RIFE - 9

Radioactivity in Food and the Environment, 2003

ENVIRONMENT AGENCY

ENVIRONMENT AND HERITAGE SERVICE

FOOD STANDARDS AGENCY

SEPA
SCOTTISH ENVIRONMENT PROTECTION AGENCY

2004

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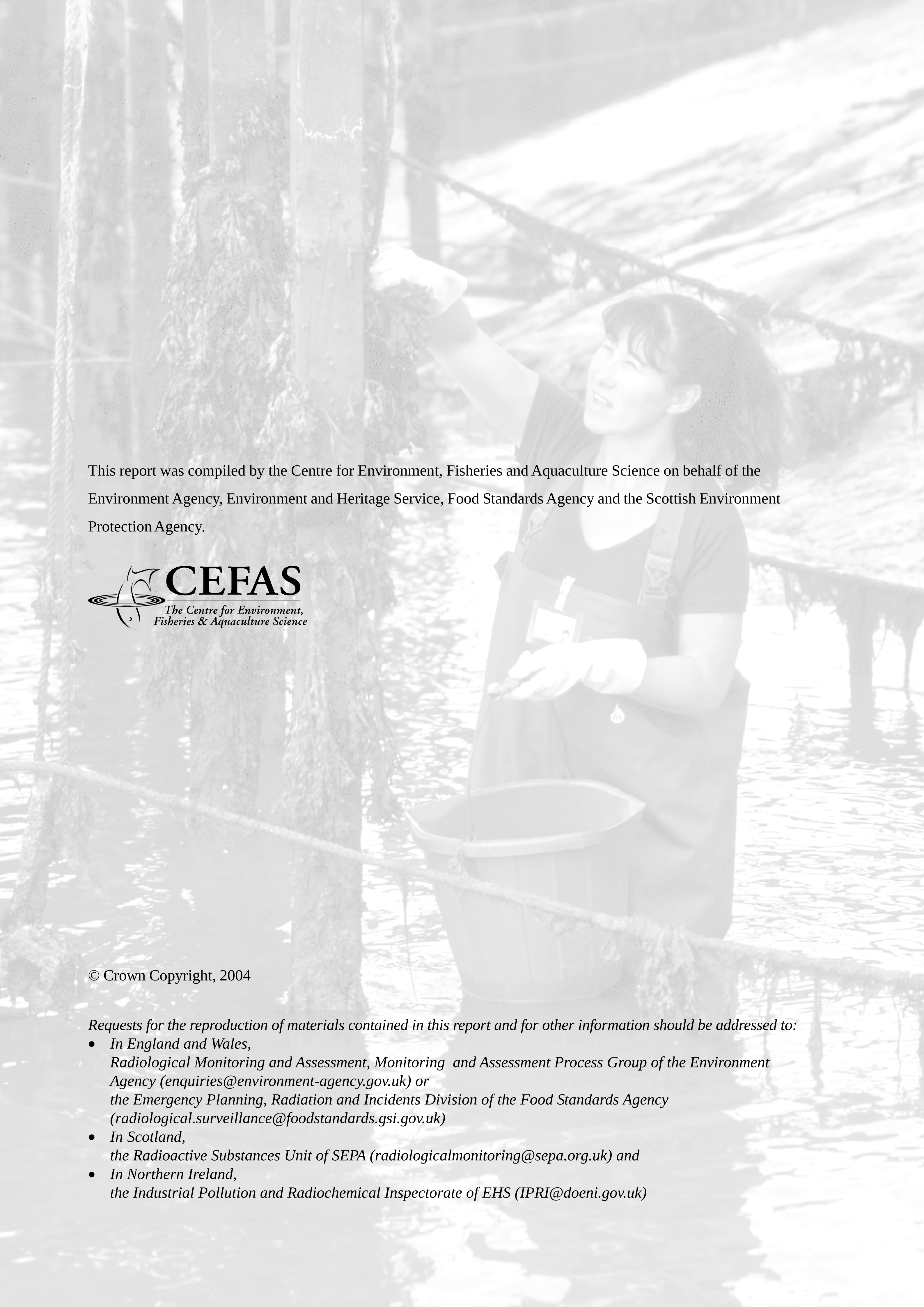

This report was compiled by the Centre for Environment, Fisheries and Aquaculture Science on behalf of the Environment Agency, Environment and Heritage Service, Food Standards Agency and the Scottish Environment Protection Agency.

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

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FOREWORD

We are pleased to present the 9th annual Radioactivity in Food and the Environment report, which contains radiological monitoring data for 2003. This report is the second to contain radiological monitoring data from our four agencies, providing a complete picture of the levels of radioactivity found in food and the environment in the UK.

The report builds on the success of last year's report by considering a new methodology of assessing dose to the public for some of the UK's nuclear sites. This new methodology takes account of all public exposure routes in a realistic way, leading to an improved and more reliable assessment of dose to the public from discharges to the environment. This assessment also incorporates estimates of doses from direct exposure to radiation and we would like to thank the Nuclear Installations Inspectorate for the supply of this data.

