Sellafield Ltd

Monitoring Our Environment

Discharges and Monitoring in the United Kingdom

Annual Report 2007

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

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Sellafield Ltd

1. Sellafield Ltd is a specialist site management and nuclear clean-up business, employing around 14,000 people, and is part of the BNFL Group. The strategy and focus of Sellafield Ltd is to deliver accelerated nuclear clean-up programmes, safely and cost-effectively for customers in the UK and overseas. Sellafield Ltd products and services range from fuel manufacture, electricity generation and reprocessing of spent fuel, through to the decommissioning and clean-up of redundant nuclear facilities and the disposal of solid low-level radioactive waste.

2 Sellafield Ltd (established in April 2007) was previously operating as British Nuclear Group Sellafield Ltd as a consequence of restructuring of its parent company BNFL and in response to the formation of the Nuclear Decommissioning Authority (NDA), a new public body tasked by Her Majesty's Government with taking strategic responsibility for the decommissioning of civil public sector nuclear sites in the UK. 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 2007 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 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 Radioactive Substances Act (RSA) authorisations (see paragraph 14); 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-compliances with numerical limits are 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 (see paragraphs 10 and 12), even more so for a five-year period. 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 Environmental measurements required under the terms of non-radioactive consents and authorisations are reported, together with site- specific Environmental Quality Standard (EQS) information where available.

8 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

9 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 12), 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).

10 Regulation of non-radiological discharges changed regimes during 2007, moving from Integrated Pollution Control (IPC) authorisations to a Pollution Prevention and Control (PPC) permit. Both regimes included discharge limits (aerial and liquid) and conditions aimed at protecting the environment. The IPC authorisations were issued under EPA 1990 and were regulated by the Environment Agency. Air pollution control authorisations were also issued under EPA 1990 and were regulated by the local authority. The IPC authorisation required the application of Best Available Techniques Not Entailing Excessive Costs (BATNEEC) to prevent or minimise releases of the most polluting substances and render them harmless.

11 The PPC permit was issued under the PPC Regulations 2000, which implement the requirements of the EC Integrated Pollution Prevention and Control Directive (IPPC). PPC extends the IPC regime to cover new areas such as energy, water, raw material usage and noise. Central to compliance with the permit is the application of Best Available Techniques (BAT) which aims to balance the costs to the operator with the benefit to the environment.

12 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 and the Control of

Pollution Act in Scotland. 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 and the Sewerage Scotland Act 1968. 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 on instantaneous concentrations.

13 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/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

14 The control of radioactive wastes is subject to the provisions of RSA 1993. Under this Act, 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.

15 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 25-28) and collective doses (paragraphs 29-32). They were incorporated into UK law in the Radioactive Substances (Basic Safety Standards) Direction 2000 issued by the appropriate ministers to the Environment Agency to implement those parts of the Euratom Basic Safety Standards Directive (BSS) 1996 relating to dose limits (paragraph 28). Other provisions of the BSS Directive were implemented through the Ionising Radiation Regulations 1999.

16 All discharges of radioactivity are subject to the requirement to use best practicable means (BPM) to limit the amount of radioactivity discharged. To enable the Environment Agency to monitor the application of best practicable means, 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.

17 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 aquatic 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 Nuclear Installations Inspectorate (NII) 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.

18 The nuclear regulators employed by the Environment Agency regularly pay inspection visits to nuclear sites to critically review operations against radiological protection criteria. Thus the authorisation process is one of continual review (see also paragraph 15). 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 radiological methodologies, to ensure that radiological impacts are assessed with the most up-to-date information.

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

- controlling, monitoring and recording discharges to the environment;
- 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.

20 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 NII requires the assessment of doses to members of the public from direct radiation.

21 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

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.

reduced to levels at which the resulting concentrations additional to historic levels are close to zero. Following defra's (see Glossary) publication in July 2002 of the UK Strategy for Radioactive Discharges 2001-2020', 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

22 A key concept for assessment of dose to the public is the 'critical group'. This represents those members of the public who are most exposed to radiation due to operations at a given site[2,3]. 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 37). These sums are for convenience termed 'effective doses' (see Glossary). Committed 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[4,5]. From this, it follows that the mean dose to the critical group provides a stringent assessment of radiation dose against limits or constraints.

23 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)[3] defines only the most exposed group at any given time as the critical group.

24 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

25 The current position on dose limits and constraints, which are applicable to controlled releases of radioactivity, is based on the '1990 Recommendations' of the International Commission on Radiological Protection (ICRP)[2] 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 22 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.

26 The '1990 Recommendations' also placed emphasis on the optimisation of radiation protection (see paragraph 32) 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.

27 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[3]. 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.

28 The 1000 μSv dose limit was incorporated into the Euratom Basic Standards Directive 1996 and implemented in UK law through Direction 2000 (paragraph 15). 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 external exposure and internal exposure from intakes of radionuclides.

Collective doses

29 In addition to estimating doses to critical groups, doses to populations as a whole can be estimated[6]. 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.

30 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.

31 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[7] 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.

32 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[3] 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

33 The structure of the Statutory Environmental Monitoring Programmes (paragraph 20) 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.

34 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.

35 Data identifying critical groups and their habits by pathway have been provided by the Food Standards Agency, Environment Agency, SEPA and the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), or their predecessors, based on published survey work[8,9,10]. 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[11]. Where appropriate, such generalised advice may be supplemented by other Health Protection Agency advice[12], or by information from local habits surveys.

36 In assessing doses, the Company takes account of research studies carried out both nationally and internationally, and also sponsors extensive programmes of 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, its predecessor NRPB[3] and the most recent dose coefficients in ICRP Publication 72[13] 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[2,14]. 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.

37 In accordance with regulatory guidance[15], radiation dose rates in air ('air kerma') are generally measured in primary units of $\mu Gy\ h^{-1}$, the absorbed dose rate. In order to express this as a dose rate equivalent, $\mu Sv\ h^{-1}$, a conversion factor of 0.86 μSv per μGy is appropriate in most cases[15]. 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 $\mu Sv\ h^{-1}$ and making allowance for background dose rates [8,9,16,17], a direct estimate of the dose to man can be obtained.

38 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 [8,9,18-21].

39 Collective doses have been calculated, using a 500 year integration period (paragraph 31), based on the most recent EU methodology[22-24]. 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[8]. A summary of collective dose per unit release factors is included in the Appendix.

Analytical measurements, limits of detection and rounding of data

40 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.

41 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 consistently below the level at which it is practicable to make positive determinations. 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 concentrations derived using environmental models.

42 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.

43 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.

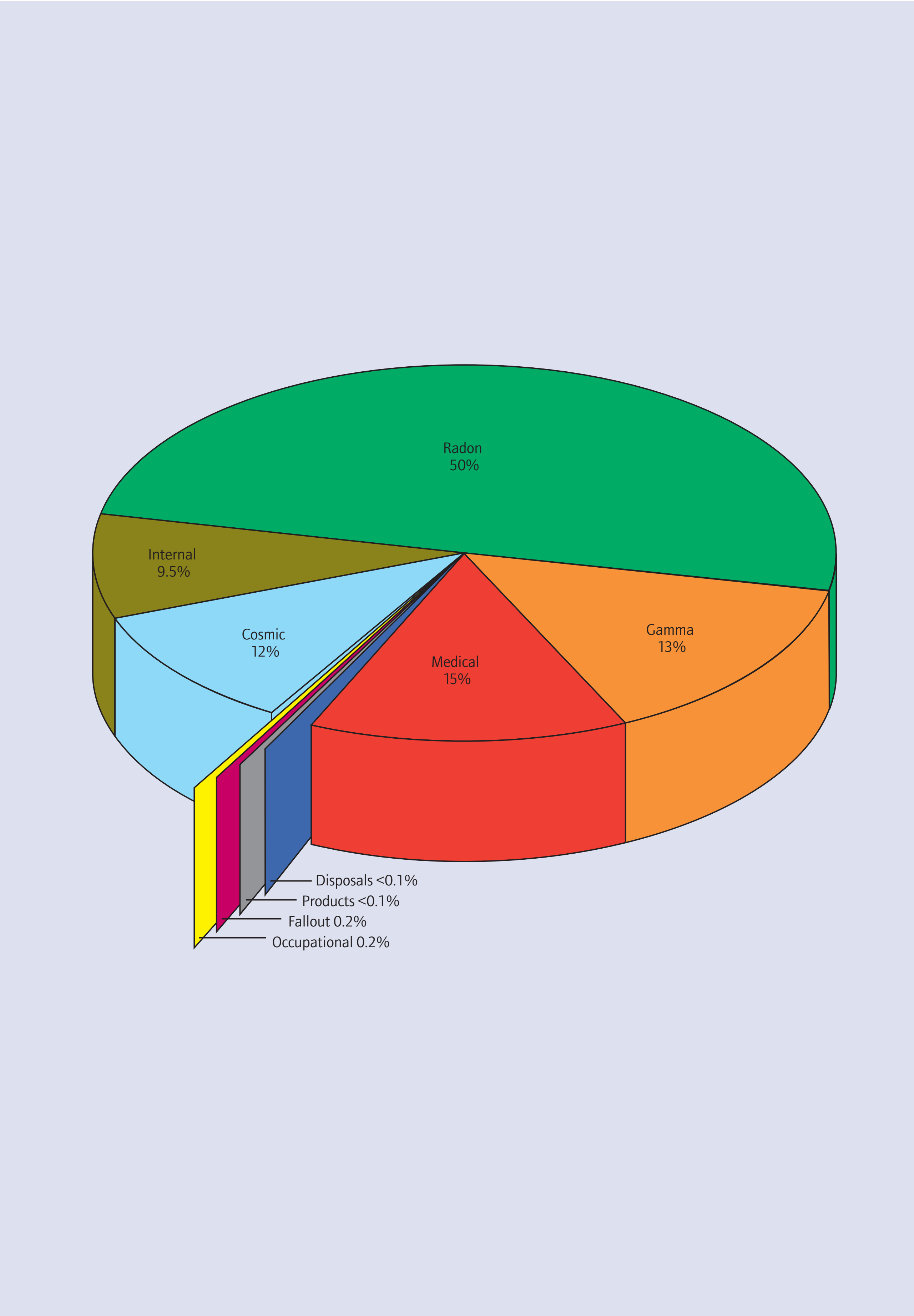
Protection of the environment

44 In its 1990 Recommendations[2], 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[25,26,27] and, on the basis of work to date, there is no reason to believe that radioactive discharges from Sellafield Ltd are harming the environment.

Natural radioactivity

45 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 Chernobyl make small contributions to overall doses. The subject has been reviewed comprehensively by the Health Protection Agency[16,17] and others[28].

Figure 1. Sources of annual average radiation dose to the UK population[16]



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46 Individual doses from natural radioactivity in the UK range broadly from 1000 μSv to 100,000 μSv per year[16]. 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 15, 28, 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 solid short-lived decay products of the gas[16].

47 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.

48 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[16]. In areas of higher natural background radiation (e.g. Cornwall), the average dose may exceed 7000 μSv per year[17].

Acknowledgements

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The Capenhurst chapter was written by Ray Atherton of the QEH&S Department at Capenhurst. URENCO (Capenhurst) collected the environmental samples and measured environmental dose rates. External laboratories and URENCO (Capenhurst) analysed the samples.

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

Table 2. Summary of doses to the UK population from natural sources[16]

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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Summary

1 There were no instances in 2007 of non-compliance with numerical limits in authorisations regulating discharges and disposals of radioactive wastes at Sellafield.

2 Radioactive discharges were generally lower than 2006, reflecting reprocessing throughputs (paragraphs 11 and 20-22).

3 The estimated dose in 2007 due to discharges to sea from Sellafield to members of the critical group who consume fish and shellfish from the local area was about 150 µSv. Taking into account doses due to beach occupancy and aerial pathways, the total dose to this group was about 187 µSv. Doses due to direct radiation from plant on site were estimated as being up to 1.3 µSv to the most exposed members of the public who live nearby, who may, in addition, have received up to 25 µSv from aerial discharge pathways. These doses are summarised in table 1.

4 There were no instances in 2007 of non-compliance with numerical limits in IPC and PPC authorisations.

Operations at Sellafield

5 Sellafield is one of the most complex and compact nuclear sites; activities are centred around remediation, decommissioning and clean up of the historic legacy. The site is also home to the Thorp and Magnox reprocessing plants, the Sellafield MOX plant and a wide range of waste management and effluent treatment facilities.

6 During reprocessing operations, some effluents containing a small fraction of the radioactivity originally present in the used fuel are discharged to sea and atmosphere, or disposed of as solid wastes to the Low Level Waste Repository (LLWR). Discharges of radioactivity to sea have declined significantly since the 1970s (figure 1a) as a result of the considerable investments and improvements in effluent treatment plants that have been described in previous reports.

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 (WVP) which converts both historic 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 and is now fully operational, treats arisings of solvent as well as historic solvent wastes currently stored at Sellafield.

10 The Sellafield MOX (Mixed Oxide) Fuel Plant (SMP) manufactures reactor fuel.

11 Magnox reprocessing throughputs were lower than those in 2006 (374 te compared to 720 te in 2006). Decommissioning work on older plants continued throughout the year.

12 During 2004 it was discovered that, in Thorp, 83 m^3 of highly active liquor had spilled from a stainless steel vessel into a stainless steel lined cell (the secondary containment). The plant was shut down to facilitate recovery operations and as a consequence throughput for 2005 and 2006 was zero.

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

Pathway	2006	2007	Position in text (paragraph no.)
Marine critical group			
seafood consumption	179	150	53
aerial pathways	2.7	1.2	53
external radiation from beach occupancy	30	36	54
Total dose to marine critical group	212	187	53, 54
Terrestrial critical group			
inhalation (adults)	1.4	1.3	58
immersion (adults)	0.58	0.34	61
external radiation from beach occupancy (all ages)	<5	<5	60
terrestrial foodstuff consumption (infants)	18	18	57, 58
(of which milk)	(13)	(15)	57
marine foodstuff consumption (adults)	1.7	1.7	60
All discharge pathways (infants)	25	25[a]	62
direct radiation	3.6	1.3	63
Total dose to terrestrial critical group (infants)	28	26[a]	62, 63

a. Assuming external radiation at the maximum of 5 µSv.

Thorp received permission to recommence operations in January 2007. Reprocessing throughputs were limited to 33 te during 2007.

Radioactive discharges and disposals

13 Sellafield discharges are regulated by 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 (SEMP) and the required format for discharge returns.

14 A review of SEMP was undertaken in 2005, and has 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. The results of the Sellafield Ltd environmental monitoring programme for 2007 (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).

15 The Geoffrey Schofield Laboratory, situated on the Westlakes Science Park on the outskirts of Whitehaven, has a separate authorisation to handle, store and dispose of waste containing low levels of radioactivity arising from the analysis of environmental samples. In addition, a number of inter-site transfer authorisations cover the transfer of radioactive waste between Sellafield and the LLWR and between the Geoffrey Schofield Laboratory and the LLWR.

Liquid discharges via the pipeline

16 Radioactive liquid effluents arise from fuel reprocessing and storage operations, Calder Hall, on-site decommissioning operations, and the laboratories of the UKAEA. Highly active liquors from the reprocessing plant that contain the highest levels of activity are routed directly to storage pending incorporation into solid glass form in the WVP; they are not therefore discharged from the site.

17 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.

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

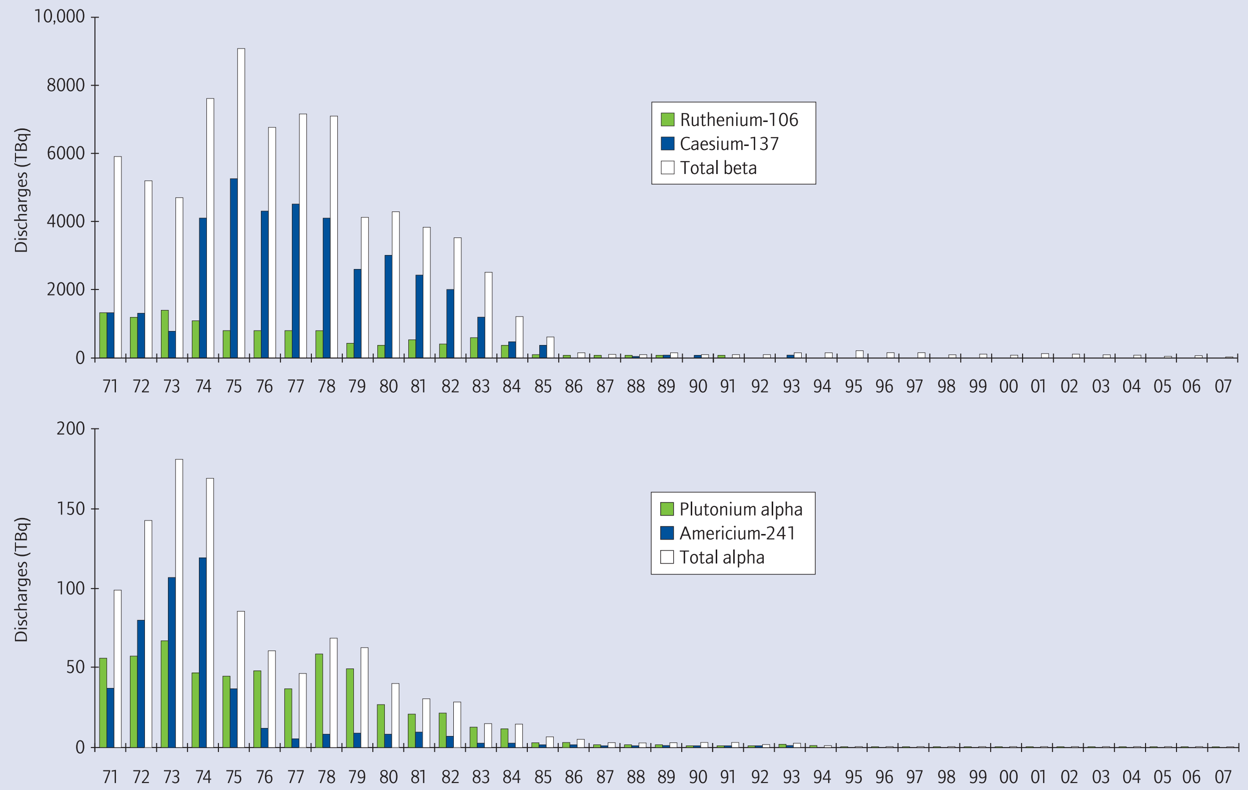
- Storage pond water from the old Magnox decanning plants and the new Fuel Handling Plant (FHP). This water is treated in the Site Ion-Exchange Effluent Plant (SIXEP) to remove radioactive contaminants, principally caesium-137 and strontium-90.
- Storage pond water from the oxide fuel reprocessing plant,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

19 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 report, only performance against the Site Limits is considered. To comply with the authorisation, samples from each waste stream are analysed daily (i.e. Thorp Receipt and Storage, SIXEP, laundry, surface drainage water) or prior to discharge (i.e. 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.

