, refrigeration and air conditioning equipment.

**Food Standards Agency** Formed in April 2000 from parts of ***MAFF*** and the Department of Health. It is responsible for food safety issues in the UK. Although it is a Government agency it does not report to a specific minister and is free to publish any advice it issues. It is accountable to Parliament through Health Ministers, and to the devolved administrations in Scotland, Wales and Northern Ireland for its activities within their areas.

**Gray** The SI unit of absorbed ***dose***.

**Half-life (radioactive)** The time taken for the radioactivity of a radionuclide to decrease to one half of its initial value by radioactive decay. Half-lives range from fractions of a second to millions of years.

**Half-life (biological)** The effective half-life in the human body of a quantity of ingested radioactivity is a function of the radioactive half-life and biokinetic behaviour.

**High Level Waste (HLW)** Waste that is sufficiently radioactive that the generation of heat needs to be taken into account in the design of disposal or storage facilities.

**HPA (Health Protection Agency)** A non-departmental public body established in 2003 to provide an integrated approach to protecting UK public health through the provision of support and advice to the NHS, local authorities, emergency services, the Department of Health and the devolved administrations in Scotland, Wales and Northern Ireland. Merged with the NRPB on 1 April 2005 to form the HPA Radiation Protection Division.

**Intermediate Level Waste (ILW)** Waste with radioactivity levels exceeding the upper boundaries for low level waste but which does not require heat generation by the waste to be accounted for in the design of disposal or storage facilities.

**ICRP** International Commission on radiological Protection. An independent group of experts founded in 1928 which provides guidance on principles and criteria in the field of radiological protection. The recommendations are not legally binding but are accepted as the basis for national legislation in most countries including the UK.

**IPC (Integrated pollution Control)** A statutory means of controlling industrial pollution set up under the ***EPA 1990***. Thus, discharges from 'Prescribed Processes' are controlled by IPC authorisations (issued by the ***EA*** and ***SEPA***) or by air pollution control authorisations issued by local authorities. These ensure compliance with quality objectives and standards by specifying discharge limits (i.e. to air and water) and other conditions. There is also a 'residual duty' in these authorisations that ***BATNEEC*** is used to prevent or minimise releases of the most polluting substances and render them harmless. Where releases of a substance may affect more than one environmental medium, the authorisation must have regard to the ***BPEO***. See ***IPPC***.

**IPPC (Integrated Pollution Prevention and Control)** In October 2007 Prescribed Process (***IPC***) authorisations were replaced by permits issued under the Pollution Prevention and Control Regulations 2000 (PPC). These regulations implement the requirements of the EC Directive on IPPC.

**Ionising Radiation Regulations 1999 (IRRs 1999)** These regulations under the Health and safety at Work Act 1974 in part implement the European ***Basic Safety Standards Directive*** of 1996.

**ISTA** Informal abbreviation for 'inter-site transfer authorisation' (Radioactive Substances Act).

**Low level waste (LLW)** Waste containing levels of radioactivity greater than those acceptable for dustbin disposal but not exceeding 4 GBq per tonne of alpha-emitting radionuclides or 12 GBq per tonne of beta-emitting radionuclides.

**LLWR** Low Level Waste Repository.

**MAFF (Ministry of Agriculture, Fisheries and Food)** Superseded by ***Defra***. MAFF's statutory responsibilities for food safety issues in the UK have been passed to the ***Food Standards Agency***.

**Magnox** A magnesium/aluminium alloy that is used in the manufacture of the canister for uranium fuel metal ('Magnox fuel') used in a type of nuclear reactor ('Magnox reactor').

**Multi-media Authorisation (MMA)** Authorisation issued by the Environment Agency under the Radioactive Substances Act 1993 of a 'multi-media' or integrated type covering radioactive waste disposals to land, sea and air.

**National Dose Assessment Working Group (NDAWG)** Publishes guidance on the assessment of public dose from past, present and future discharges and direct radiation from the nuclear industry and minor users of radioactivity. Membership comprises UK Government agency, nuclear industry and independent experts.

**NDA (Nuclear Decommissioning Authority)** the public body set up in 2005, tasked by Her Majesty's Government with taking strategic responsibility for the decommissioning of civil public sector nuclear sites in the UK. The NDA owns the 20 nuclear legacy sites in the UK including the operating and decommissioning plants at Sellafield in West Cumbria. The NDA does not carry out the operations or clean-up work itself but places contracts with ***Site Licensee Companies***, who are responsible for operations on site.

**NRPB (National Radiological Protection Board)** Merged with the ***Health Protection Agency*** on 1 April 2005 forming its new Radiation Protection Division. An independent statutory body set up by the Radiological Protection Act 1970 to advance the acquisition of knowledge about the protection of mankind from radiation hazards and to provide information and advice on matters relating to radiological protection and radiation hazards including the interpretation of ***ICRP*** recommendations.

**Notice of Variation** The means by which the conditions or limitations of an Authorisation are changed.

**ONR (Office for Nuclear Regulation)** Part of the Health and Safety Executive. It is responsible for enforcing legislation relating to nuclear safety under the Nuclear installations Act 1965.

**OSPAR Convention** The Oslo Paris Convention, where contracting parties (including the UK) agreed to take all possible steps to prevent and eliminate pollution, and to take all necessary measures to protect the maritime area against the adverse effects of human activities, so as to safeguard human health and to conserve marine ecosystems and, where practicable, restore marine areas which have been adversely affected. See ***Sintra Agreement***.

**Ozone Depleting Substances (ODS)** Substances that, if allowed to escape, damage the ozone layer in the upper atmosphere. Ozone depleting substances include chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Many ODS are banned or being phased out by fluorinated greenhouse gases.

**PPC** Pollution Prevention and Control Regulations 2000 (see also ***IPPC***)

**Quarterly Notification Level (QNL)** Quarterly discharge or disposal levels that the ***EA*** may specify in ***RSA*** authorisations They enable the application of ***BPM*** to be monitored by the EA. Exceeding a QNL requires the operator to submit a written justification of the BPM used to limit discharges.

**Radioactive Substances Act (RSA) 1960, 1993** Statutory legislation to control the keeping and use of radioactive substances and the accumulation discharge or disposal of ***radioactive waste***.

**Radioactive waste** Material that contains radioactivity above the appropriate levels specified in the ***Radioactive Substances Act 1993*** and which meets the definition of waste given in the Act.

**Radioactivity** The spontaneous disintegration of atomic nuclei. Radioactive substances or the radiation they emit (e.g. ***alpha*** particles, ***beta*** particles, gamma rays); the rate of radioactive decay. Measured in the standard international (SI) unit, ***Becquerels*** (Bq) or their multiples or sub-multiples (see inside front cover).

**Radionuclide** A radioactive isotope of an element.

**SEPA** Scottish Environment Protection Agency.

**Sievert** The SI unit of ***equivalent dose and effective dose***.

**Sintra Agreement** An agreement made at a ministerial meeting of the ***Ospar*** Commission in Sintra, Portugal, 22-23 July 1998. The ultimate aim is to achieve concentrations of radioactivity in the environment that are near background levels for naturally occurring radioactive substances and close to zero for artificial radioactive substances.

**Site Licence Company** An organisation that holds the nuclear licence for a particular site and is responsible for the maintenance and operation of the site.

**Thorp (Thermal Oxide Reprocessing Plant)** A plant at Sellafield where oxide fuels from Advanced Gas Cooled Reactors and Light Water Reactors have been reprocessed since 1995.

**UKAEA** United Kingdom Atomic Energy Authority.

Sellafield Ltd

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