There have been some slight alterations in the order of the sections in the report. This is to reflect the planned restructuring of the nuclear industry due to the formation of the Nuclear Decommissioning Authority (NDA). The advent of the NDA will mean that independent monitoring of radioactivity in food and the environment has a very important role to play in ensuring the protection of the public as clean up and decommissioning programmes are accelerated in the future.

The monitoring programmes reported here provide reasurance that discharges from nuclear sites do not cause unacceptable harm to the environment and food safety. Substantial progress was made in 2003 towards one of the key objectives of the UK Discharge Strategy, a reduction in liquid discharges of technetium-99 from Sellafield following the introduction of new abatement technology. We look forward to further progress in reducing discharges which should lead to lower concentrations in food and the environment.

This report demonstrates that in 2003 radiation doses to the public resulting from radioactive discharges to the environment were well below national and international limits in all parts of the UK.

Sir John Harman
Chairman, Environment Agency

Mr Ken Ledgerwood
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Professor Sir John Krebs
Chairman, Food Standards Agency

Sir Ken Collins
Chairman, Scottish Environment Protection Agency

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EXECUTIVE SUMMARY

Radiation Safety – Food and the Environment at Nuclear Sites

This report contains the results of radiological monitoring of food and the environment throughout the United Kingdom, the Channel Islands and the Isle of Man. The primary purposes of the monitoring programmes are (a) to provide an independent check on the effects of discharges of radioactive materials in the United Kingdom, and (b) to ensure that any radioactivity present in food and the environment due to discharges does not compromise environmental or public health. It represents a comprehensive summary of results across the United Kingdom from programmes sponsored by the Environment Agency, the Environment and Heritage Service, the Food Standards Agency and the Scottish Environment Protection Agency.

The results of these monitoring programmes demonstrate that in 2003 even the most exposed members of the public received radiation doses from consumption of food and exposure to environmental radioactivity due to discharges and direct radiation that were below the statutory United Kingdom annual dose limit to members of the public of 1 mSv (millisievert), European Union limits and Government targets. Many of the dose estimates use levels of radioactivity that are below the limits of detection and are therefore likely to be an overestimate. Assessed doses at all major sites in the United Kingdom are shown in Figure S and are detailed in the Summary Table.

The highest radiation doses were received by a group of high-rate consumers of fish and shellfish in Cumbria. The doses received by these consumers are a combination of contributions from liquid discharges from both Sellafield and from radioactivity in the environment as a result of past discharges from the Rhodia Consumer Specialties Ltd. (formerly Albright and Wilson) plant at Whitehaven. The dose to these high-rate consumers (including external doses) from Sellafield discharges was estimated to be 0.21 mSv in 2003 compared with 0.19 mSv in 2002. The main reason for the small increase in dose was an increase in the amount of seafood eaten. This group also received an estimated dose of 0.41 mSv from natural radioactivity due to the legacy of past operations at the Rhodia Consumer Specialties Ltd. works at Whitehaven. Phosphogypsum used to be discharged as liquid slurry and contained thorium and uranium in concentrations enhanced above natural background levels. This waste is called Technologically enhanced Naturally Occurring Radioactive Material (TNORM). Operations at this site ceased at the end of 2001 and the plant is being demolished.

In terms of radiation exposure, the second most important group was people living near Dungeness nuclear power stations. Their dose was 0.11 mSv, mostly due to gaseous discharges of argon-41. This is a small reduction on the dose received in 2002 of 0.12 mSv. The highest exposures in Scotland were to the group of seafood consumers on the Dumfries and Galloway coast who received an annual dose of 0.036 mSv largely as a result of liquid discharges from Sellafield. In 2002, this group was estimated to have received a dose of 0.045 mSv.

Doses due to gaseous discharges from Sellafield were 0.034 mSv, slightly less than the dose in 2002 of 0.038 mSv. The assessment included the consumption of milk, vegetables, fruit and meat and intakes from inhalation and external exposure from gaseous discharges. Most of the seafood and external exposure doses that can be attributed to Sellafield were from historic liquid discharges. Recent and current discharges of technetium-99 contributed 0.032 mSv, which is around 15% of the 0.21 mSv dose to the Sellafield seafood consumers.