20 Table 2 presents data on discharges over the last five years and provides a basis for comparison with current authorised limits. Trends in liquid effluent discharges from the Sellafield pipeline are illustrated in figures 1a and 1b. All discharges during 2007 were within those limits.

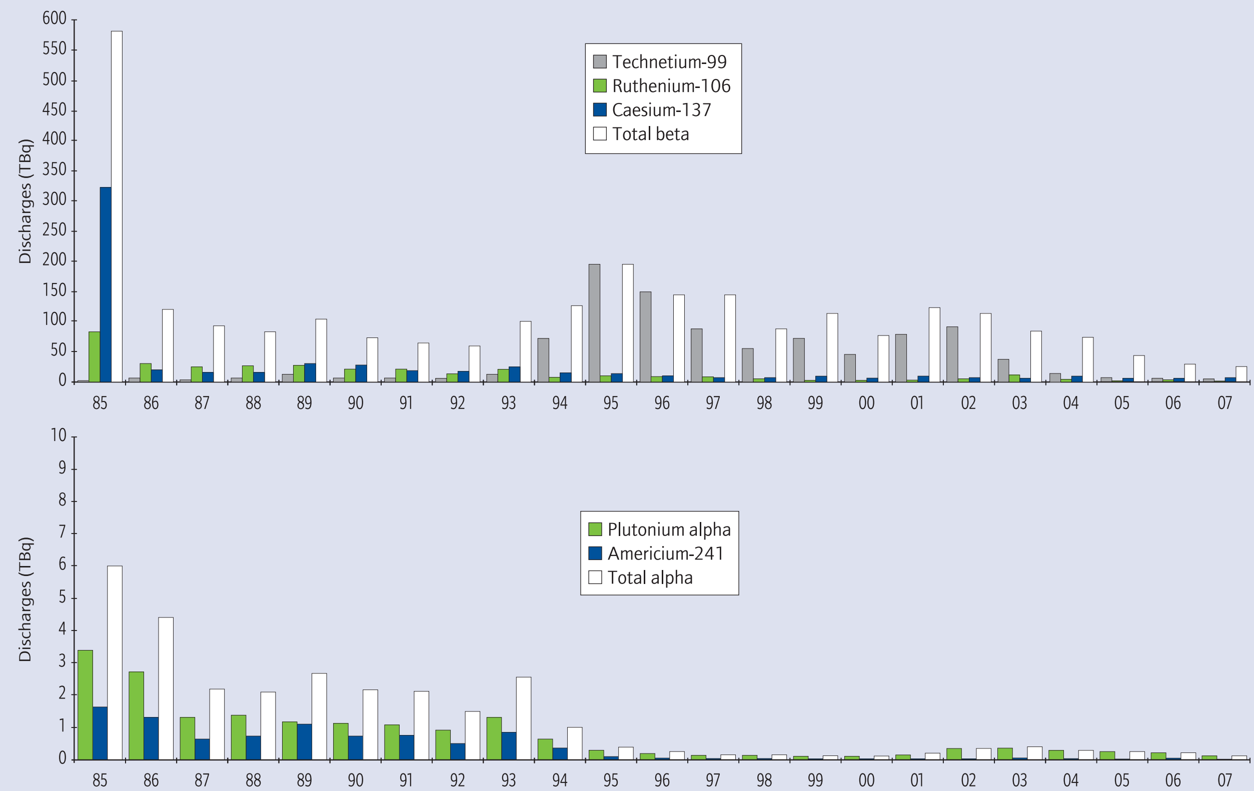
21 The discharges of the actinides (and hence of 'total alpha') decreased again in 2007, consistent with trends in 2005 and 2006. Discharges of antimony-125 were reduced in 2007 as a result of decreased decanning of legacy fuels in FHP.

Figure 1a. Marine pipeline discharges from Sellafield, 1971-2007



'Total alpha' and 'total beta' are overall control measures which do not reproduce precisely the contributions of individual radionuclides.

Figure 1b. Marine pipeline discharges from Sellafield, 1985-2007



'Total alpha' and 'total beta' are overall control measures which do not reproduce precisely the contributions of individual radionuclides.

Table 2. Radioactive discharges to the Irish Sea via the pipeline

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)[b]
	2003	2004	2005	2006	2007	
Tritium	3900	3200	1600	1100	600	20,000
Carbon-14	17	16	5.0	11	4.7	21
Sulphur-35	0.19	0.12	0.08	0.06	0.05	
Manganese-54	0.02	0.01	0.01	0.007	0.007	
Iron-55	0.02	0.04	0.02	0.03	0.02	
Cobalt-60	0.43	0.78	0.70	0.14	0.05	3.6
Nickel-63	0.39	0.34	0.90	1.9	0.41	
Zinc-65	0.03	0.03	0.02	0.02	0.02	
Strontium-89	0.56	1.7	1.1	0.50	0.45	
Strontium-90	14	18	13	5.0	5.0	48
Zirconium-95	0.14	0.13	0.09	0.09	0.07	3.8 (Zirconium-95 and Niobium-95)
Niobium-95	0.16	0.10	0.07	0.07	0.05	
Technetium-99	37	14	7.0	6.0	4.9	90
Ruthenium-103	0.18	0.19	0.12	0.13	0.11	
Ruthenium-106	12	4.4	1.8	3.5	1.5	63
Silver-110m	0.10	0.12	0.07	0.07	0.07	
Antimony-125	23	29	12	8.0	5.1	
Iodine-129	0.55	0.65	0.30	0.20	0.10	2
Caesium-134	0.39	0.40	0.16	0.15	0.14	1.6
Caesium-137	6.2	9.7	6.0	6.0	7.0	34
Cerium-144	0.88	0.82	0.54	0.60	0.40	4
Promethium-147	0.67	0.35	0.30	0.17	0.06	
Europium-152	0.23	0.22	0.17	0.11	0.13	
Europium-154	0.22	0.17	0.11	0.08	0.09	
Europium-155	0.19	0.14	0.12	0.06	0.07	
Neptunium-237	0.05	0.06	0.05	0.05	0.04	
Plutonium alpha	0.36	0.29	0.20	0.15	0.11	0.7
Plutonium-241	10	8.1	5.0	3.6	2.8	25
Americium-241	0.06	0.04	0.03	0.05	0.02	0.3
Curium-242	0.01	0.006	0.004	0.002	0.001	
Curium-243+244	0.01	0.01	0.004	0.002	0.003	0.069
Total alpha[a]	0.40	0.29	0.25	0.21	0.12	1
Total beta[a]	83	73	43	29	25	220
Uranium (kg)	480	440	370	440	300	

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

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

Liquid discharges via the Factory Sewer

22 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 RSA 1993 authorisation 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

23 Aerial effluents are discharged from a number of stacks 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. Major release points are monitored continuously and fitted with appropriate abatement equipment, such as high efficiency particulate filters or scrubbers.

Table 3. Radioactive discharges to the Irish Sea via the Factory Sewer

Radionuclide	Annual discharge (GBq)					Authorised Limit (GBq)[a]
	2003	2004	2005	2006	2007	
Total alpha	0.07	0.18	0.12	0.06	0.06	3.3
Total beta	0.46	0.52	0.29	0.58	0.68	13.5
Tritium	27	30	14	21	11	132

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

24 The authorisation has 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).

25 Discharges of radioactivity to the atmosphere also take place from "Other Outlets and Miscellaneous Sources". These are largely associated with the re-suspension of radioactivity from open fuel storage ponds and other places. As in previous years, releases in 2007 were calculated by a methodology agreed with the Environment Agency using data on activity concentrations in air at the site perimeter.

26 The four cooling towers at Calder Hall were brought down safely by explosive demolition in September 2007. Additional monitoring before, during and after demolition showed the vast majority of analyses were either indistinguishable from pre-demolition levels or at the limit of detection. Discharge of radioactivity to the atmosphere as a result of the demolition is accounted for as part of the sites total airborne radioactive discharges.

27 Discharges for the years 2002 to 2007 are summarised in table 4. The discharges of tritium and carbon-14 generally reflect the reprocessing throughput (paragraphs 11 and 12). Argon-41 discharges ceased immediately, and sulphur-35 discharges significantly decreased, when the Calder Hall reactors shut down in 2003. Most of the remaining radionuclides are associated with particulate material and their annual discharges are not directly related to annual reprocessing rates. Antimony-125 and caesium-137 discharges declined in 2007. This is thought to be due to the type of fuel being decanned and improved pond management in the FHP.

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. In consequence, the inter-site transfer authorisation also includes allowances for the transfer of non-Sellafield Ltd waste from WAMAC to the LLWR. Annual radionuclide disposals from Sellafield 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 the Calder Floodplain Landfill Extension - Segregated Area and the South Landfill Site (18000 te [11970 m^3] and 0 te respectively in 2007). It should be noted this figure includes 2468m^3 of material that Sellafield Ltd stored in the basal area of the landfill in 2006. These disposals are included in the Site's multi-media authorisation rather than under the terms of a separate RSA authorisation (see paragraph 68). The terms include an activity limit of 3.7×10^4 Bq 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 fish and shellfish) and of local agricultural produce (particularly milk).
- External gamma radiation from exposed intertidal sediments, particularly the fine 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[1]. The Statutory Environmental Monitoring Programme, which is reviewed annually by the Environment Agency, 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.

31 Concentrations of radioactivity in the marine environment reflect discharges through the Sellafield pipeline, whereas radioactivity in the terrestrial environment generally reflects discharges to atmosphere. Some overlap does occur, however, with sea to land transfer processes[2,3] and on tidally inundated pastures[4]. Concentrations of caesium-137, plutonium and americium-241 in most environmental materials are dominated by 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, and the Isle of Man. The precise locations are reviewed periodically. In certain cases, additional samples are obtained through commercial suppliers, representing foodstuffs available for general consumption.

(continued on page 22)

Table 4. **Total airborne radioactive discharges, 2002 - 2007**

Radionuclide	2002	2003	2004	2005	2006	2007	Authorised Limit[a] (all sources)
	Annual discharge (TBq)						
Tritium	250	370	320	93	200	83	1100
Carbon-14	0.81	0.71	0.85	0.91	0.71	0.36	3.3
Argon-41	330	150	-	-	-	-	
Krypton-85	100,000	120,000	120,000	49,800	22,800	14,100	440,000
	Annual discharge (GBq)						
Sulphur-35	12	6.5	0.026	-	-	-	-
Cobalt-60	0.006	0.002	0.0003	-	-	-	-
Strontium-90	0.046	0.054	0.055	0.05	0.05	0.04	0.71
Ruthenium-106	1.3	1.4	1.6	1.5	1.6	1.3	28
Antimony-125	0.38	1.1	0.46	0.38	1.5	0.71	2.3
Iodine-129	21	17	16	15	6.7	4.8	70
Iodine-131	0.45	0.60	0.68	1.0	0.66	0.56	55
Caesium-137	0.43	0.50	0.43	0.61	0.59	0.17	5.8
Plutonium alpha	0.02	0.07	0.05	0.03	0.03	0.03	0.19
Plutonium-241	0.10	0.39	0.32	0.33	0.22	0.28	3
Americium-241 + Curium-242	0.02	0.04	0.04	0.03	0.03	0.02	0.12
Total alpha[b]	0.05	0.12	0.12	0.09	0.11	0.14	0.88
Total beta[c]	0.92	1.2	1.5	1.7	2.0	2.1	42

a. Current discharge authorisation dates from 01/10/2004.
b. Corrected for contribution from Miscellaneous and other outlets; 2002, 2005.
c. Corrected for contribution from Miscellaneous and other outlets; 2005.

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

Radionuclide	Radioactivity disposed (GBq)[d]					Current Authorised Limit (GBq)[e]	Previous Authorised Limit (GBq)
	2003	2004[f]	2005	2006	2007		
Tritium	8.7	8.5	2.3	2.1	3.4	1400	10,000
Carbon-14	0.89	1.9	0.30	0.30	0.15	50	50
Cobalt-60[a]	17	43	6.9	11	2.3	2000	2000
Iodine-129	0.18	0.45	0.03	0.08	0.17	0.22	50
Others[b]	750	910	950	700	480	15,000	15,000
Radium-226 + Thorium-232	0.09	0.03	0.03	0.02	0.02	30	30
Uranium	20	22	22	4.6	4.5	300	300
Other alpha emitters[c]	15	25	43	92	31	300	300
Volume (m^3 a^{-1})[d,e]	5700	5600	4900	6000	4000	34,000	38,000

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 the waste and its primary containment.
e. Includes waste consigned by other customers for treatment at Sellafield and that generated at Sellafield by AEA Windscale. Current disposal authorisation dates from 01/10/2004.
f. These data have been updated from those published previously in the 2004 report following an internal audit.

Figure 2. Marine environmental monitoring around Sellafield

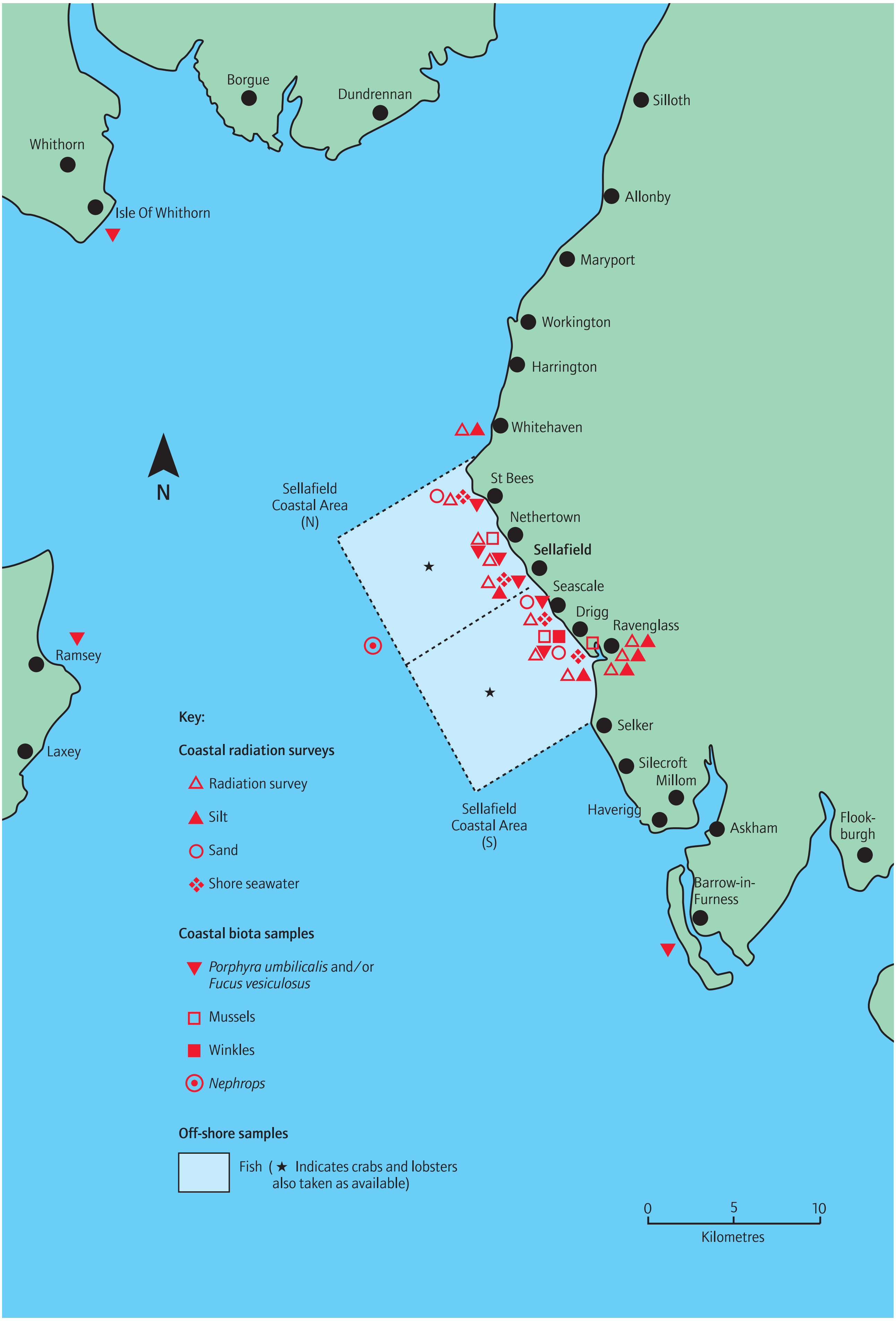


Table 6. **Radioactivity in fish**

Species	Location	Mean radionuclide concentration (Bq kg^{-1} wet weight)					
		$^{14}C^{a}$	^{99}Tc	^{106}Ru	^{137}Cs	Pu(α)	^{241}Am
plaice	Sellafield coastal area	100	2.4	<0.28	3.7	0.02	0.02
	Sellafield offshore area	140	2.2	<0.31	5.4	0.02	0.02
	Sellafield area[b]	110	2.3	<0.29	4.1	0.02	0.02
	Whitehaven	110	2.2	<0.23	4.4	<0.01	0.01
cod	Sellafield coastal area	190	<0.28	<0.50	8.5	<0.01	0.009
	Sellafield offshore area	150	<0.30	<0.24	7.4	<0.01	<0.01
	Sellafield area[b]	170	<0.28	<0.41	8.1	<0.01	<0.01
	Whitehaven	86	0.42	<0.22	5.6	<0.01	<0.01

a. *^{14}C data includes background (see paragraph 33).*
b. *Combined average for Sellafield coastal and offshore areas, this is consistent with the St Bees-Selker location reported in previous reports.*