The third most significant site was Springfields where people living in houseboats in the Ribble estuary received 0.079 mSv in 2003. The major part of this was from Sellafield radionuclides incorporated into intertidal sediments. At Heysham, high-rate seafood consumers were estimated to have received 0.075 mSv and most of this was attributable to Sellafield discharges. Gaseous discharges from Sizewell power stations gave a slightly lower dose, 0.057 mSv. High concentrations of tritium have been found in food and the environment near Cardiff where radiochemicals for research, medicine and industry are produced. However,

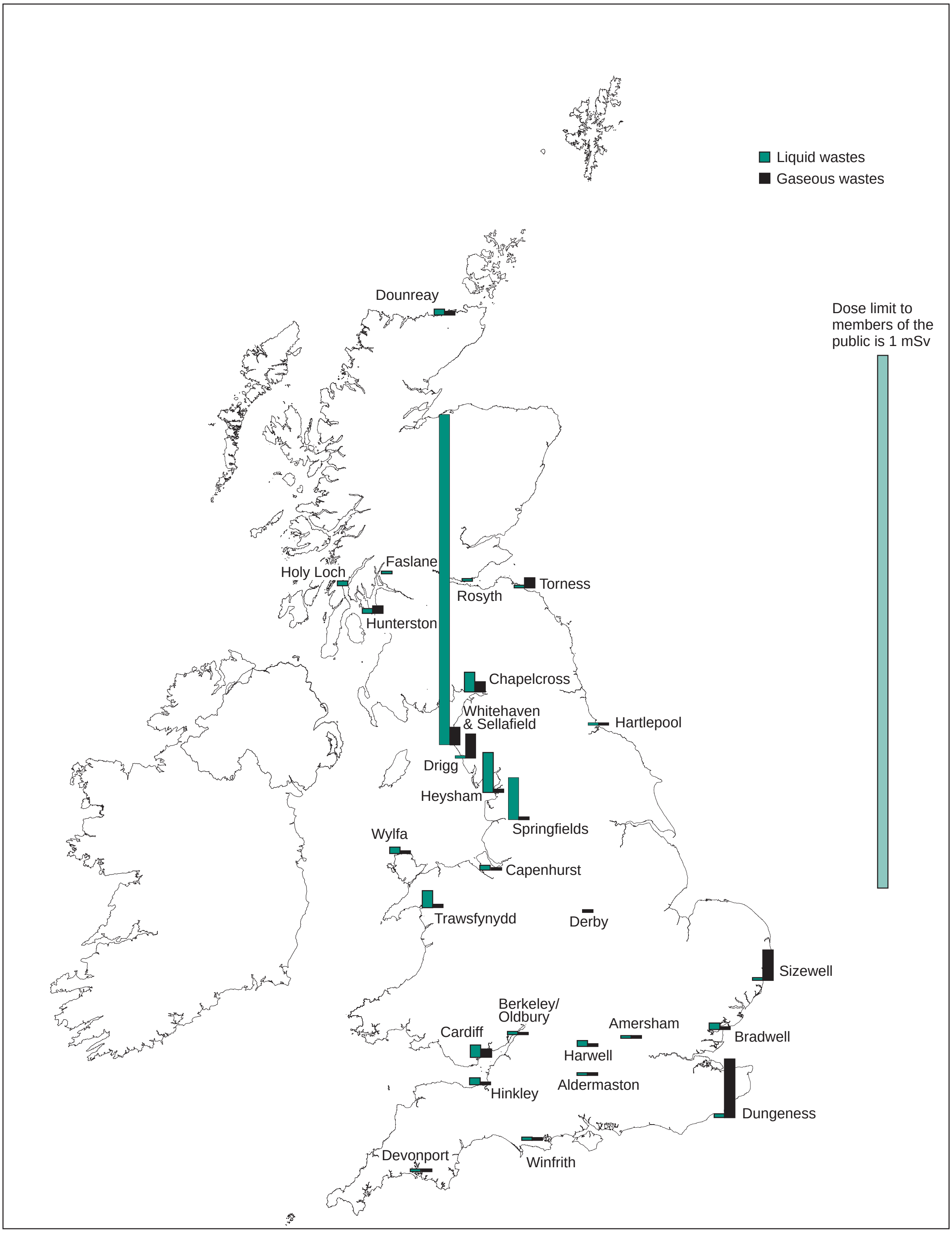

Figure S. ***Radiation exposures in the UK due to radioactive waste discharges, 2003 (Exposures at Whitehaven and Sellafield are mostly due to the legacy of enhanced natural radioactivity from the non-nuclear industry)***

Summary Table: Radiation doses due to discharges of radioactive waste in the United Kingdom, 2003

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b]	Contributors[c]
Nuclear fuel production and processing				
Capenhurst	Inadvertent ingestion of water and sediment and external[g]	L	0.009	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{3}H U
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (1999-2003 surveys) (excluding natural radionuclides)[k]	L	0.21	$^{239/240}Pu$ ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (1999-2003 surveys) (including natural radionuclides)[l]	L	0.62	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2003 surveys)	L	0.28	$^{239/240}Pu$ ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	G	0.034	^{90}Sr ^{106}Ru
	Terrestrial foods at Ravenglass[i]	G/L	0.019	^{60}Co ^{106}Ru
	External in intertidal areas (Ravenglass)[a]	L	0.041	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)[a]	L	0.079	Ext ^{241}Am
	External (skin) to anglers	L	0.21[f]	Beta
	Handling of fishing gear	L	0.11[f]	Beta
	Porphyra/laverbread consumption in South Wales	L	0.005	^{106}Ru ^{241}Am
	Seaweed/crops at Sellafield	L	0.026	^{99}Tc ^{241}Am
Springfields	External (skin) to fishermen	L	0.67[f]	Beta
	Fish and shellfish consumption	L	0.019	^{137}Cs ^{241}Am
	Terrestrial foods	G	<0.005[h]	^{90}Sr ^{129}I
	External in intertidal areas (children playing)[g,a]	L	<0.005	Ext ^{234}Th
	Occupancy of houseboats[a]	L	0.079	Ext ^{241}Am
	External in intertidal areas (anglers)	L	0.009	Ext
Research establishments				
Culham	Drinking water[n]	L	<0.005	^{3}H ^{137}Cs
Dounreay	Fish and shellfish consumption	L	<0.005	^{14}C ^{106}Ru
	External in intertidal areas	L	0.011	Ext
	Terrestrial foods	G	0.006	^{90}Sr ^{241}Am
Harwell	Fish consumption and external to anglers	L	0.011	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{3}H
Winfrith	Fish and shellfish consumption and external in intertidal areas	L	0.006	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C ^{137}Cs
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.007	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{35}S
Bradwell	Fish and shellfish consumption and external in intertidal areas	L	0.013	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Chapelcross	Fish and shellfish consumption and external in intertidal areas	L	0.037	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.020	^{35}S ^{90}Sr
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.007	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site	G	0.11	^{14}C ^{41}Ar
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.075	Ext ^{241}Am
	Terrestrial foods[i]	G	0.006	^{14}C ^{137}Cs
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.013	Ext ^{3}H
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Hunterston	Fish and shellfish consumption	L	<0.005	^{99}Tc ^{241}Am
	External in intertidal areas	L	0.007	Ext
	Terrestrial foods[i]	G	0.014	^{35}S ^{90}Sr

Summary Table: continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b]	Contributors[c]
Nuclear power production *continued*				
Sizewell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site	G	0.057	^{14}C ^{41}Ar
Torness	Fish and shellfish consumption and external in intertidal areas	L	0.005	Ext ^{241}Am
	Terrestrial foods[i]	G	0.019	^{90}Sr ^{241}Am
Trawsfynydd	Fish consumption and external to anglers	L	0.032	Ext ^{137}Cs
	Terrestrial foods[i]	G	0.006	^{90}Sr ^{137}Cs
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.012	Ext ^{137}Cs
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Defence establishments				
Aldermaston	Fish consumption and external to anglers	L	<0.005	Ext ^{137}Cs
	Terrestrial foods[i]	G	<0.005[h]	^{137}Cs U
Derby	Drinking water[n]	L	<0.005	^{60}Co
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods	G	<0.005	^{60}Co ^{137}Cs
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
Holy Loch	External in intertidal areas	L	0.009	Ext
Rosyth	External in intertidal areas	L	<0.005	Ext
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	0.005	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{35}S ^{75}Se
Cardiff	Fish and shellfish consumption and external in intertidal areas	L	0.024	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	0.016	^{3}H ^{14}C
	Inadvertent ingestion (River Taff)	L	<0.005	^{131}I ^{137}Cs
	Wildfowl consumption	L	<0.005	^{3}H
Industrial and landfill				
Drigg	Terrestrial foods[i]	G	0.046	^{60}Co ^{106}Ru
	Drinking water[n]	L	<0.005	^{90}Sr ^{241}Pu
Whitehaven	Fish and shellfish consumption[j]	L	0.41	^{210}Po ^{210}Pb
	Fish and shellfish consumption[m]	L	0.62	^{210}Po ^{241}Am

[a] *Includes a component due to inadvertent ingestion of water or sediment or inhalation of resuspended sediment where appropriate*
[b] *Unless otherwise stated represents committed effective dose calculated using methodology of ICRP-60 to be compared with the dose limit of 1 mSv (see section 3). Exposures due to marine pathways include the far-field effects of discharges of liquid waste from Sellafield. Unless stated otherwise, the critical group is represented by adults*
[c] *The top two contributors to the dose; either 'ext' to represent the whole body external exposure from beta or gamma radiation, 'beta' for beta radiation of skin or a radionuclide name to represent a contribution from internal exposure. Some contributions from radionuclides to internal exposure are based on concentration data at limits of detection*
[d] *Dominant source of exposure. G for gaseous wastes. L for liquid wastes or surface water near solid waste sites*
[e] *The estimates for marine pathways include the effects of liquid discharges from Drigg. The contribution due to Drigg is negligible*
[f] *Exposure to skin including a component due to natural sources of beta radiation, to be compared with the dose limit of 50 mSv (see section 2)*
[g] *10 y old*
[h] *Includes a component due to natural sources of radionuclides*
[i] *1 y old*
[j] *Excluding the effects of artificial radionuclides from Sellafield*
[k] *Excluding the effects of enhanced concentrations due to the legacy of discharges of natural radionuclides from Rhodia Consumer Specialties Ltd., Whitehaven*
[l] *Including the effects of enhanced concentrations due to the legacy of discharges of natural radionuclides from Rhodia Consumer Specialties Ltd., Whitehaven*
[m] *Including the effects of artificial radionuclides from Sellafield*
[n] *Water is from rivers and streams and not tap water*

doses to high-rate seafood consumers were estimated to be relatively low at 0.024 mSv in 2003, similar to 0.031 mSv in 2002. Most of the dose was due to tritium and carbon-14 in fish from the Bristol Channel.