Table 7. **Radioactivity in molluscs and crustaceans**

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)
Molluscs																				
winkles	Sellafield coastal area	26	91	130	2.5	-	150	7.2	0.84	1.2	-	4.7	-	7.0	-	-	34	15	-	1.5
mussels	Sellafield coastal area	38	59	130	2.2	0.94	170	7.0	-	2.5	0.02	2.3	0.03	8.0	1.4	6.6	43	15	<0.06	1.7
	Ravenglass Garth mussel bed	32	110	170	3.2	0.52	1200	7.3	-	2.3	-	2.0	0.04	7.9	1.4	6.6	44	15	<0.08	2.2
Crustaceans																				
crabs	Sellafield coastal area	-	-	240	1.0	0.41	21	<3.6	-	-	-	1.5	-	0.32	-	-	-	1.3	-	0.15
lobsters	Sellafield coastal area	-	-	240	0.49	-	360	-	-	-	0.05	2.4	-	0.21	-	-	-	2.0	-	0.05
Nephrops	Sellafield coastal area	-	-	-	-	-	70	-	-	-	-	-	-	-	-	-	-	1.0	-	-

a. *^{14}C data includes background (see paragraph 33).*

Table 8. **Radioactivity in seaweed**

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	^{134}Cs	^{137}Cs	Pu(α)	^{241}Am	U(α)
Porphyra umbilicalis	St Bees-Selker	16	140	50	0.46	<0.39	5.5	<5.6	1.1	<0.12	2.0	4.3	7.0	0.36
Fucus vesiculosus	Nethertown	18	260	46	1.9	0.46	1600	<0.91	1.3	<0.19	4.1	12	4.2	3.4
	Drigg	33	310	110	3.4	0.61	2700	<1.9	1.8	<0.13	4.4	20	<5.4	4.7
	Walney Island	18	340	32	0.83	<0.35	1900	<0.53	0.84	<0.07	4.2	7.7	<2.3	4.4
	Ramsey, IOM	23	180	17	-	0.18	280	<0.47	<0.18	<0.06	0.72	0.58	0.78	5.5
	Isle of Whithorn	16	150	14	0.21	0.31	140	0.56	0.47	0.07	3.1	2.6	4.1	3.1

a. *^{14}C data includes background (see paragraph 33).*

Figure 3a. Radioactivity in seafoods and indicators (St Bees to Selker), 1972 -2007

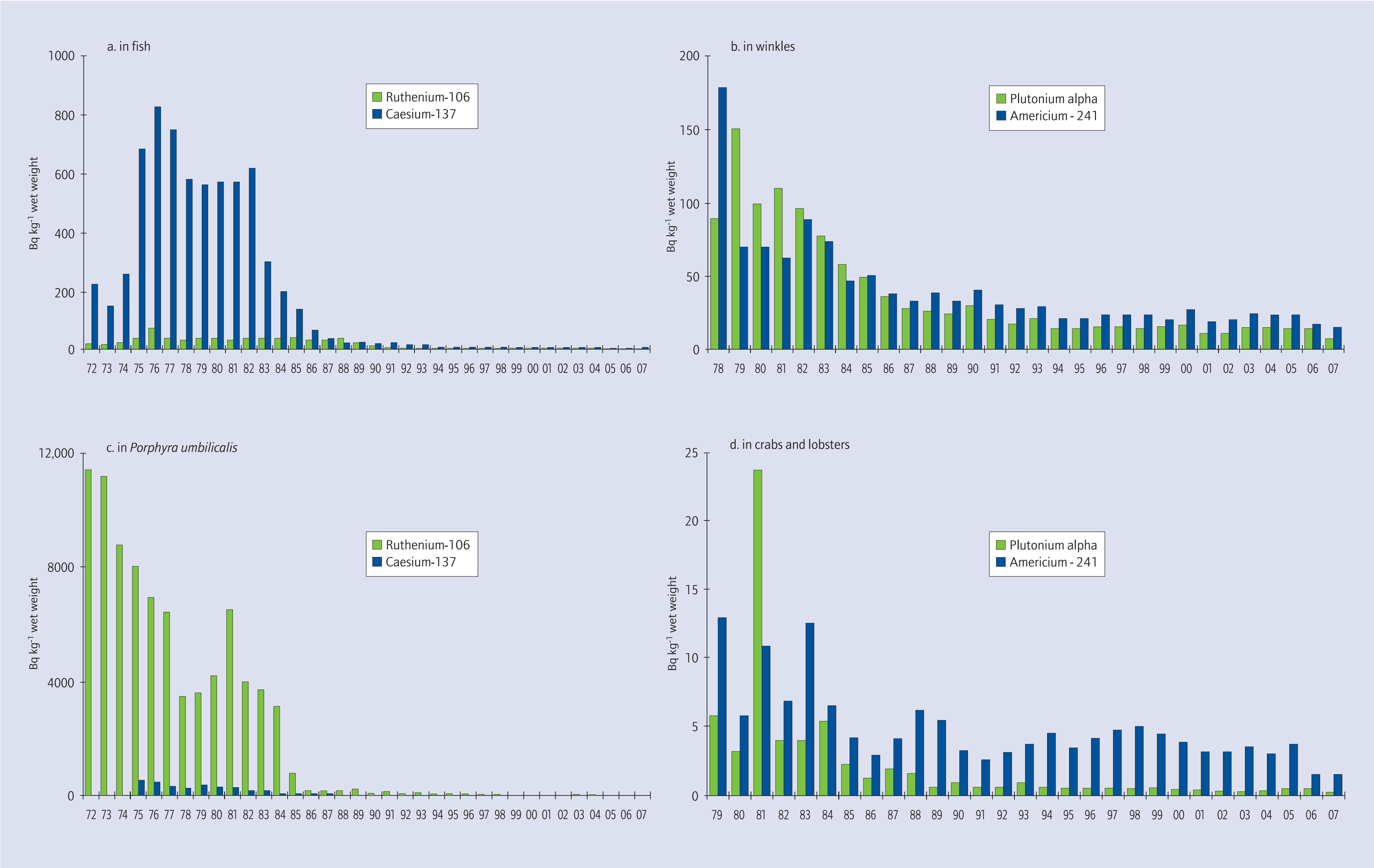


Figure 3b. Radioactivity in seafoods and indicators (St Bees to Selker), 1985-2007

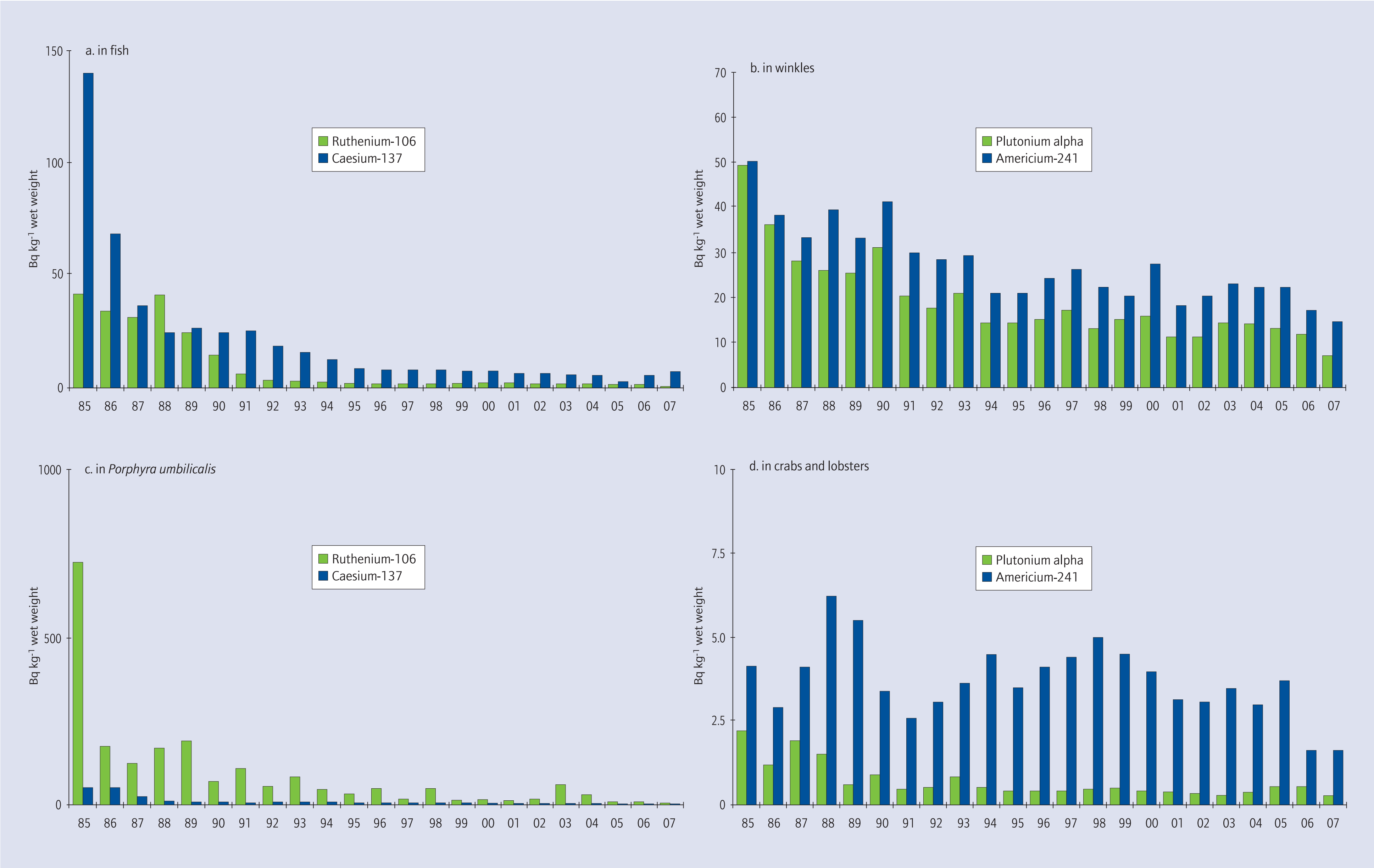


Figure 3c. Radioactivity in seafoods and indicators (St Bees to Selker), 1993-2007

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 3a - 3c. Data for carbon-14 presented in tables 6 and 7 are not corrected for the levels which are present naturally[5]. However, background corrected values for carbon-14 in fish, molluscs and crustaceans have been used in the radiological exposure assessment (paragraph 52). For these marine foodstuffs, natural concentrations of carbon-14 have been taken from data presented by the Environment Agency and Food Standards Agency[1]. Concentrations of radioactivity in seafood in 2007 were generally similar to those in recent years. The average concentrations of technetium-99 in crustaceans continued to decline in 2007 in response to the reduced discharges since 2004. There has been a delay in the decline as in some species concentrations typically lag behind discharges by a year or more.

Indicators

34 Seaweeds are useful marine indicators (see paragraph 29). *Fucus vesiculosus* is collected because it accumulates technetium-99 and other nuclides rapidly following discharge and is particularly sensitive to fluctuations in concentrations of this radionuclide in seawater. Thus, the reduction in discharges from 2002 onwards was soon reflected in the levels in this species (table 8 and figure 3c).

Seawater and sediments

35 Sellafield Ltd routinely collects samples of seawater from the shore at locations close to Sellafield. Concentrations of radioactivity in seawater (table 9) were generally similar to those of recent years. It is worth noting the apparent decrease of strontium-90 in seawater in 2007 is due to a reduced limit of detection.

36 Concentrations of radioactivity in sediments (table 10) were generally similar to those of recent years (figure 4) but with slight increases in americium-241, reflecting in-growth contribution from the decay of historically discharged plutonium-241. Resuspension of sub-surface sediments in this area may have also led to slight increases in plutonium-alpha and americium-241.

External pathways

37 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 surveys are also conducted around the site perimeter and the surrounding district (see table 12 and paragraph 47).

38 Dose rates fell steadily until 1993/1994 (figure 5) and have subsequently stayed fairly constant. The steep increases in the Sellafield beach dose rates in 2004 and 2005 were due to the uncovering of redundant sea discharge pipelines prior to their removal.

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. In addition to the routine monitoring programme, extra monitoring is carried out in the event of exceptionally high tides or severe storms. During 2007, 1498 man-hours of effort were spent monitoring 456 km of coastline. Monitoring was concentrated on recent tide-lines and wind-blown debris in near-shore areas. There were no finds of items with higher than normal activity.

40 In November 2006 Sellafield Limited employed a contractor to carry out trials using a large area contamination monitor on Sellafield beach. Contamination monitoring continued during 2007 and is now part of the routine programme. A total of about 150 hectares was monitored in 2007 and 145 stones and 114 particles were found and removed to Site for analysis. The latest information is available on the Sellafield Ltd website (http://www.sellafieldsites.com).

Airborne and terrestrial pathways

41 The extent of the terrestrial environmental monitoring programme is illustrated in figure 6.

Airborne

42 High flow rate air sampling equipment, located close to the site perimeter (table 13a) and in nearby centres of population (table 13b), 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 historical marine discharges.

43 Atmospheric krypton-85 measured fortnightly at the Met station averaged 34.4 Bq/m^3. Significant variation in atmospheric krypton-85 was observed due to discontinuities in reprocessing operations on Sellafield site combined with the variability in meteorological conditions.

Foodstuffs and water

44 Milk consumption remains the main contributor to the critical group dose from terrestrial foodstuffs and represents one of the more rapid food transfer pathways. 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 14. 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, radiological exposure calculations (paragraph 52) have been made by subtracting natural background levels

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

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	<4.6	10	<3.7	<0.50	0.05	<0.04	<0.06	0.13	0.001	0.006	<0.07	<0.20	0.11
	solid	0.25	<0.27	-	-	0.01	-	-	0.03	0.0001	0.06	0.28	0.10	0.003
Sellafield	filtrate	<4.3	10	8.2	<0.51	0.08	0.07	<0.06	0.20	0.001	0.007	0.08	<0.21	0.10
	solid	0.55	0.39	-	-	0.02	-	-	0.06	0.0002	0.12	0.53	0.18	0.006
Seascale	filtrate	<4.8	8.8	<7.3	<0.56	0.06	0.06	<0.05	0.15	0.001	0.007	<0.07	<0.32	0.09
	solid	0.51	<0.46	-	-	0.02	-	-	0.08	0.0002	0.13	0.58	0.21	0.01
Drigg	filtrate	<4.2	9.1	7.1	<0.51	0.05	0.05	<0.06	0.13	0.006	0.006	<0.06	<0.26	0.10
	solid	0.37	0.36	-	-	0.01	-	-	0.03	0.0002	0.10	0.39	0.15	0.004

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

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	500	510	2.0	-	-	<4.3	-	<0.47	54	-	60	-
	Seascale Neb	450	400	1.8	-	-	<5.0	<2.3	<0.56	36	-	110	-
	Drigg Barnscar	430	460	1.7	-	-	<4.3	-	<0.47	31	-	100	-
Silt	Ravenglass Ford	1,400	770	8.8	44	31	<26	<9.9	<1.5	140	310	430	37
	Ravenglass Salmon Garth	580	440	2.9	27	5.9	<13	-	<1.5	43	110	120	22
	Ravenglass Opp Raven Villa	1,400	870	8.2	62	38	43	7.3	<1.4	200	350	490	39
	Eskmeals	1,600	860	8.8	43	64	<19	12	<1.9	160	460	590	54
	Newbiggin Marsh	2,500	1,200	20	98	150	59	-	2.8	460	830	1,300	62
	Muncaster Rd Bridge	3,000	1,500	13	170	120	27	-	<1.7	650	880	1,400	62
	Whitehaven Outer harbour (south)	550	520	1.6	0.95	3.7	<5.1	<3.7	<0.54	110	110	140	27
	River Calder	430	450	<1.6	1.9	<2.2	<18	-	<1.9	93	49	<40	15
	Waberthwaite	2,700	1,300	1.5	120	93	<6.3	-	<0.26	54	770	1,400	53

of carbon-14. For milk and other terrestrial foodstuffs, vegetation and soil, a background level of 240 Bq kg^{-1} carbon is used. The milk results for 2007 are generally similar to those observed for previous years, taking into account natural background levels for carbon-14, with many analyses at the limit of detection.