The dose estimates given above apply to discharges from nuclear and other sites. There is an additional source of public radiation exposure near some of these facilities, that is radiation emanating directly from buildings due to operations on the site. The Health and Safety Executive as the relevant regulatory authority has provided estimates of direct radiation doses at sites in the UK making use of information from the site operator and these have been incorporated in this report into a holistic assessment of total dose to members of the public where data are available to do so. For the sites considered, this has shown that no total dose was in excess of the limit of 1 mSv in 2003. These assessments will be extended to all sites in future Radioactivity In Food and the Environment reports as the required data become available.

Radioactivity levels in samples collected around nuclear sites

No major changes in levels of radioactivity in food, environmental materials or external dose rates were observed in 2003. Levels of carbon-14 and ruthenium-106 in seafood from the vicinity of Sellafield showed an increase over levels in 2002. However, the assessed dose from these radionuclides was less than 10% of the total from man-made radionuclides i.e. an increase from 0.011 mSv to 0.018 mSv. Sea-to-land transfer of technetium-99 occurred on a small scale via the harvesting of seaweed for use as a soil conditioner and fertiliser but there was no evidence for significant transfers of technetium-99 through animals feeding on seaweed.

Concentrations of tritium (as organically bound tritium) in seafood near Cardiff remained at levels in excess of 15,000 Bq kg^{-1} (fresh weight) though some reductions were observed compared with 2002. Tritium concentrations in freshwater fish in the Thames river catchment and in seafood at various coastal locations around the UK were above an expected background tritium concentration of 1 Bq kg^{-1}. However, the degree of bioaccumulation was relatively minor.

The UK Discharge Strategy was published in 2002. It provides a description of how the UK will implement the agreements reached at the 1998 and subsequent meetings of the Oslo and Paris Convention. One of the aims is progressive and substantial reductions of liquid radioactive discharges and discharge limits. The progressive reductions require plans and actions on the main nuclear sites to reduce the discharges and will have a significant impact on concentrations of radionuclides near nuclear sites in future years. In 2003 steps were taken toward implementation at Sellafield and Cardiff.

During 2003, discharges of technetium-99 were reduced due to a successful trial of abatement technology and are expected to reduce further in 2004 and subsequent years. Technetium-99 from Sellafield can be detected in the Irish Sea, in Scottish waters and the North Sea. It is expected that levels of technetium-99 in the marine environment will begin to decline in future years. Abatement technology was introduced in April 2004 at Cardiff that will reduce discharges of organic tritium to the environment and concentrations of tritium around Cardiff in the future.

Gaseous releases of argon-41 from the older of the remaining operational Magnox power stations continued to have a significant local effect on concentrations in air. This was particularly evident at Chapelcross, Dungeness and Sizewell. As it is not practicable to monitor for argon-41 estimates of the effects of the discharges are made using dispersion modelling. In March 2003, Calder Hall power station at Sellafield closed and discharges of argon-41 ceased.

Site incidents and non-routine surveys

During 2003, further radioactive fragments were recovered near Dounreay. Three radioactive fragments were recovered from the site foreshore, 24 from Sandside Bay and 56 from the seabed near to the Dounreay site. The fishing restrictions under the Food and Environment Protection Act 1985 are still in force.

An incident occurred near British Nuclear Fuels Sellafield in November 2003 and the Environment Agency responded by immediate monitoring of the beach. At the time, British Nuclear Fuels were in the process of removing redundant pipelines that were used to discharge to sea. One of the pipelines which had been used to carry lightly contaminated surface water from the site had been cut into sections and was stored on the seabed. In bad weather, some of the cut sections were washed up on local beaches. Beta/gamma strandline monitoring between Nethertown and Seascale beach was undertaken to check for any contamination in the vicinity of the washed up sections. No contamination was found.

There were 12 other occasions where ‘special’ sampling (referred to as *ad hoc* sampling) was required because of concerns raised about site operations. The majority of cases involved higher than normal gaseous releases of radioactivity, which triggered reporting procedures that are a condition of the operators’ authorisations. These cases occurred at Dungeness, Oldbury, Hartlepool, Heysham, Hinkley Point, Sizewell and Wylfa. Each time, samples in the routine monitoring programme were collected earlier, and analysed more quickly than scheduled. No increases above normal levels were detected except at Dungeness and Heysham. In both these cases the increases were small and had negligible effects on dose.

Ad hoc sampling was also required on two other occasions. The Food Standards Agency investigated the potential offsite transfer of radioactivity by rabbits at Dounreay. Along with the Environment Agency, they also undertook investigations at Avonmouth because of an unauthorised release of tritium from a (non-nuclear) industrial site. The results showed there were no food safety implications.