45 For terrestrial foodstuffs, other than milk, the results of the Sellafield environmental monitoring programme for 2007 (black text) are presented alongside supplementary data published by the Foods Standards Agency (grey text) (tables 15 and 16)[6]. 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 in tables 15 and 16 (see paragraph 41). 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[1].

46 Water samples are collected from the River Calder and from other local rivers, lakes and domestic supplies. The results (table 17) 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[1]

Indicators

47 Grass and soil sampling is included in the monitoring programme since it is a useful indicator material and is often used to provide time trend data on environmental concentrations of radioactivity. Grass samples (table 18) are collected quarterly from five locations on the Sellafield site and from one at the Ravenglass Estuary. Soil samples (5 cm cores) (table 19) are collected annually from the same locations.

(continued on page 31)

Figure 4. Radioactivity in silts, 1985-2007

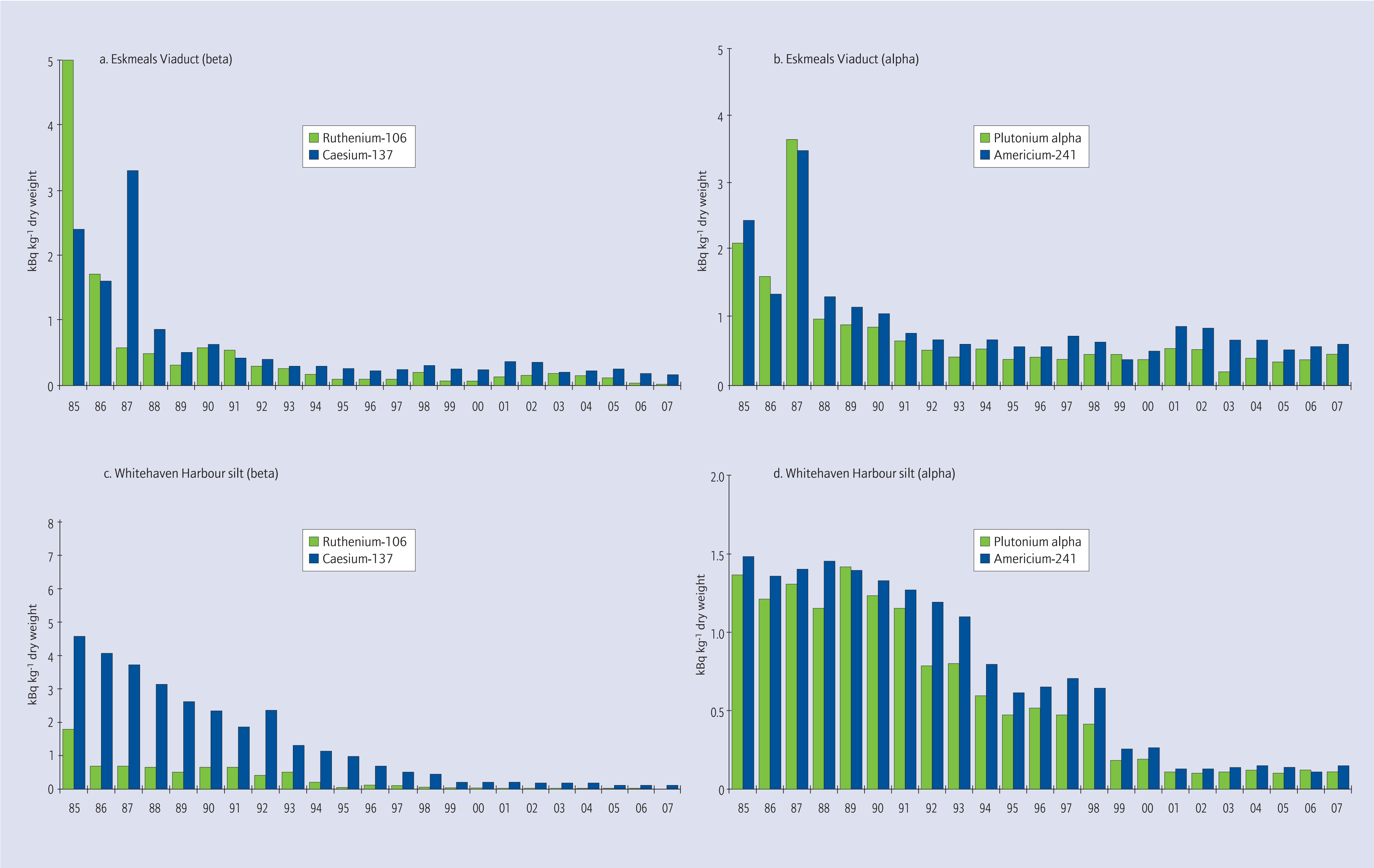
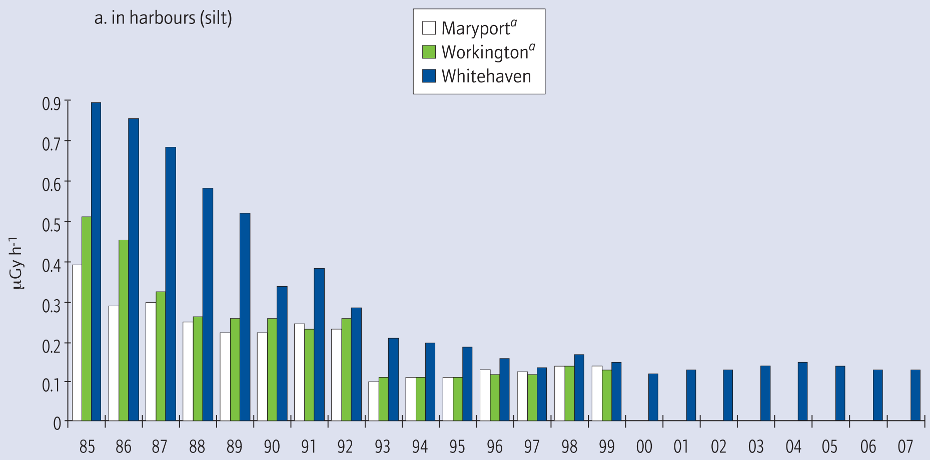
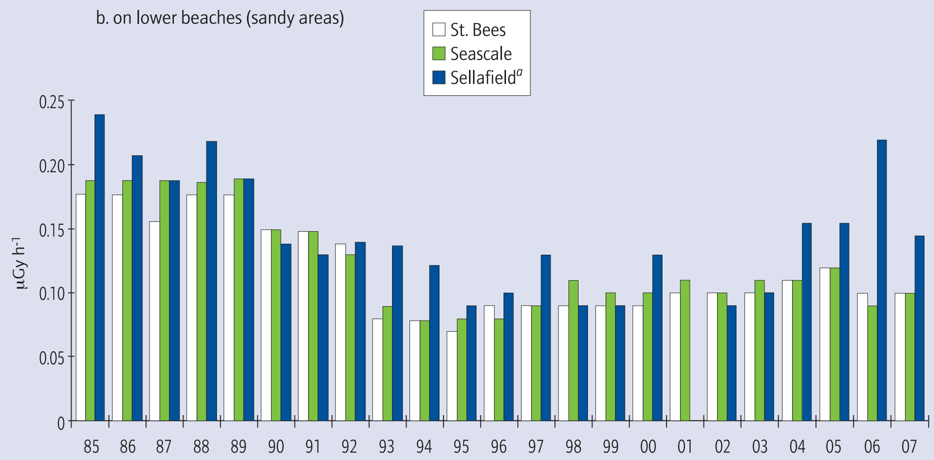


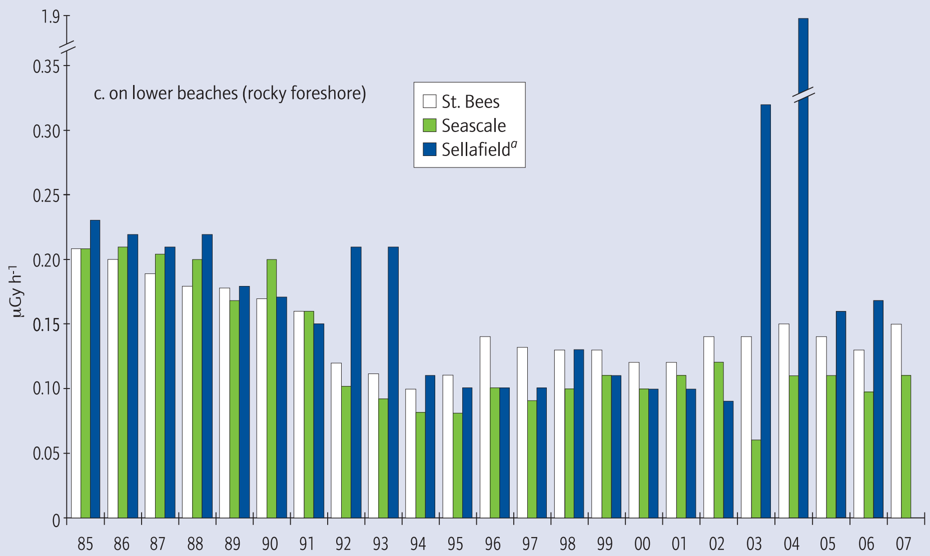
Figure 5. Gamma dose rates in coastal areas, 1985-2007



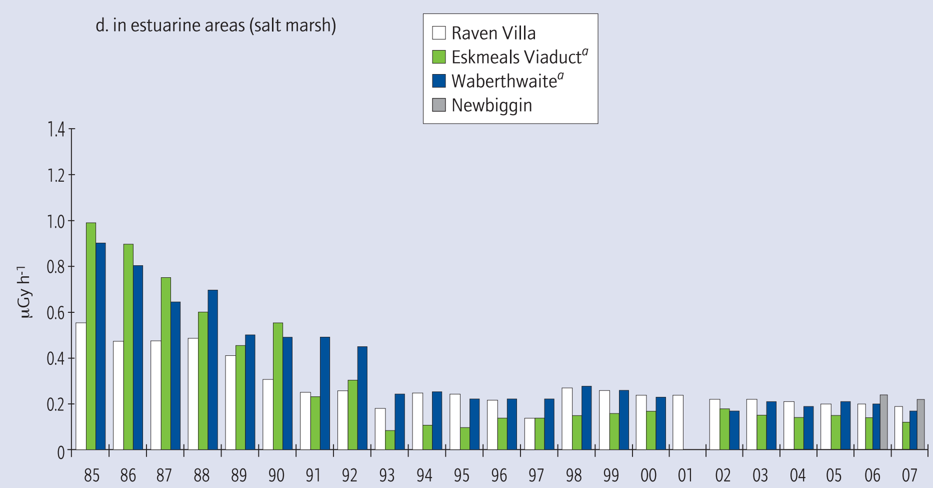
a. Not monitored from 2000 onwards following regulatory review of the statutory monitoring programme in 1999.



a. Not monitored in 2001 because of foot and mouth disease access restrictions.



a. See paragraph 38.



a. Not monitored in 2001 because of foot and mouth disease access restrictions.

Figure 6. Terrestrial environmental monitoring around Sellafield

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

Area of survey	Description	Nature of ground	Number of observations[a]	Mean dose rate (µGy h^{-1})
Whitehaven Harbour (north)	outer harbour	mud/silt	12	0.12
Whitehaven Harbour (south)	outer harbour	soft mud	12	0.13
St Bees (beach)	beach	sand	2	0.10
St Bees (groynes)	groynes	pebbles/rocks	2	0.15
St Bees	promenade and car park	concrete/grass	2	0.11
St Bees	Seamill Lane car park	car park	2	0.12
Coulderton	grassed areas/beach bungalows	grass banks	2	0.10
Nethertown	beach	pebbles/shingle	2	0.14
Nethertown	car park	concrete/grass	2	0.11
Nethertown	grassed area/beach bungalows	grass banks	2	0.14
Braystones	beach	pebbles/shingle	2	0.13
Braystones	grassed areas/beach bungalows	grass banks	2	0.14
Sellafield beach	beach		2	0.14
Sellafield	Pipeline 3	sand	12	0.14
Sellafield	Pipeline 4	sand	12	0.13
Seascale beach	north of pipeline	sand	12	0.10
Seascale beach	south of pipeline	rocks/sand	12	0.11
Drigg	Barn Scar	mussel beds/silt/rocks	4	0.10
Drigg beach	beach	sand	10	0.13
Ravenglass	Raven Villa	saltmarsh	2	0.19
Ravenglass	River Mite ford		2	0.13
Ravenglass	small boat area	firm silt/pebbles	2	0.13
Ravenglass	Salmon Garth	mussel beds	2	0.11
Ravenglass	Salmon Garth (saltmarsh)	sand/firm silt	2	0.13
Factory sewer	outfall	rocks/boulders/sand/shingle	12	0.13
Eskmeals Viaduct	saltmarsh	saltmarsh	2	0.13
Newbiggin	saltmarsh	saltmarsh	12	0.21
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 12. **Mean gamma dose rates measured in air at Sellafield site perimeter**

Area of survey	Number of locations	Mean dose rate (µSv h^{-1})[a]
North	4	0.07
East	5	0.13
South	3	0.06
West	4	0.10
River Ehen	2	0.07
River Calder	12	0.26
(includes critical group location)	1	0.09
Average of the above 30 locations	-	0.16

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

Table 13. **Radioactivity in air in the vicinity of Sellafield: site perimeter locations**

a. Site perimeter locations

Radionuclide	Mean radionuclide concentration (mBq m^{-3})				
	Calder Gate	Met Station	North Gate	West Ring Road	South Side
Total alpha	0.05	0.06	0.07	0.06	0.05
Total beta	0.38	0.36	0.54	0.36	0.27
Strontium-90	0.005	0.008	0.02	0.005	0.002
Ruthenium-106	<0.04	<0.04	<0.04	<0.04	<0.04
Antimony-125	<0.01	<0.02	<0.03	<0.02	<0.01
Caesium-134	<0.005	<0.004	<0.005	<0.004	<0.005
Caesium-137	0.04	0.07	0.16	0.06	0.01
Plutonium alpha	0.001	0.001	0.003	0.0009	0.001
Plutonium-241	<0.04	<0.04	<0.03	<0.03	<0.03
Americium-241	0.001	0.001	0.002	0.001	0.001
Uranium alpha	0.002	0.001	0.002	0.0022	0.002

b. Residential locations

Radionuclide	Mean radionuclide concentration (mBq m^{-3})									
	Beckermet	Braystones	Brow Top	Calderbridge	Cleator	Gosforth	Ravenglass	Seascale	St Bees	Whitehaven
Total alpha	0.05	0.05	0.05	0.04	0.04	0.05	0.06	0.06	0.05	0.07
Total beta	0.23	0.26	0.27	0.24	0.21	0.24	0.24	0.28	0.24	0.22
Strontium-90	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.001	<0.001
Ruthenium-106	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Antimony-125	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Caesium-134	<0.005	<0.004	<0.005	<0.004	<0.005	<0.004	<0.005	<0.004	<0.004	<0.004
Caesium-137	<0.01	0.01	<0.01	<0.005	<0.004	<0.004	<0.004	<0.01	<0.004	<0.01
Plutonium alpha	0.0003	<0.0003	<0.0002	<0.0002	<0.0002	<0.0001	<0.0002	0.001	<0.0002	0.0004
Plutonium-241	<0.03	<0.04	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Americium-241	0.0002	0.0004	<0.0002	0.0002	<0.0001	<0.0001	0.0003	0.002	0.0002	0.0006
Uranium alpha	0.0007	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0007	0.0005	0.0008

Table 14. **Radioactivity in milk from farms near Sellafield**

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]	<0.12	38	<3.8	14	<0.58	0.37	<0.35	<0.10	<0.02	<0.04	0.43
Farm B	<0.11	36	<3.0	15	<0.70	0.13	<0.38	<0.10	<0.02	<0.04	0.29
Farm C	<0.11	41	<3.6	17	0.90	0.16	<0.38	<0.10	<0.02	<0.04	0.26

a. Including natural background (see paragraph 44).
b. Excluding natural background.
c. Farms A to C are within the 0-4 km zone previously reported.
d. Milk from farm A has been used in the radiological assessment (see paragraph 57).