Surveys of the diets and occupancy habits of members of the public conducted near nuclear sites at Sellafield, Cardiff, Dounreay and Winfrith were completed. The results were used to improve radiological assessments of the monitoring programmes in 2003.

Radiation doses and levels at other locations in the UK

Analyses of food and drinking water in the general diet and sources of public drinking water were made throughout the United Kingdom. The results demonstrated that radioactivity from natural sources was by far the most significant source of exposure to communities in areas remote from nuclear sites. Man-made radionuclides only contributed a small proportion of the dose.

Monitoring of artificially-produced radioactivity on the Isle of Man and in Northern Ireland showed that doses were all less than 2% of the annual limit of 1 mSv. A survey on the Channel Islands confirmed that doses due to discharges from the French reprocessing plant at Cap de la Hague and other local sources were less than 1% of the limit.

As mentioned before, concentrations of natural radionuclides in fish and shellfish near the (now closed) Rhodia Consumer Specialties Ltd. site continued to be enhanced above normal levels. The dose to high-rate seafood consumers, including the effects of artificial radionuclide discharges from the Sellafield site nearby, was estimated to be 0.62 mSv for the critical group. The contributions from artificial and ‘enhanced natural’ (TNORM) radionuclides were 0.21 and 0.41 mSv, respectively.

The programme of monitoring the effects of discharging wastes at other non-nuclear industrial sites continued. The sites included pharmaceutical manufacturers, a research facility and hospitals. There was no evidence for increased concentrations of radionuclides in the environmental samples tested near the sites that were studied in relation to gaseous discharges.

Tritium was found in leachate from some landfill sites at levels that were of very low radiological significance. This is thought to be due to the legacy of disposal of gaseous tritium light devices.

A small programme of monitoring of the effects of the Chernobyl accident continued in 2003. Restrictions on the movement, sale and slaughter of sheep remain in some upland areas of the United Kingdom.

Monitoring of far-field distributions of radionuclide levels in coastal seas has continued in support of United Kingdom marine environmental policies and international treaty commitments. Government research vessels are used in the sampling programme and the results have been used to show trends in the quality status of the United Kingdom's coastal seas.

The monitoring programmes and additional research

These monitoring programmes involved the collaboration of six specialist laboratories, each with rigorous quality assurance audits, and a wide range of sample collectors throughout the United Kingdom. They were organised independently of the industries discharging wastes by the Environment Agency, the Environment and Heritage Service, the Food Standards Agency and the Scottish Environment Protection Agency. The programmes include monitoring undertaken on behalf of the Scottish Executive, Channel Island States, the Department for Environment, Food and Rural Affairs, the Manx Government and the Welsh Assembly Government. Overall, more than 20,000 analyses or dose rate measurements were completed in 2003.

Results of the analysis of food samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries on the Food Standards Agency's website (www.food.gov.uk). Further details of all programmes described in this report can be obtained by contacting the sponsoring agencies. Contact details are given on the back cover.

The routine monitoring programmes were supported by a number of research studies investigating specific issues such as radioactivity in bottled water and technetium-99 in seabed sediments. Results of the studies that are completed are reported in Section 10. The Agencies are also jointly funding work to improve the methodology for estimating public exposure including site-specific surveys of consumers' dietary habits and way of life.

A summary of the research and links to the results are provided in the report.

1. INTRODUCTION

1.1 Background

This report contains the results of the radiological monitoring of food, environmental materials and dose rates in 2003 throughout the United Kingdom (UK), the Channel Islands and the Isle of Man. The report is published jointly by the Environment Agency, the Environment and Heritage Service (EHS), the Food Standards Agency and the Scottish Environment Protection Agency (SEPA).

The data in this report cover the calendar year of 2003. This is the second report in the Radioactivity in Food and the Environment (RIFE) series to include a complete coverage of programmes operated by the Environment Agency in England and Wales and the EHS in Northern Ireland. Previously the results were published separately (Environment Agency, 2002a and Environment and Heritage Service, 2004). The results of the programmes have been assessed by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) on behalf of the environment agencies, the Food Standards Agency, the Department for Environment, Food and Rural Affairs (Defra), the Welsh Assembly Government, the Manx Government and the Channel Island States.

The purpose of the programmes is to ensure that any radioactivity present in foods does not compromise food safety and to check that public radiation exposure more generally is within national and international limits. The effect of changes in discharges from industry and in radiological pathways is taken into account. The Food Standards Agency has responsibility for food safety throughout the UK. The Environment Agency, EHS and SEPA, referred to collectively as the environment agencies in the report, are responsible for environmental protection matters in England and Wales, Northern Ireland and Scotland respectively. They act as regulators of radioactive waste disposal under the Radioactive Substances Act 1993 (United Kingdom - Parliament, 1993). The Environment Agency and SEPA have a broad responsibility (under the Environment Act 1995 (United Kingdom - Parliament, 1995a)) for protecting (and determining general levels of pollution in) the environment. The data reported here are also used to assess the environmental impact of radioactive discharges.

The monitoring undertaken by the environment agencies and the Food Standards Agency is independent of monitoring programmes carried out by nuclear site operators as a condition of their authorisations to discharge radioactive wastes. Results from the monitoring programmes are used as a check on monitoring programmes undertaken by the site operators required as part of their authorisation conditions. Comparisons between operator and agency data are not within the scope of this report. The majority of the report concerns the local effects of discharges from nuclear sites in the UK. However, data on the marine environment of the whole of the British Isles and further afield, together with information on the levels of radioactivity in foods, environmental materials and dose rates in areas of the UK remote from nuclear sites, are included.

Where appropriate, the monitoring data for nuclear sites are supplemented by results from other projects related to the behaviour of radioactivity in the environment. The most recent summary of the scope of all radioactivity monitoring programmes as undertaken by nuclear site operators and local and central government can be found in the report from Department of the Environment, Transport and the Regions (2001).

To place the monitoring results from the programme in context, radioactive waste discharges from nuclear establishments in the UK for 2003 are first addressed in Section 1.2. Before the results of monitoring are presented, an explanatory section gives details of methods of sampling and analysis and explains how results are interpreted in terms of public radiation exposures. In general, the doses reported around each nuclear establishment are for the critical group, which receives the greatest dose from artificially produced radionuclides. Where practicable, the dose estimates exclude the dose from natural background radiation (see Section 2 and Appendix 6). Direct radiation from nuclear facilities is the primary regulatory responsibility of the Health and Safety Executive (HSE). This report considers the additivity of doses from direct radiation with doses from other pathways for certain sites where data are available (see Appendix 7). The doses are compared with the annual limit of 1 mSv applicable for controlled releases of radioactivity from artificial sources (see Section 2) and would be in addition to the average annual UK dose of approximately 2.2 mSv received by the general public due to natural (uncontrolled) radiation (Hughes, 1999). Dose limits are based on recommendations made by the International Commission on Radiological Protection (ICRP), which are embodied in European Union (EU) and UK law.

A glossary of abbreviations is provided in Appendix 3.

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from nuclear sites

Discharges of radioactive wastes as liquids and/or gases are made from nuclear sites in the UK. In addition, solid low-level wastes from nuclear sites are transferred to Drigg for disposal. These discharges and disposals are authorised by the environment agencies in the UK under the Radioactive Substances Act 1993 (RSA 93) (United Kingdom - Parliament, 1993). Details of discharges and disposals are available from public records held by the environment agencies. A summary of the discharges during 2003 from the nuclear sites and disposals at Drigg and Dounreay is included in Appendix 1. The Environment Agency publishes the discharge information for England and Wales on its web site as a pollution inventory and has proposed to introduce a mandatory reporting scheme for RSA 93 activities to improve access to information (Environment Agency, 2003e).

The sites that are the principal sources of waste containing man-made radionuclides are shown in Figure 1.1. The programmes include monitoring at each of these sites. For completeness, it should be noted that discharges of radioactive waste from other sites such as hospitals, industrial sites and research establishments are also authorised under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993) but are not subject to the Nuclear Installations Act 1965 (United Kingdom - Parliament, 1965). Occasionally, the presence of radioactivity in the environment resulting from such discharges is detected within this programme. For example, iodine-131 originating from hospitals is occasionally detected in some marine samples. Small amounts of very low-level solid waste are also disposed of in specified landfill sites. As noted in Figure S and the Summary Table, there is a significant impact due to the legacy of past discharges of naturally-occurring radionuclides from the non-nuclear site at Whitehaven. Discharges from other non-nuclear sites are generally considered insignificant and as such environmental monitoring of their effects is often not required. However, this situation is reviewed from time to time and surveys are included in the programme where relevant. Discharges of radioactive substances by the non-nuclear industry into the sea have been reviewed (OSPAR, 2002).

Appendix 1 presents the principal discharges of liquid and gaseous radioactive waste and disposals of solid radioactive waste from nuclear establishments in the UK during 2003. The tables also list the discharge and disposal limits that are authorised or, in the case of the Ministry of Defence (MOD), administratively agreed. In some cases, the authorisations specify limits in greater detail than can be summarised in a single table: in particular, periods shorter than one year are specified at some sites. The authorised limits are usually significantly lower than discharge levels that would result in a dose equal to the 1 mSv dose limit. In addition, the actual discharges are often well below the authorised (or agreed) limits. The percentages of the authorised (or agreed) limits taken up in 2003 are also stated in the tables.

Where changes in the rates of discharge in 2003 have affected the levels of radioactivity in the environment, this is discussed in the relevant section of the report.