Table 15. Radioactivity in animal produce

Species	Mean radionuclide concentration (Bq kg^{-1} wet weight)[c]											
	^{3}H	^{14}C$_{Total}$[a]	^{14}C$_{Net}$[b]	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb	^{129}I	^{137}Cs[d]	^{238}Pu	$^{239+240}$Pu	^{241}Am
Bovine Muscle	<5.0	17	-	<0.60	<0.01	<1.5	<0.20	<0.04	0.78	<0.0003	<0.0006	0.0005
Bovine Kidney	<8.0	37	6.0	<0.10	0.43	<1.2	<0.40	<0.04	0.44	<0.0002	<0.0003	0.003
Bovine Liver	11	19	-	<0.20	0.03	<1.3	<0.50	<0.04	0.41	0.0006	0.005	0.007
Eggs - General	<6.0	28	-	<0.20	0.02	<0.60	<0.40	<0.04	0.09	<0.0003	<0.0002	<0.0002
Ovine Muscle	<9.0	43	-	<0.20	0.07	<1.7	<0.60	<0.04	2.6	<0.0001	<0.0003	0.0004
Ovine Kidney/Liver	<12	24	-	<0.25	0.31	<1.3	<0.55	<0.10	0.77	<0.0003	0.002	0.002
Rabbit	6.0	19	-	<0.10	<0.03	<0.10	<0.30	<0.05	0.72	<0.0001	<0.0005	0.002
Pheasants	<6.0	28	-	<0.10	0.02	<0.80	<0.30	<0.05	0.72	<0.0001	<0.0005	<0.0006
Duck	<7.0	97	25	<0.10	0.03	<0.90	<0.40	<0.03	0.31	<0.0001	0.0003	0.0003

a. Including natural background (see paragraph 44).
b. Excluding natural background (values taken from RIFE-12). Measured concentration 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 (paragraph 56, table 25).

Table 16. Radioactivity in fruit and vegetable produce

Species	Mean radionuclide concentration (Bq kg^{-1} wet weight)[c]											
	^{3}H	^{14}C$_{Total}$[a]	^{14}C$_{Net}$[b]	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb	^{129}I	^{137}Cs[f]	^{238}Pu	$^{239+240}$Pu	^{241}Am
Potatoes	2.9	13	0.37[d]	-	-	<0.40	-	<0.02	0.11	-	-	-
Cabbage	<4.0	7.0	-	<0.20	0.10	<0.90	<0.30	<0.03	0.02	<0.0002	<0.0002	<0.0002
Blackberries	8.0	20	10	<0.15	1.3	<0.85	<0.40	<0.03	0.43	<0.0002	0.001	0.005
Apples	<5.0	13	3.0	<0.30	0.12	<1.1	<0.40	<0.03	0.13	<0.0003	<0.001	<0.001
Elderberries	9.0	19	9.0	<0.20	0.39	<1.6	<0.70	<0.03	0.23	0.001	0.004	0.01
Honey	<8.0	57	-	<0.20	0.05	<0.12	<0.30	<0.03	1.3	<0.0002	0.0004	0.0004

a. Including natural background (see paragraph 44).
b. Excluding natural background. 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. Natural background calculated assuming 240 Bq kg^{-1} natural ^{14}C per kg carbon (see paragraph 41).
e. Natural background concentrations taken from RIFE-12.
f. Cs-Total reported by the FSA has been assumed to be dominated by 137Cs, hence dose factors for that radionuclide have been used in the radiological exposure assessment (paragraph 56, table 25).

Table 17. Radioactivity in local waters

Location		Mean radionuclide concentration (Bq l^{-1})							
		Total alpha	Total beta	^{3}H	^{90}Sr	^{99}Tc	^{137}Cs	Pu(α)	Am+ Cm
River water:	River Calder at Sellafield	<0.02	<0.14	<3.3	0.01	-	<0.01	<0.002	<0.003
	River Calder at Calderbridge	<0.02	<0.14	<3.3	0.006	-	<0.01	<0.002	<0.003
	River Ehen upstream of of factory sewer outfall	<0.03	0.21	8.1	0.01	-	<0.01	<0.002	<0.003
	River Ehen at Sellafield station	<0.02	0.13	<3.0	0.005	-	<0.01	<0.002	<0.003
Lake water:	Ennerdale water	<0.01	0.16	<3.3	0.004	-	<0.02	<0.001	<0.002
	Wastwater	<0.02	0.11	<3.4	0.006	-	<0.02	<0.001	<0.002
Tap water:	Calderbridge	<0.02	<0.06	<3.0	0.004	-	<0.01	<0.001	<0.001
	Sellafield Site	<0.02	0.08	<2.9	0.005	-	<0.01	<0.001	<0.001
	Ravenglass	<0.01	0.08	<2.9	0.005	-	<0.01	<0.001	<0.001
	Seascale	<0.02	0.09	<3.9	0.004	-	<0.01	<0.001	<0.001
	Whitehaven	<0.02	0.09	<2.9	0.005	-	<0.01	<0.001	<0.002
Spring water:	Braystones beach	-	-	<4.4	-	-	-	-	-
	Sellafield beach[a]	-	-	650	-	<1.5	0.80	0.01	-

a. Results corrected for seawater content.

Table 18. **Radioactivity in grass**

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
Calder Gate	10	90	16	26	2.8	2.8	<1.1	<2.1	<1.0	<0.02	<0.23	6.7	0.59	0.30
Met Station	10	110	8.1	22	1.0	10	<1.0	<1.3	<0.43	<0.03	<0.15	8.4	1.5	0.79
North Gate	8.4	120	11	24	1.8	18	<1.2	<1.6	<0.71	<0.02	<0.17	34	2.0	0.50
South Side	15	130	37	24	1.0	1.7	1.3	<2.1	<1.3	<0.02	<0.24	3.5	0.34	0.29
West Ring Road	12	130	4.6	20	<0.70	1.8	<0.83	<1.5	<0.64	<0.02	<0.19	4.6	1.3	0.78
Ravenglass	12	90	<2.8	26	0.53	0.65	3.6	<1.1	<0.41	<0.02	<0.13	1.6	1.2	1.7

a. ^{14}C data includes background.
b. Excluding natural background. Natural background calculated assuming 240 Bq kg^{-1} natural ^{14}C per kg carbon (see paragraph 44).

Table 19. **Radioactivity in soil**

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	510	370	4.6	7.8	2.0	7.1	<2.2	<39	<10	<22	<4.0	120	30	12	43
Met Station	890	680	4.3	8.1	1.7	24	<2.2	<47	<13	<30	<3.2	320	100	40	61
North Gate	810	890	9.7	8.8	4.2	43	<2.2	<48	<14	<33	<4.5	490	300	40	56
South Side	650	590	3.5	14	2.0	9.3	<2.2	<50	13	<34	<5.8	80	10	7.1	56
West Ring Road	590	820	1.8	5.0	0.70	5.7	<2.2	<52	<12	<33	<4.9	150	40	30	94
Ravenglass	570	700	1.1	13	0.40	3.2	35	<45	<13	<24	<4.2	360	80	100	45

a. Including natural background.
b. Excluding natural background. Natural background calculated assuming 240 Bq kg^{-1} natural ^{14}C per kg carbon (see paragraph 44).

Table 20. **Groundwater and non-radiological environmental monitoring at Sellafield**

Borehole number	Mean radionuclide concentration (Bq m^{-3})					
	Total alpha	Total beta	^{3}H	^{90}Sr	^{99}Tc	^{137}Cs
708P1	<20	430	30,900	-	<70	<80
733P1	<20	590	<5,400	-	-	-
1239P1	<20	<270	<4,600	<170	-	-
2028PP1	<20	500	<5,100	<250	-	-
2564P1	<30	<400	<5,200	<260	-	-
738P1	<30	510	7,900	270	<70	-
739P1	<20	<290	7,000	<160	<80	<80
4683P1	<20	<220	<4,800	<300	-	-
4684P1	<20	<360	<7,000	500	-	-
2796P1	<10	<240	<4,700	-	-	-
801P1	<20	300	<6,600	-	3,600	-
6986P1	50	430	3,450,000	<160	7,500	<70
1241P1	<10	<220	<5,400	<130	-	-
4688P1	<20	<210	8,500	<180	<200	60
1248PP1	<20	410	<5,200	<130	-	-
4025P1	<20	720	442,000	<160	40,200	70
4996P1	<20	270	<5,900	<140	100	-

Groundwater

48 The statutory monitoring programme includes the routine monitoring of groundwater from 17 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 8. The routine results in 2007 (table 20) were similar to those reported in recent years, except for an apparent reduction of total alpha and tritium due to decreasing limit of detection. Most other results were near or below limits of detection, except for tritium and technetium-99 in boreholes 6986P1 and 4025P1 which are in the vicinity of the main gate/southwest perimeter. Old waste disposal trenches, which were used before disposal operations commenced at the LLWR, are believed to be the source of the tritium in these boreholes and also of that monitored in groundwater up-welling on the Sellafield beach (figure 7). 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.

Direct radiation

49 Some of the older Magnox buildings, principally 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.

50 Gamma dose rates are measured on a quarterly basis at 30 locations around the site perimeter (table 12) and on an annual basis at a further 28 locations in the surrounding district up to 4 km from the site. 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 0.13 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.

Radiological impact of operations at Sellafield

Critical group doses

51 Critical group doses have been calculated following the Principles for Total Retrospective Dose Assessment[7], which is consistent with last years report. In 2005 several changes were made to the dose calculation methodology in order to make the Sellafield Ltd. dose calculations more consistent with those presented by the Environment Agency and Foods Standards Agency, the methodology for which is presented in the National Dose Assessment Working Group (NDAWG) Paper 11-03[8]. These changes in methodology include:

- Milk dose is based on the mean concentration at a nearby farm with the highest individual result (paragraph 53).
- 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 effects of radiations from short-lived daughter radionuclides. 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 has been used in previous assessments.
- Tritium dose has 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

52 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[1]. In this report, the consumption and occupancy rates used by Sellafield Ltd for dose assessment purposes (table 21) are taken from the data published by Food Standards Agency for the five years 2003-2007[1]. 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[1].

53 Table 22 shows dose to the critical group of consumers of seafood (caught locally between St Bees and Selker). The estimated critical group dose was about 150 μSv compared to 179 μSv in 2006. 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 its dose by only about 1 μSv. The doses from the consumption of molluscs are likely to be overestimated because no account has been taken of the effects of food preparation procedures, such as the soaking of winkles to eliminate their gut contents which contain most of the

Figure 7. Tritium concentration in beach seepage (freshwater component), 1986-2007

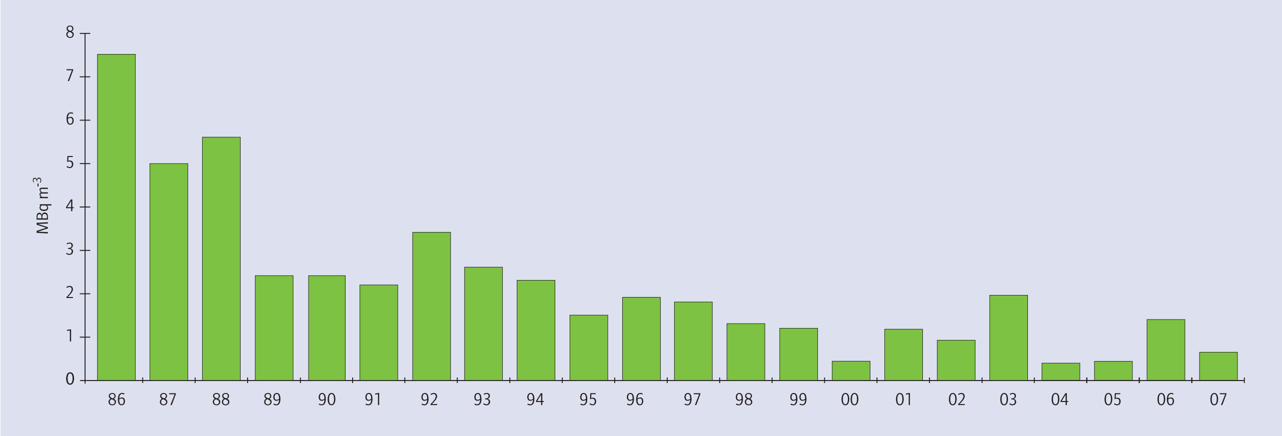


Table 21. Seafood consumption rates for people associated with marine discharges

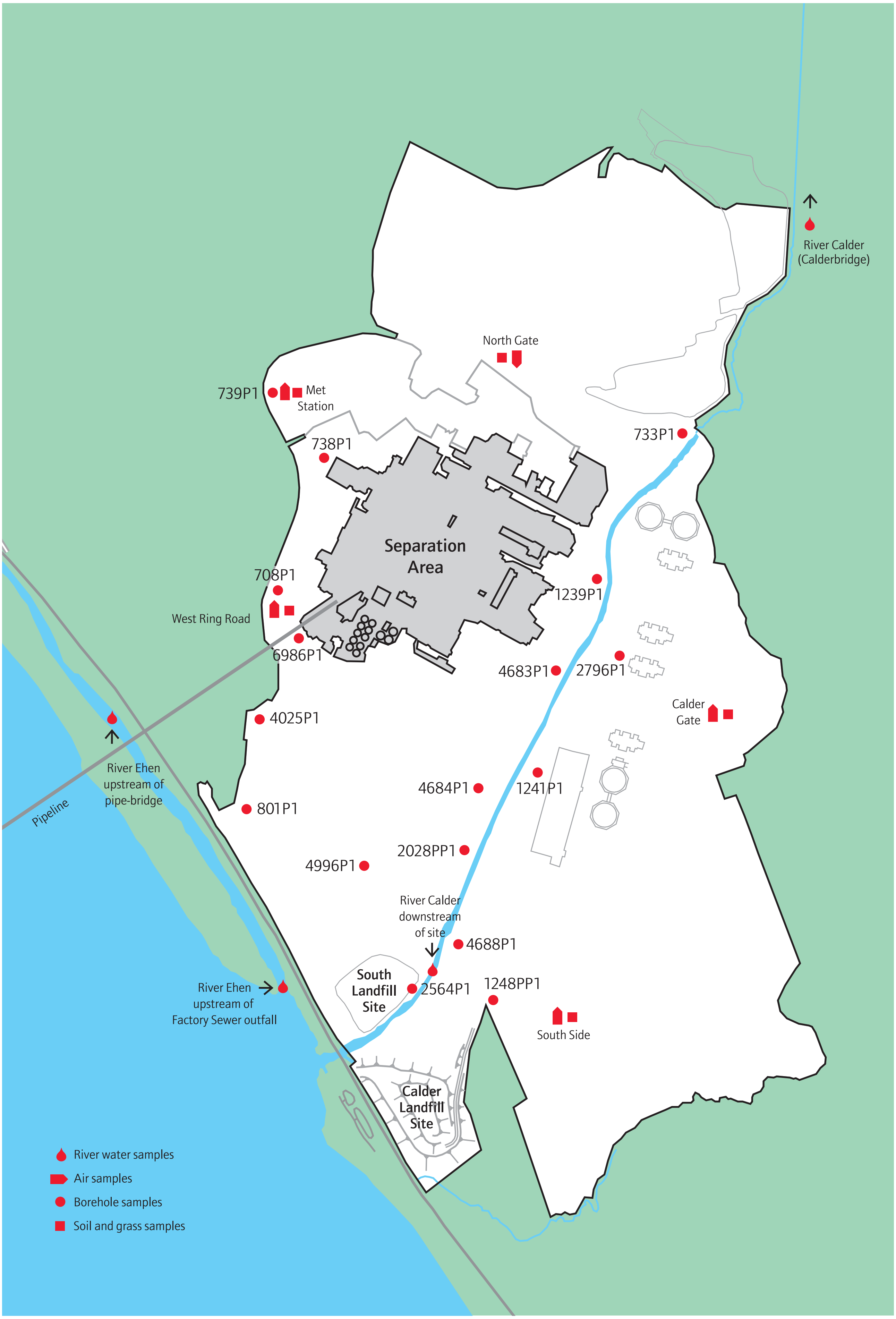
Seafood	Consumption rates (kg y-1)		
	Critical group (Sellafield fishing community)	Consumers associated with Whitehaven fishery	Typical fish eating public (Whitehaven)
Fish:			
cod	24.6	20	7.5
plaice	16.4	20	7.5
Crustaceans:			
crabs	13.2	-	
lobsters	5.3	-	-
Nephrops	3.8	9.7	-
Molluscs:			
winkles	17.6	-	-
mussels	16.4	-	-

Table 22. Summary of doses associated with marine discharges (μSv): Critical group consumers of seafoods[b] (Sellafield fishing community)

Radionuclide	Cod	Plaice	Lobster	Crab	*Nephrops*	Winkles	Mussels	Total for radionuclide
Carbon-14[a]	2.1	0.83	0.58	1.5	-	0.86	1.2	7.1
Cobalt-60	-	-	0.01	0.04	-	0.15	0.12	0.32
Strontium-90	-	-	-	0.17	-	-	0.48	0.65
Technetium-99	0.004	0.02	1.2	0.18	0.17	1.7	1.8	5.1
Ruthenium-106	0.07	0.03	-	0.33	-	0.89	0.80	2.1
Silver-110m	-	-	-	-	-	0.04	-	0.04
Antimony-125	-	-	-	-	-	0.02	0.05	0.07
Iodine-129	-	-	0.03	-	-	-	0.04	0.07
Caesium-137	2.6	0.87	0.17	0.26	-	1.1	0.49	5.5
Curium-alpha	-	-	-	-	-	-	0.15	0.15
Neptunium-237	-	-	-	-	-	-	0.05	0.05
Plutonium-alpha	0.06	0.08	0.28	1.1	-	13	33	48
Plutonium-241	-	-	-	-	-	1.1	3.4	4.5
Americium-241	0.05	0.07	2.1	3.4	0.76	21	49	76
Total for species	4.9	1.9	4.4	7.0	0.93	40	91	150
Total for group	150							

a. Calculated using background corrected activity concentrations (see paragraph 44).
b. Based on Sellafield area data for fish (Table 6) and Sellafield coastal area data for crustaceans and molluscs (Table 7)

Figure 8. Groundwater and radiological environmental monitoring at Sellafield



actinide radioactivity (adsorbed onto silt particles). Doses to typical fish-eating members of the public were as usual very low (1.9 µSv). Doses to consumers associated with the Whitehaven fishery (7.5 µSv) were lower than those of last year (11 µSv).

54 The Food Standards Agency and the Environment Agency[1] 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 890 hours each year on local beaches. This additional dose was estimated to be 36 µSv using averaged habit data for 2002-2006.

55 The Health Protection Agency[18] (HPA) continues to keep under review the monitoring and finding of radioactive particles on beaches near the Sellafield site. However, acting on the information supplied by the EA in July 2007, the HPA considered no special precautionary actions to be necessary regarding access to or use of these beaches.

Airborne and terrestrial pathways

56 For some years Sellafield Ltd has used consumption rates obtained from the approach used by the Health Protection Agency (HPA)[9], 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 potatoes in 2006; milk and beef in 2007). The remainder are assigned national mean consumption rates. The consumption rates used for 2007 are summarised in table 23. 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 24)[10,11].

57 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 A (excluding ruthenium-106 and iodine-131) reported in table 14, the estimated annual dose to infants who drink milk obtained only from local farms would have been about 15 µSv and the corresponding doses to adults, children and foetus about 4.8, 8.0 and 5.0 µSv (table 25). The doses from ruthenium-106 and iodine-131 in milk, shown in table 25, are assessed using standard modelling techniques[10,12,13] (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.

58 Based on the average concentrations reported in tables 13a, 13b, 15 and 16 for radioactivity in air, and in terrestrial foodstuffs other than milk, infants would have received an estimated dose of about 3.0 µSv (3.8, 3.7 and 1.8 µSv for adults, children and foetus) from these other foodstuffs and from inhalation. Detailed data are provided in tables 25 and 26.

59 Table 26 shows that overall, the main radionuclides contributing to doses from consumption and inhalation are strontium-90, ruthenium-106, iodine-129 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 Chernobyl (for caesium-137).

60 Members of the critical group also received a dose of less than 6.7 µSv arising from liquid effluent discharges. This dose contained an external component (<5 µSv) from radioactivity deposited on local beaches, based on data published by the Environment Agency and Food Standards Agency, and an internal component (1.7, 0.73, 0.73 and 1.3 µSv respectively to adults, children, infants and foetus) from an assumed consumption of locally caught fish (table 27).

Table 23. Consumption rates of critical group consumers associated with aerial discharges

Foodstuff[a]	Consumption rate (kg y^{-1})[g]		
	Adult	Child	Infant
milk	240	240	320
beef	45	30	10
beef liver	5.5	3	1
mutton	8	4	0.8
poultry[b]	10	5.5	2
game[c]	6	4	0.8
fish (cod + plaice)	15	6	3.5
leafy vegetables[d]	35	15	5
root vegetables[e]	50	45	10
fruit[f]	7	3	1
honey	2.5	2	2
eggs	8.5	6.5	5

a. Based on HPA/FSA recommendations.
b. Ducks only.
c. Rabbits and pheasants.
d. Cabbages and sprouts.
e. Local potatoes only.
f. Apples, blackberries and elderberries.
g. Consumption rates for foetal exposure are taken to be the same as those for adults.

Table 24. 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 y^{-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 HPA, 2005)[14].

Table 25. Summary of doses to the terrestrial critical group from terrestrial foodstuffs and inhalation (μSv)[a]

Radionuclide	Milk				Beef				Beef offal			
	Adult	Child	Infant	Foetus	Adult	Child	Infant	Foetus	Adult	Child	Infant	Foetus
Total tritium	0.04	0.05	0.15	0.06	0.009	0.009	0.006	0.014	0.002	0.002	0.001	0.003
Carbon-14[b]	0.08	0.11	0.30	0.11	-	-	-	-	0.02	0.01	0.01	0.03
Cobalt-60	-	-	-	-	0.09	0.20	0.16	0.05	0.003	0.005	0.004	0.002
Strontium-90	2.7	5.8	11	4.0	0.014	0.02	0.009	0.021	0.04	0.05	0.02	0.06
Ruthenium-106	0.0002	0.0004	0.002	0.00001	0.47	0.68	0.74	0.026	0.05	0.06	0.06	0.003
Antimony-125	0.03	0.05	0.19	0.01	0.010	0.01	0.012	0.004	0.003	0.003	0.003	0.001
Iodine-129	0.60	1.0	1.6	0.24	0.20	0.23	0.09	0.08	0.02	0.02	0.01	0.01
Iodine-131	0.008	0.02	0.09	0.009	-	-	-	-	-	-	-	-
Caesium-134	-	-	-	-	-	-	-	-	-	-	-	-
Caesium-137	1.3	1.0	1.6	0.59	0.46	0.23	0.09	0.20	0.03	0.01	0.005	0.01
Plutonium alpha	-	-	-	-	0.007	0.005	0.0025	0.00026	0.004	0.002	0.001	0.0001
Plutonium-241	-	-	-	-	-	-	-	-	-	-	-	-
Americium-241	-	-	-	-	0.005	0.003	0.0019	0.00006	0.006	0.003	0.002	0.00007
Total	4.8	8.0	15	5.0	1.27	1.39	1.11	0.40	0.18	0.17	0.12	0.12

Radionuclide	Mutton				Poultry				Eggs			
	Adult	Child	Infant	Foetus	Adult	Child	Infant	Foetus	Adult	Child	Infant	Foetus
Total tritium	0.003	0.002	0.001	0.005	0.003	0.002	0.002	0.004	0.002	0.002	0.004	0.003
Carbon-14[b]	-	-	-	-	0.15	0.11	0.08	0.20	-	-	-	-
Cobalt-60	0.005	0.01	0.004	0.003	0.003	0.006	0.005	0.002	0.006	0.01	0.03	0.003
Strontium-90	0.02	0.02	0.005	0.03	0.009	0.01	0.006	0.01	0.01	0.01	0.01	0.01
Ruthenium-106	0.10	0.10	0.07	0.005	0.06	0.07	0.09	0.003	0.04	0.06	0.15	0.002
Antimony-125	0.005	0.005	0.003	0.002	0.004	0.005	0.005	0.002	0.004	0.005	0.01	0.002
Iodine-129	0.04	0.03	0.01	0.01	0.03	0.03	0.01	0.01	0.04	0.05	0.04	0.01
Iodine-131	-	-	-	-	-	-	-	-	-	-	-	-
Caesium-134	-	-	-	-	-	-	-	-	-	-	-	-
Caesium-137	0.27	0.10	0.02	0.12	0.04	0.02	0.01	0.02	0.01	0.006	0.01	0.004
Plutonium alpha	0.001	0.0003	0.0001	0.00002	0.001	0.0004	0.0003	0.00003	0.0004	0.0004	0.0004	0.00002
Plutonium-241	-	-	-	-	-	-	-	-	-	-	-	-
Americium-241	0.001	0.0004	0.0001	0.00001	0.001	0.0004	0.0002	0.00001	0.0003	0.0003	0.0004	0.000005
Total	0.45	0.27	0.11	0.18	0.30	0.25	0.21	0.26	0.11	0.14	0.25	0.03

Radionuclide	Game				Honey				Potatoes			
	Adult	Child	Infant	Foetus	Adult	Child	Infant	Foetus	Adult	Child	Infant	Foetus
Total tritium	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.01	0.01	0.003	0.01
Carbon-14[b]	-	-	-	-	-	-	-	-	0.01	0.01	0.01	0.01
Cobalt-60	0.002	0.004	0.002	0.001	0.002	0.004	0.01	0.001	-	-	-	-
Strontium-90	0.005	0.01	0.002	0.01	0.004	0.007	0.01	0.006	-	-	-	-
Ruthenium-106	0.02	0.03	0.02	0.001	0.002	0.004	0.012	0.0001	0.14	0.3	0.2	0.01
Antimony-125	0.002	0.003	0.001	0.001	0.001	0.001	0.004	0.0004	-	-	-	-
Iodine-129	0.03	0.04	0.01	0.01	0.008	0.011	0.013	0.003	0.11	0.17	0.04	0.04
Iodine-131	-	-	-	-	-	-	-	-	-	-	-	-
Caesium-134	-	-	-	-	-	-	-	-	-	-	-	-
Caesium-137	0.06	0.03	0.01	0.02	0.041	0.025	0.030	0.018	-	-	-	-
Plutonium alpha	0.0008	0.0005	0.0002	0.00003	0.0004	0.0003	0.0005	0.00001	-	-	-	-
Plutonium-241	-	-	-	-	-	-	-	-	-	-	-	-
Americium-241	0.002	0.001	0.0004	0.00002	0.0002	0.0002	0.0003	0.000003	-	-	-	-
Total	0.12	0.12	0.05	0.05	0.06	0.05	0.08	0.03	0.27	0.49	0.25	0.07

a. Values in grey have been calculated using FSA monitoring data
b. Calculated using background corrected activity concentrations (see paragraph 44).

Table 25. continued

Radionuclide	Green Veg				Fruit				Drinking Water			
	Adult	Child	Infant	Foetus	Adult	Child	Infant	Foetus	Adult	Child	Infant	Foetus
Total tritium	0.003	0.002	0.001	0.004	0.002	0.001	0.001	0.003	0.08	0.06	0.10	0.12
Carbon-14[b]	-	-	-	-	0.03	0.02	0.01	0.04	-	-	-	-
Cobalt-60	0.01	0.02	0.01	0.01	0.005	0.01	0.01	0.003	-	-	-	-
Strontium-90	0.05	0.05	0.02	0.08	0.13	0.12	0.06	0.19	0.09	0.11	0.11	0.13
Ruthenium-106	0.11	0.10	0.11	0.01	0.06	0.05	0.06	0.003	-	-	-	-
Antimony-125	0.01	0.005	0.005	0.002	0.004	0.003	0.003	0.002	0.0007	0.0007	0.002	0.0003
Iodine-129	0.06	0.04	0.02	0.02	0.02	0.02	0.01	0.01	-	-	-	-
Iodine-131	-	-	-	-	-	-	-	-	-	-	-	-
Caesium-134	-	-	-	-	-	-	-	-	-	-	-	-
Caesium-137	0.005	0.002	0.001	0.002	0.02	0.01	0.003	0.01	0.08	0.04	0.03	0.03
Plutonium alpha	0.0017	0.0008	0.0004	0.0001	0.004	0.002	0.001	0.0002	0.15	0.09	0.11	0.01
Plutonium-241	-	-	-	-	-	-	-	-	-	-	-	-
Americium-241	0.001	0.0003	0.0002	0.00001	0.01	0.004	0.002	0.0001	0.14	0.09	0.12	0.002
Total	0.25	0.22	0.17	0.13	0.29	0.24	0.16	0.26	0.54	0.39	0.47	0.29

Radionuclide	Inhalation			
	Adult	Child	Infant	Foetus
Total tritium	-	-	-	-
Carbon-14[b]	-	-	-	-
Cobalt-60	-	-	-	-
Strontium-90	0.003	0.002	0.002	0.001
Ruthenium-106	0.01	0.01	0.01	0.0002
Antimony-125	0.001	0.001	0.001	0.00004
Iodine-129	-	-	-	-
Iodine-131	-	-	-	-
Caesium-134	0.0003	0.0001	0.0001	0.0001
Caesium-137	0.003	0.001	0.001	0.001
Plutonium alpha	0.59	0.32	0.18	0.01
Plutonium-241	0.30	0.15	0.06	0.005
Americium-241	0.43	0.23	0.14	0.003
Total	1.3	0.71	0.39	0.02

a. Values in grey have been calculated using FSA monitoring data
b. Calculated using background corrected activity concentrations (see paragraph 44).

61 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 2007 to adults, children, infants and foetus living near to Sellafield would have been respectively 0.34, 0.24, 0.24 and 0.34 μSv using modelling and dosimetry published by the EU and the ICRP[12,13] (table 28).

62 The doses to the terrestrial critical group are summarised in table 28. If all the above pathways are considered to be additive, the highest dose to infants in 2007 was about 24 μSv. Doses to adults, children and foetus were slightly lower. The changes to the dose assessment methodology (paragraph 48), and the inclusion of an external dose that is quoted as a less 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 also assumed that members of this critical group are also exposed to direct radiation (see next paragraph and table 1).

Direct radiation

63 Due to the closure of Calder Hall in March 2003 (paragraph 26), direct radiation doses to local residents have reduced significantly from about 9 μSv. Based on recent surveying work conducted in 2007 the upper bound of the dose range to residents living closest to the site is about 1.3 μSv.

Collective doses

64 Collective doses resulting from the effects of discharges from Sellafield in 2007, summed over 500 years, have been calculated in accordance with paragraphs 29-31 and 39 of the Introduction (amplified in the Appendix). The results (table 29) give collective dose commitments (combined aerial and marine) of about 1.8 man Sv to the UK population, 7.2 man Sv to the European population (including the UK) and 72 man Sv to the world population. These are lower than the values reported in 2006 due to a decrease in tritium and carbon-14 discharges reflecting reduced reprocessing throughputs (paragraphs 11 and 20-22).

65 Most of the collective dose commitment from Sellafield discharges results from carbon-14 because of its long radioactive half-life (5760 years) and its incorporation into the global carbon cycle. However, individual doses from this source are generally small.

66 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[14].

Non-radioactive discharges and disposals

67 Non-radioactive discharges and disposals from the Sellafield site are made in accordance with the requirements of appropriate authorisations, consents and licences. Liquid effluent discharges are summarised in table 30 and include all discharges for which load or concentration limits are specified, together with other discharges for which no limits have been specified. Aerial discharges are summarised in table 31.

Discharges made under the terms of consents

68 Liquid effluent discharges, from plants on the Sellafield site not covered by the IPC authorisations or PPC permit(s), are subject to separate discharge consents. These consents generally place limits on pH, temperature and a range of instantaneous concentrations.

69 In particular, the Calder interceptor sewer constructed on the southern side of the River Calder receives outfalls which had previously discharged directly into the river. This sewer discharges directly to sea via a pipeline outfall. It was installed primarily to protect the River Calder from non-radioactive pollutants and consequently is not authorised to discharge radioactivity. Similarly, discharges from the Geoffrey Schofield Laboratories into the public sewerage system are subject to the conditions of a consent issued by United Utilities North West.

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

70 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 28). 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

71 The Company is committed to minimising the use of ozone depleting substances. Routine releases are estimated from the amounts used to top up systems on site. Site releases of ozone depleting substances are summarised in table 32.

Carbon dioxide and other greenhouse gases

72 Sellafield discharges of carbon dioxide and methane are mainly from Fellside combined heat and power plant, which is wholly owned by Sellafield Ltd and its emissions controlled by the Sellafield IPC authorisations and subsequently PPC permit(s) (table 31). In addition, small amounts of carbon dioxide are released from the process plants. Discharges of carbon dioxide in 2007 were slightly lower than those in 2006.

73 Sulphur hexafluoride is used periodically in small quantities for testing the effectiveness of stack and duct sampling systems (table 31). Discharges were about 150 g in 2007 compared to about 100 g in 2006.

Off-site disposals of solid waste

74 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

75 The Prescribed Process authorisations, which came into force in 1996, included a requirement for Sellafield Ltd to agree a monitoring programme with the Environment Agency and this has been carried out since 1997 (see figure 8). 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.

Air sampling

76 Measurements of nitrogen dioxide and sulphur dioxide concentrations in air are made at five locations on the Sellafield site: West Ring Road, Meteorological Station, South Side, North Group roundabout and Calder Gate. (It should be noted that significant discharges of these gases are also made from the nearby Fellside Combined Heat and Power plant and these will strongly influence airborne concentrations measured in the environment in the vicinity of Sellafield.) Measurements are made using passive diffusion tubes which are exposed for one month before being analysed. In addition, air samplers are used at the same locations for making measurements of heavy metals associated with particulates in air. Air sampling results are summarised in table 33.

Water sampling

77 Water samples are obtained from the Rivers Calder and Ehen at locations both upstream and downstream of the site (table 34). The downstream samples are taken above

Table 26. Summary of radionuclide doses to the terrestrial critical group from terrestrial foodstuffs and from inhalation

Radionuclide	Total dose per radionuclide (μSv) in 2007			
	Adult	Child	Infant	Foetus
Tritium	0.16	0.14	0.27	0.23
Carbon-14[a]	0.29	0.26	0.41	0.39
Cobalt-60	0.13	0.27	0.24	0.08
Strontium-90	3.1	6.2	11	4.6
Ruthenium-106	1.1	1.5	1.5	0.06
Antimony-125	0.07	0.09	0.24	0.03
Iodine-129	1.2	1.6	1.9	0.44
Iodine-131	0.01	0.02	0.09	0.01
Caesium-134	0.0003	0.0001	0.0001	0.0001
Caesium-137	2.3	1.5	1.8	1.03
Plutonium alpha	0.8	0.4	0.3	0.02
Plutonium-241	0.30	0.15	0.06	0.005
Americium-241	0.60	0.33	0.27	0.005
Total overall dose	10	12	18	6.8
Inhalation	1.3	0.71	0.39	0.02
All foodstuffs	9	12	18	6.8
Milk	4.8	8.0	15	5.0
Foodstuffs other than milk	3.8	3.7	3.0	1.8

a. Calculated using background corrected activity concentrations (see paragraph 44).

Table 27. Summary of doses to the terrestrial critical group from seafood consumption (μSv)

Radionuclide	Dose in 2007 (μSv)			
	Adult	Child	Infant	Foetus
Carbon-14[a]	0.65	0.36	0.42	0.90
Technetium-99	0.01	0.01	0.02	0.01
Ruthenium-106	0.02	0.02	0.04	0.001
Caesium-137	0.98	0.30	0.21	0.43
Plutonium alpha	0.04	0.02	0.02	0.002
Americium-241	0.04	0.02	0.02	0.0004
Total	1.7	0.73	0.73	1.3

a. Calculated using background corrected activity concentrations (see paragraph 33).

Table 28. Summary of doses to the terrestrial critical group (μSv) in 2007

Pathway	Adult	Child	Infant	Foetus
Food consumption:				
terrestrial foods	8.6	12.0	17.8	6.8
marine foods	1.7	0.73	0.73	1.3
Inhalation	1.3	0.71	0.39	0.02
Immersion:				
krypton-85	0.34	0.24	0.24	0.34
External	<5	<5	<5	<5
Total	17	19	24	13

a. Assuming external radiation at the maximum of 5μSv.

Table 29. **Collective doses from Sellafield's discharges**

Radionuclide	Collective dose (man Sv) from discharges in 2007					
	Aerial discharges			Marine discharges		
	UK	Europe	World	UK	Europe	World
Tritium	0.06	0.13	0.16	0.0003	0.001	0.03
Carbon-14	0.08	0.71	6.4	1.2	4.5	60
Krypton-85	0.07	0.38	3.7	-	-	-
Technetium-99	-	-	-	0.01	0.03	0.03
Iodine-129	0.21	1.0	1.4	0.002	0.01	0.03
Caesium-137	0.001	0.002	0.002	0.11	0.26	0.29
Plutonium Alpha	0.004	0.01	0.01	0.01	0.02	0.02
Americium-241	0.003	0.004	0.004	0.0004	0.001	0.001
Other nuclides	0.002	0.003	0.003	0.07	0.14	0.15
Total	0.4	2.2	12	1.4	5.0	60

Table 30. **Non-radioactive liquid effluent discharges[a]**

Substance	Release points	Discharge (te)
Mercury	SETP, EARP, Thorp-C14 removal plant	0.001
Cadmium	Thorp-C14 removal plant	0.00000003
Copper	SETP, EARP, Lagoon	0.01
Zinc	SETP, EARP, Lagoon	0.04
Lead	SETP, EARP, Lagoon	0.004
Chromium	SETP, EARP, SIXEP	0.24
Arsenic	SETP, SIXEP, Thorp C-14 removal plant	0.001
Boron	SETP, EARP, SIXEP, Thorp ponds	1.4
Barium	Thorp-C14 removal plant	0.01
Nickel	SETP, EARP	0.01
Iron	SETP, EARP	0.20
N as NO_2 and NO_3	SETP, EARP, Factory sewer, Thorp-C14 removal plant	900
COD[b]	Factory sewer, Calder interceptor sewer	99
Glycol	SETP, EARP, SIXEP	0.89
TBP[b]	SETP, EARP	11
Uranium[c]	SETP, SIXEP, EARP	0.30

a. Data presented are either load data (based on bulk sampling) as reported under the terms of the IPC Authorisation, or estimated from spot sample results.
b. Chemical Oxygen Demand (COD) and tributylphosphate (TBP).
c. This data is taken from the radioactive discharges report, Table 2, and is derived from the analysis of half-monthly bulks.

the confluence of the two rivers, and at times which minimise contamination with seawater. As a result of the review of the SEMP (paragraph 14), seawater samples are now obtained from the shoreline areas given in table 34 rather than from offshore sites as performed in previous years.

Monitoring of Sellafield's landfill sites

78 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 comprised water sampling from the River Calder upstream and downstream of the tips and gas monitoring over their surfaces. The river water was spot sampled monthly and gas monitoring carried out quarterly as a minimum. The results are summarised in table 35.

Environmental impact of non-radioactive discharges

79 In this report, the impact of aerial discharges has been addressed (table 33) by comparing the measured environmental concentrations with the most restrictive (annual mean) national air quality objectives[15] for nitrogen dioxide and lead, the international standard[16] for sulphur dioxide, and Long Term Environmental Assessment Levels (LTEAL)[17] for vanadium, cadmium and phosphorus.
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

(continued on page 42)

Table 31. **Non-radioactive aerial effluent discharges**

Substance	Release point	Discharge (te)	Annual Limit (te)
Oxides of nitrogen (as NO_2)	Thorp main stack	12	90
Oxides of nitrogen (as NO_2)	Thermal denitration plant scrubber	0.40	35
Oxides of nitrogen (as NO_2)	B204 stack, B6 cell vent stack, WVP secondary off- gas system, B230 stack, EARP, STP stack and CHP	10	-
Volatile organic compounds (VOCs)	B204 stack, B6 cell vent stack, STP stack, flask maintenance paint spray booth, Thorp main stack and CHP	96	-
Particulate matter	STP stack, flask maintenance grit blast booth	0.0006	0.05
Particulate matter	CHP (as PM_{10})	0.65	-
Uranium	B204 stack, B6 cell vent stack, thermal denitration plant scrubber, WVP secondary off-gas system, STP stack	0	-
Carbon dioxide	CHP, B204 stack, B6 cell vent stack, SIXEP stack	550,000	-
Carbon monoxide	CHP, B230 stack	25	-
Methane	CHP, STP stack	63	-
Sulphur hexafluoride	Ventilation system commissioning and testing	0.00015	-

Table 32. **Discharges of ozone depleting substances**

Substance	Discharge (te)
R22 HCFC	1.3
R407C HFC	0.18

Table 33. **Non-radioactive monitoring of air**

	Mean concentration in air (µg m^{-3})					
	NO_2	SO_2	Lead	Vanadium	Cadmium	Phosphorus
North Gate	13	13	0.007	0.003	0.0001	0.02
Meteorological Station	8.1	8.1	0.005	0.002	0.0001	0.02
Calder Gate	12	5.2	0.005	0.002	0.00009	0.02
West Ring Road	15	5.1	0.005	0.003	0.00009	0.03
South Side	12	7.9	0.003	0.002	0.00007	0.02
Air quality objective[a]	40	50	0.25	-	-	-
LTEAL[a]	-	-	-	5	0.005	1

a. *See paragraph 76.*

Table 34. Non-radioactive monitoring of river and coastal waters

	pH	Conductivity (μSiemens cm^{-1})	milligrammes per litre			
			NO_3	N as NO_2	Fe	TBP[a]
River Calder - downstream of site	7.4	110	3.1	<0.07	0.09	0
River Calder - upstream of site	7.6	100	6.4	<0.07	0.08	0
River Ehen - downstream of pipebridge	8.1	690	6.5	<0.07	0.17	0
River Ehen - upstream of Factory sewer outfall	8.2	220	6.2	<0.07	0.16	0

	pH	milligrammes per litre												
		NO_3	N as NO_2	Ba	B	Cd	Cu	Fe	Pb	Ni	U	Zn	TBP[a]	VFP[a]
Braystones	8.0	0.58	<0.11	0.01	4.0	0.00003	0.001	<0.004	<0.0002	0.001	0.004	0.004	0	0
Drigg	8.0	0.32	<0.11	0.01	4.0	0.00003	0.001	0.02	<0.0002	0.001	0.004	0.006	0	0
Seascale	8.0	1.5	<0.11	0.01	3.7	0.00003	0.001	0.006	<0.0002	0.001	0.003	0.008	0	0
Sellafield	8.1	0.50	<0.11	0.01	3.9	0.00003	0.001	<0.005	<0.0001	0.001	0.004	0.004	0	0
St. Bees	8.0	0.96	<0.11	0.01	4.0	0.00003	0.001	0.004	<0.0002	0.001	0.004	0.004	0	0

a. *Tributylphosphate (TBP) and Visible Free Phase (VFP). A zero VFP is recorded if no oil film is visible on the water surface.*

Table 35. Non-radioactive monitoring of surface water and gases on Sellafield's landfill sites

Surface water analysis	pH	Temperature (°C)	Conductivity[a] (mSiemens cm^{-1})	Dissolved O_2 (ppm)	N as NH_3 (mg l^{-1})	Cl (ppm)	COD (mg l^{-1})	Total suspended solids (mg l^{-1})
North Landfill Site Extension								
Stream to north	7.0	9.0	0.34	9	0.04	33	21	68
River Calder upstream	7.1	8.0	0.14	11	0.01	12	2.0	1.0
River Calder downstream	7.0	8.0	0.14	11	0.01	12	2.0	1.0
North Landfill Site								
River Calder upstream	-	-	-	-	-	-	-	-
River Calder downstream	-	-	-	-	-	-	-	-
Calder Floodplain Landfill								
River Calder downstream	-	-	-	-	-	-	-	-
Calder Floodplain Landfill Extension								
New Mill Beck upstream	7.0	9.0	0.30	10	0.13	32	28	9.0
River Calder downstream	7.0	9.0	0.37	10	0.08	51	26	5.0
South Landfill Site								
River Calder upstream	-	-	-	-	-	-	-	-
River Calder downstream	-	-	-	-	-	-	-	-

Gas spike probe monitoring	CH_4 (ppm)	CO_2 (%)	O_2 (%)
North Landfill Site Extension	0	1.6	19
North Landfill Site	0	4.0	15
Calder Floodplain Landfill	1.2	1.6	16
Calder Floodplain Landfill Extension	0	0.8	19
South Landfill Site	0	1.3	19

a. *In Table 35 of 2005 and 2006 reports, conductivity units should have been mSiemens cm^{-1}.*

sources. The data in table 33 show that the measured concentrations in air on the Sellafield site were all below the guideline value.

80 The results in table 34 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.

81 Environmental monitoring results (table 35) confirm that the impact of Sellafield's landfill sites remains negligible. No significant concentrations of carbon dioxide or methane from off-gas have been measured at these sites.

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Capenhurst

Discharges and Monitoring of the Environment in the UK
Annual Report 2007

Summary

1 At no time during 2007 have discharges and disposals of 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 continued to be less than 1 μSv (table 1) and were therefore radiologically insignificant.

Table 1. Summary of critical group doses in the vicinity of Capenhurst (μSv)

Pathway	Liquid discharges		Aerial discharges		Position in text (paragraph no.)
	2006	2007	2006	2007	
Rivacre Brook: child playing	<1	<1*	-	-	21
Milk consumption: infant	-	-	<1	<1*	23

** Estimate only (figures are based on RIFE-12). Actual figure not available until issue of RIFE-13 report in Autumn of 2008.*

Operations at Capenhurst

2 Capenhurst, situated near Ellesmere Port on the Wirral, consists principally of centrifuge plants and a redundant gaseous diffusion plant. In 1993, the Capenhurst site was split into two companies: BNFL Capenhurst, and URENCO (Capenhurst) Ltd who own and operate the centrifuge plants on site. In 2005, BNFL Capenhurst became part of British Nuclear Group Sellafield Ltd. In June 2007, this company was rebranded as Sellafield Ltd. For future reference throughout this chapter, Capenhurst relates to the site run by Sellafield Ltd. URENCO (Capenhurst) Ltd will be referred to as appropriate. The main activities undertaken during 2007 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.

3 URENCO (Capenhurst) Ltd has been granted its own authorisations for the transfer of both liquid and solid waste to Capenhurst for onward disposal. Summaries of these transfers are given in the Health, Safety and Environmental Report 2007 published by URENCO (Capenhurst) Ltd. This is available from the latter's Health, Physics and Safety Records Office, Capenhurst, Chester CH1 6ER.

Radioactive discharges and disposals

4 Capenhurst holds a number of authorisations covering discharges and disposals of radioactive wastes to the Rivacre Brook, to atmosphere and by burial in the ground at Clifton Marsh and the LLWR. A further authorisation covers very low levels of radioactivity in special waste. The Environment Agency commenced a review of all of the site's authorisations in 2001. A public consultation commenced during the latter part of 2006 to consider the new multi-media authorisation limits and conditions. The new MMA became effective on 1st September 2007. Consequently, all previous RSA93 authorisations were revoked.

Liquid discharges into the Rivacre Brook

5 Liquid wastes principally arise from decommissioning operations. These wastes, together with those from URENCO (Capenhurst) Ltd, are all discharged into the Rivacre Brook by means of a partly culverted ditch. Prior to September 2007 the discharges were covered by two quantitative authorisations, one for uranic type discharges and one specific to discharges from the former tritium processing facility. This latter authorisation has now been revoked.

6 Collectively, the authorisations include quarterly limits for a number of individual radionuclides. Discharges of 'total alpha' activity are subject to daily (24 hour) limits. In order

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

Radionuclide	Mean radionuclide concentration					
	2003	2004	2005	2006	2007	Authorised Limit[a]
Total alpha (Bq l^{-1})	<5	<5	<5	<5	<5	100
Tritium (Bq ml^{-1})	0.1	0.07	0.05	0.05	0.05	111
	Annual discharge (GBq)					
Total uranium alpha activity	0.9	0.39	0.19	0.10	0.09	20
Uranium daughters	<0.9	0.56	0.39	0.18	0.07	20
Non-uranic alpha emitters (mostly neptunium-237)	0.007	0.012	0.009	0.021	0.030	3
Technetium-99	0.9	0.38	0.17	0.08	0.04	100
Tritium	100	67	31	33	31	78,000[b]

a. Where authorised limits are specified for periods of three consecutive calendar months, annual equivalents have been derived by multiplying these limits by four. Authorised limits changed from 01/09/2007 but have been retained for 2007 reporting purposes.
b. Derived limit based on quarterly limit and average brook flow of 80 m^3 h^{-1}. Revoked from 01/09/2007.

Table 3. Airborne radioactive waste discharges

Radionuclide	Annual discharge (GBq)					Authorised Limit (GBq)[a]
	2003	2004	2005	2006	2007	
Uranium	0.010	0.006	0.001	<0.001	<0.001	-
Tritium	10	1	1	<1	<1	1,600,000[b]

a. Authorised limits changed from 01/09/2007 but have been retained for 2007 reporting purposes.
b. Revoked from 01/09/2007.

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.

7 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.

Other liquid wastes

8 Capenhurst was authorised under the Radioactive Substances Act 1960 to dispose of Special Waste within the meaning of, and in accordance with, the Control of Pollution (Special Waste) Regulations 1980. The quantities of radioactivity in this waste are very low. Under the terms of the authorisation the Company is required to use Best Practicable Means (BPM) to limit the activity content and to ensure that the total activity, excluding decay products, does not exceed 1 MBq m^{-3}. There were no disposals of such waste in 2007. This authorisation has now been revoked.

Aerial discharges

9 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.

10 The radioactive content of discharges from the incinerator and the majority of other 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 new MMA includes the introduction of quantitative limits on airborne radioactive discharges.

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

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

	2003	2004	2005	2006	2007
Bulk weight (tonnes)	1300	620	1100	1100	480
Uranium alpha content (MBq)	5000	5500	9800	6100	1400

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

	2003	2004	2005	2006	2007	Authorised Limit[a]
Volume (m^3)	360	470	1900	98	0	6000
Uranium (GBq)	3.3	15	18	18	0	250
Other alpha emitters (GBq)	1.7	2.5	5.3	0.11	0	15
Others (GBq)	70	1100	770	62	0	3000

a. Authorised limits changed from 01/09/2007 but have been retained for 2007 reporting purposes.

Solid wastes

12 The Clifton Marsh authorisation was varied in both 2004 and 2005 to control waste disposals based on the radioactive content rather than a mass limit. The Ulnes Walton authorisation (unused since 1984) was finally revoked in 2004. Meanwhile, the Statutory Environmental Monitoring Programme relating to this site is continuing as part of Springfields Fuels Limited's programme.

13 Solid waste disposals at Clifton Marsh are shown in table 4. Recent increases reflect accelerated decommissioning activities. The waste consists of ash, scrap metal and other non-combustible materials, such as glassware and building rubble. It can also include incinerator ash generated from waste transferred from URENCO (Capenhurst) Ltd under the terms of an RSA inter-site transfer authorisation. 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 were introduced as part of the MMA.

14 Solid waste which does not conform to the requirements of the Clifton Marsh authorisation is disposed of to the LLWR. An authorisation specific to Capenhurst for the disposal of waste to the LLWR came into force in 1992. A variation to this authorisation allowing disposal to the LLWR via the Waste Monitoring and Compaction (WAMAC) plant at Sellafield came into effect in 1996. A further variation took place in 2005 to increase the volume limit whilst maintaining the activity limits. Annual activity limits are revised as part of the MMA.

Table 6. Environmental monitoring related to discharges to the Rivacre Brook

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	Tritium
Point A (see figure 1)					
silt	10	560	890	12	-
Point B (see figure 1)					
water	10	0.5	0.3	0.019	50
algae - *Cladophora*	5	12	38	2.0	-
silt	10	82	250	10	-

Monitoring of the environment for radioactivity

15 The principal exposure pathways for radioactivity discharged from the Capenhurst site, as identified by environmental monitoring and habits surveys, are 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 Food Standards Agency's monitoring programme[1] and the site's Statutory Environmental and Monitoring Programme illustrated in figure 1 which also includes the sampling of water weed, grass and bovine faeces. It is worth noting the monitoring of milk and bovine faeces ceased as part of the MMA introduction. The low direct radiation dose rates from the site are also routinely monitored.

Aquatic pathways

16 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 (see figure 1 and 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

17. The discharges to atmosphere are radiologically insignificant. However, Sellafield Ltd collects samples of grass from two on-site locations and bovine faeces from four local farms (figure 1) and analyses them for technetium-99 and uranium on a fresh mass basis. The results for grass and bovine faeces were all below the limit of detection for technetium-99 (37 Bq kg^{-1}) and averaged 1.0 Bq kg^{-1} and 4.0 Bq kg^{-1} respectively for uranium.

18 The Food Standards Agency undertakes a monitoring programme for uranium in samples of milk. Recent results[1] show that mean uranium concentrations in milk samples collected from a local farm were below the limits of detection (0.0066 Bq l^{-1}).

19 Until the introduction of the MMA Sellafield Ltd also undertook a quarterly monitoring programme for tritium levels in on-site grass samples and a monthly monitoring programme for milk from three local farms. Tritium levels in on-site grass samples were all below the limit of detection (50 Bq kg^{-1}). Levels in milk were below the limit of detection (50 Bq l^{-1}). Sampling of tritium ceased as part of the MMA introduction.

Direct radiation

20 Dose rates at the site perimeter and other locations are measured annually. 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. The mean dose rate was less than 0.2 μGy h^{-1}, including natural background, with a peak level of 1.4 μGy h^{-1} at part of the site perimeter.

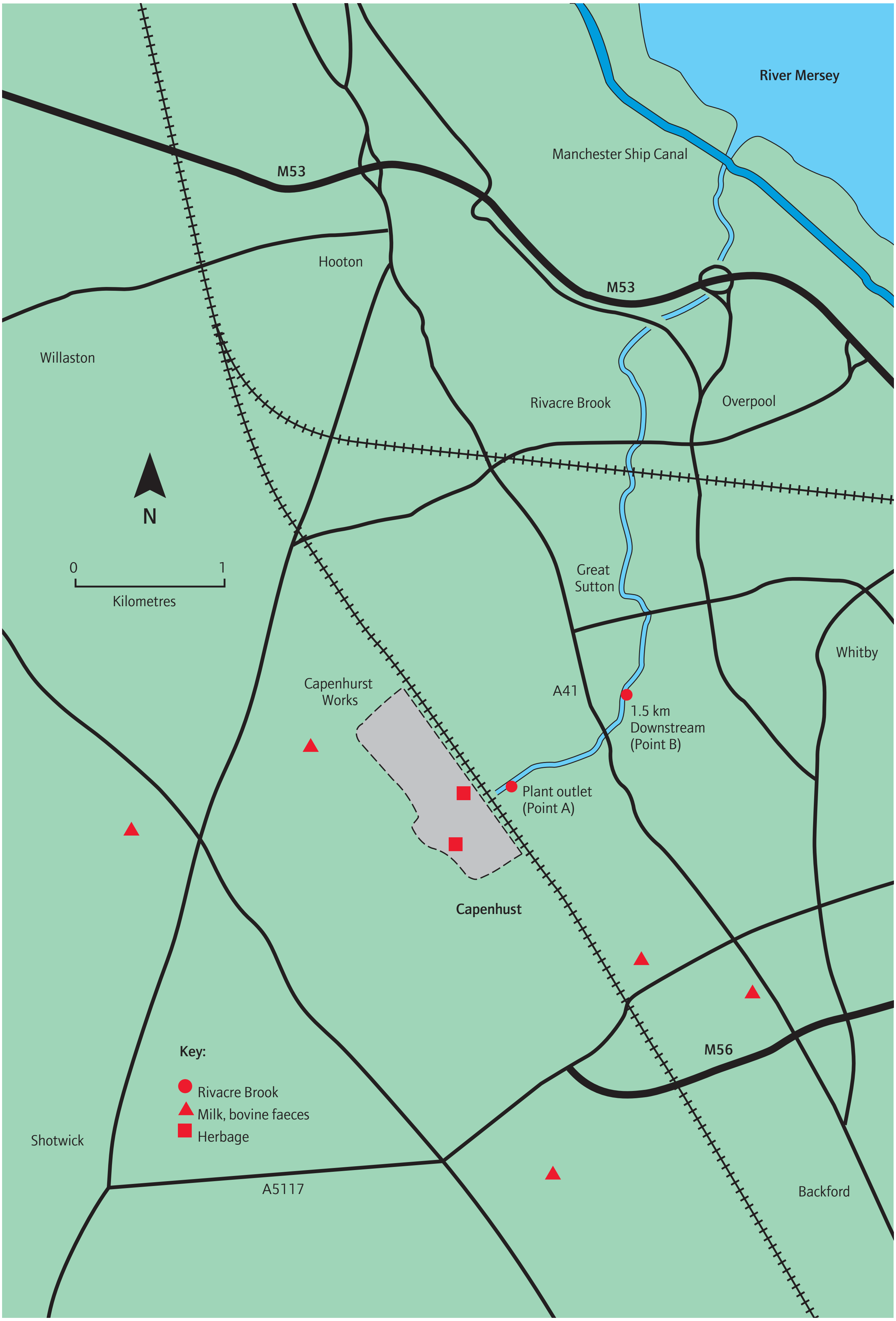
Radiological impact of operations at Capenhurst

Critical group doses

Aquatic pathways

21 The only identified critical pathway[2] for liquid discharges is the dose due to the inadvertent ingestion of water or silt by children playing on or near the Rivacre Brook. This dose is estimated at 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[2]. The number of hours children play on or near the Rivacre Brook, and any potential water and silt ingestion rates, are those recommended by the NRPB for generic use where no habit survey has been carried out[3], and previously used by the Environment Agency[2]. This data is more realistic for the critical pathway applicable to Capenhurst, than the pessimistic assumptions used by the Food Standards Agency and the Environment Agency[1].

Figure 1. Environmental monitoring around Capenhurst



Airborne and terrestrial pathways

22 The radiotoxicity of uranium is low compared with its chemical toxicity. The uranium concentrations in bovine faeces 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.

23 Assuming that all milk consumed comes from local farms, the dose to the most exposed member of the public (i.e. a one year old infant) was estimated as less than 1 μSv, including the contribution from tritium (table 1).

Direct radiation

24 Members of the public spend very little time in the immediate vicinity of the perimeter of the combined sites and so radiation levels here (paragraph 20) are of very little significance in terms of public radiation exposure. Detailed studies into the direct radiation exposure to the general public in the vicinity of the site have been carried out on an annual basis. A combination of dose rate measurements and theoretical extrapolation to locations occupied by the public has given a maximum potential dose range of 10 - 100 μSv (based on pessimistic assumptions). However, the actual dose is likely to be much lower.

Collective doses

25 Collective doses from discharges from Capenhurst were calculated, in accordance with paragraphs 29 - 31 and 39 of the Introduction (amplified in the Appendix) and are presented in table 7. Until 2000, over 99% of the collective dose arose predominantly from aerial discharges of tritium. However, with subsequent reductions in both aerial and liquid discharges of tritium, these radiologically collective doses have become even smaller than those of previous years and are now insignificant compared to the trivial collective dose components from both uranic aerial and liquid discharges.

Non-radioactive discharges and disposals

26 Discharges to the Rivacre Brook are made in accordance with a Water Resources Act consent. 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

27 Radioactive combustible waste which is necessarily generated, and for which there is no further use under the site's recycling initiatives, is burnt within Capenhurst's incinerator. Consequently, a 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. Compliance checking is effected by passing the flue gases through bubbler trains, filters and by direct spectrometry. The resultant solutions and used filters are sampled and analysed by approved methods. Discharges are not included due to the limited operation during 2007. During 2007, there were no non-compliances with the limits or the authorisations.

Table 7. Collective doses from Capenhurst's discharges

Discharge route	Collective dose (man Sv)		
	UK	Europe	World
Aerial	0.000048	0.000056	0.000056
Liquid	0.000000424	0.00000112	0.00000250

Table 8. Disposals of controlled waste

Waste type	Quantity (te)
Inert	50
Non-hazardous	3498
Hazardous	666

Discharges made under terms of consents

28 Non-radioactive liquid wastes arise principally from decommissioning operations on the Capenhurst site. These wastes, together with those transferred to Capenhurst from the URENCO (Capenhurst) Ltd site (paragraph 3), and 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 ditch used for radioactive effluents (paragraph 5).

29 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 point of discharge from the on-site sewage farm and the delay tank (when discharged). Consequently, site discharges are assumed to originate predominantly from the sewage farm and URENCO (Capenhurst) Ltd rather than at the site outlet where non-radioactive results can be affected by events unrelated to Capenhurst or URENCO (Capenhurst) Ltd operations.

Ozone depleting substances

30 Use of ozone depleting substances is limited to those which are necessarily contained within refrigeration units. Wherever practicable, the use of these will be gradually phased out or environmentally friendly substitutes used.

Off-site disposals of solid waste

31 If they cannot be recycled, controlled wastes from offices, workshops and other sources are disposed of to a local landfill site via a specialist waste contractor, and hazardous wastes to licensed disposal facilities. Hazardous wastes, which are also radioactive, are included in the LLWR disposal figures. The total amounts of wastes disposed of or recycled in 2007 are categorised and summarised in table 8. The site's accelerated decommissioning programme has involved the dismantling of a number of redundant buildings, resulting in increased quantities of building rubble and other associated waste streams. The rubble is ordinarily disposed of to landfill. However, much of it has been processed and reused on site to minimise the overall disposal quantities.

References

1 Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency (2007). **Radioactivity in food and the environment, 2006.** RIFE-12. Environment Agency, EHS, Food Standards Agency and SEPA; Bristol, Belfast, London and Stirling.

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.

Appendix

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 lifetime dose to the whole body, i.e. the 'committed effective dose' (CED), which would be incurred by an individual following the intake 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-12[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 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].

(Continued on page 54)

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.

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	6.9E-16	1.6E-15	1.9E-15	2.40E-15	3.70E-15	4.00E-15
C-14	2.2E-13	2E-12	1.8E-11			
S-35	2.8E-13	8.4E-13	8.4E-13			
Ar-41	7.7E-17	7.7E-17	7.7E-17			
Co-60	4.8E-12	7.1E-12	7.1E-12			
Kr-85	5E-18	2.7E-17	2.6E-16			
Sr-90	2.1E-12	1E-11	1E-11			
Zr-95	1.7E-13	2.4E-13	2.4E-13			
Nb-95	4.8E-14	6.9E-14	6.9E-14			
Ru-106	2.8E-13	4.2E-13	4.2E-13			
Sb-125	5.6E-13	7.9E-13	7.9E-13			
I-129	4.4E-11	2.1E-10	3E-10			
I-131	8.7E-13	8.7E-13	8.7E-13			
Cs-134	3E-12	8.8E-12	8.8E-12			
Cs-137	4.1E-12	9.7E-12	9.7E-12			
Ce-144	1.3E-13	2.2E-13	2.2E-13			
U-234	1.5E-10	2.4E-10	2.4E-10	1.30E-10	1.50E-10	1.50E-10
U-235				1.20E-10	1.40E-10	1.40E-10
U-238	2.6E-12	4.3E-12	4.3E-12	1.10E-10	1.30E-10	1.30E-10
Pu-239, Pu-240	1.5E-10	2.4E-10	2.4E-10			
Pu-241	2.6E-12	4.3E-12	4.3E-12			
Am-241	1.2E-10	2E-10	2E-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.

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 1998 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]. The Health Protection Agency recommends[15] that the calculation of marine collective dose coefficients using PC CREAM should take account of the contributions of daughter radionuclides, and this recommendation has been followed in this report. The collective dose coefficients have been recalculated for all relevant radionuclides in the liquid discharges. The effects of these recalculations on collective doses are nearly all negligible. The only significant increase in collective dose that occurs is a small increase (< 10%) in the collective dose from Sellafield arising from the Te-125m daughter of Sb-125.

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 has 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.

13 For this report, the collective committed dose follows the current Health Protection Agency advice[16,17] of a 500 year integration period and the doses are calculated to the populations of the UK, Europe and the world. Europe is

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	5E-19	2.2E-18	4.4E-17	5.20E-19	2.20E-18	4.40E-17
C-14	2.4E-13	8.9E-13	1.2E-11			
S-35	3.8E-18	7.4E-18	7.5E-18			
Mn-54	1.3E-15	1.3E-15	1.3E-15			
Fe-55	2.1E-15	3.6E-15	3.6E-15			
Co-60	1.5E-14	1.6E-14	1.6E-14			
Ni-63	9.9E-17	1.9E-16	2E-16			
Zn-65	1.1E-13	1.7E-13	1.7E-13			
Sr-89	6.7E-18	1.3E-17	1.3E-17			
Sr-90	7.7E-16	2E-15	2.2E-15			
Zr-95	5.3E-16	5.4E-16	5.4E-16			
Nb-95	1.4E-16	1.4E-16	1.4E-16			
Tc-99	1.9E-15	5E-15	5.3E-15	2.50E-15	6.10E-15	6.50E-15
Ru-103	3.8E-16	5.7E-16	5.7E-16			
Ru-106	1E-14	2E-14	2E-14			
Ag-110m	3.4E-14	6.2E-14	6.3E-14			
Sb-125	1E-14	2.5E-14	2.7E-14			
I-129	2.2E-14	7E-14	2.9E-13			
Cs-134	1.3E-14	3E-14	3.2E-14			
Cs-137	1.5E-14	3.7E-14	4.2E-14			
Ce-144	2.1E-16	2.4E-16	2.4E-16			
Pm-147	8.2E-18	1E-17	1E-17			
Eu-152	9.6E-15	9.7E-15	9.7E-15			
Eu-154	8.9E-15	9E-15	9E-15			
Eu-155	3.7E-16	3.8E-16	3.8E-16			
Th-228	5.5E-15	5.9E-15	5.9E-15			
Th-230	5.3E-15	9.6E-15	1.1E-14	6.60E-15	1.50E-14	1.60E-14
Th-232	3.4E-13	8.1E-13	8.8E-13			
Th-234	2.9E-16	3E-16	3E-16	1.60E-16	1.90E-16	1.90E-16
U-234	2.8E-15	7.9E-15	8.9E-15	3.50E-15	9.20E-15	1.00E-14
U-235	2.9E-15	7.7E-15	8.6E-15	3.60E-15	9.00E-15	9.90E-15
U-238	2.6E-15	7.1E-15	7.8E-15	3.20E-15	8.30E-15	8.90E-15
Np-237	5.6E-14	1.5E-13	1.6E-13	6.50E-14	1.60E-13	1.70E-13
Pu-238	7.6E-14	1.2E-13	1.2E-13			
Pu-239, Pu-240	8.6E-14	1.4E-13	1.5E-13			
Pu-241	1.6E-15	2.6E-15	2.6E-15			
Am-241	2.1E-14	2.6E-14	2.6E-14			
Cm-242	1.6E-15	1.9E-15	1.9E-15			
Cm-243, Cm-244	2.3E-14	2.8E-14	2.8E-14			

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.

defined as the population of the member states of the European Union, including the UK.

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. In general, 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.

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Glossary of terms and abbreviations

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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 = I 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) Radiological 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 as an electron.

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. Various forms of dose are commonly referred to and 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). It is a function of biokinetic behaviour and radioactive ***half-lives***. For radionuclides with short effective ***half-lives*** in the body (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 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 spontaneously or under the impact of another particle, with resulting increase of energy. The two nuclei are called fission products.

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 The time for the ***radioactivity*** of a ***radionuclide*** to decrease by radioactive decay to one half of its initial value. Half-lives range from fractions of a second to millions of years. 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) Highly active heat-generating radioactive waste that normally continues to generate heat for several centuries. A high level of shielding and heat dissipation is is required during handling, transportation and storage. It is chemically separated from spent nuclear fuel during reprocessing.

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 generally followed by the UK in legislation.

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*** will be 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.

NDA (Nuclear Decommissioning Authority) a new 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.

NII (Nuclear Installations Inspectorate) Part of the Health and Safety Executive. It is responsible for enforcing legislation relating to nuclear safety under the Nuclear installations Act 1965.

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.

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

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***.

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***.

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 in the environment that are near background levels for naturally occurring radioactive substances and close to zero for artificial radioactive substances.

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.

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