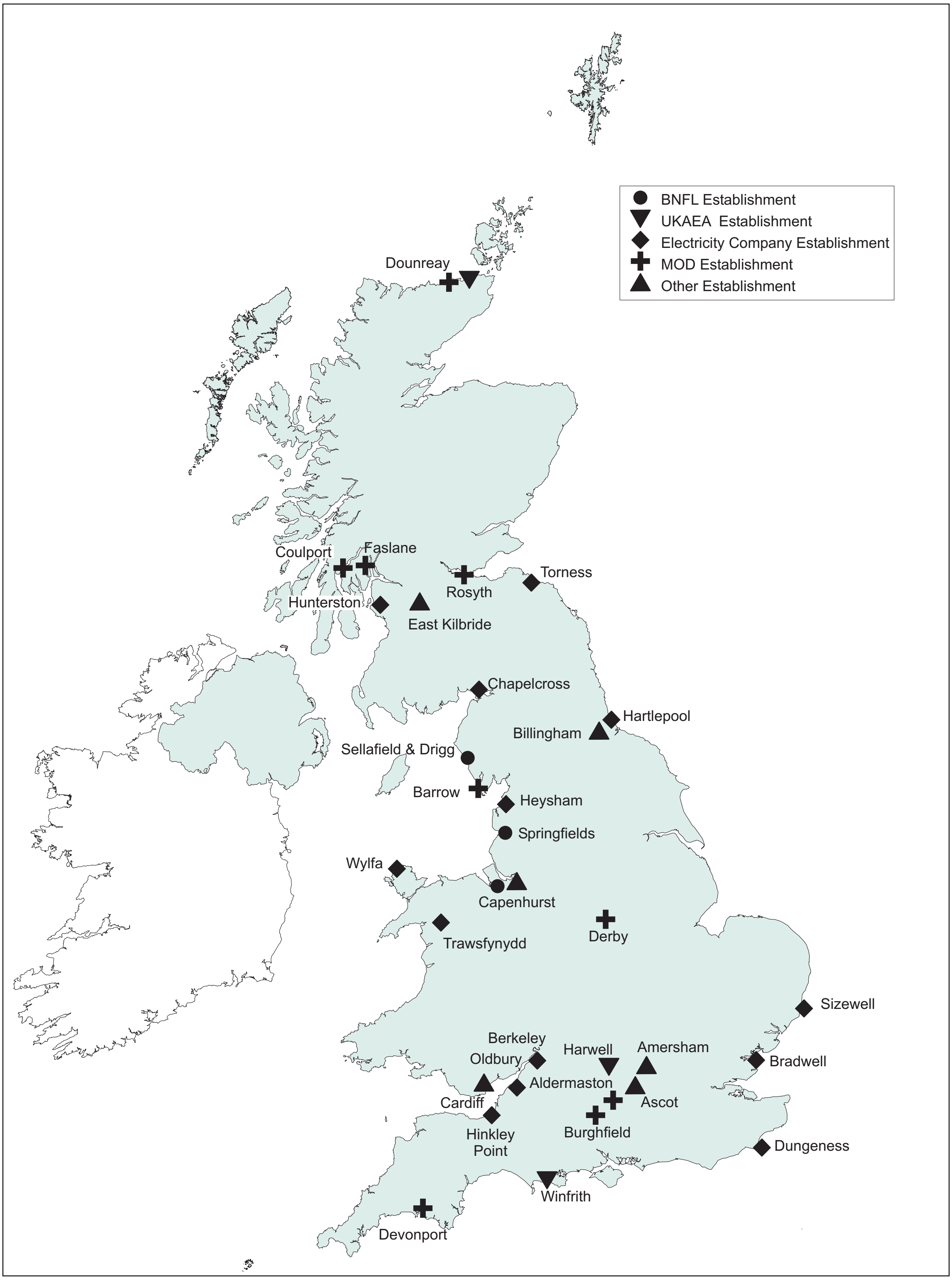

Figure 1.1 Principal sources of radioactive waste disposal in the UK

1.2.2 International agreements and the UK discharge strategy

This subsection presents information on the context of UK radioactive discharges as they relate to international agreements. The UK has ratified the Oslo and Paris (OSPAR) Convention which seeks to provide a framework for the prevention and elimination of pollution in the north-east Atlantic, including the seas around the UK (OSPAR, 2000a).

In July 1998, the Ministers of the UK Government signed the Sintra Statement which included the following commitment (OSPAR, 1998):

“We shall ensure that discharges, emissions and losses of radioactive substances are reduced by the year 2020 to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions, losses, are close to zero”

In July 2002, a UK strategy for radioactive discharges was published (Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, National Assembly for Wales and Scottish Executive, 2002). This provided a description of how the UK would implement the agreements reached at the 1998 and subsequent meetings of OSPAR. The aims of the strategy relate to liquid wastes from the major sources, primarily the nuclear industry, and not to gaseous or solid wastes. They are:

- progressive and substantial reduction of radioactive discharges and discharge limits. Targets for each industrial sector are set out.
- progressive reduction of human exposure to ionising radiation arising from radioactive discharges such that critical group doses will be less than 0.02 mSv from liquid discharges to the marine environment as a result of discharges made from 2020 onwards.
- progressive reduction of concentrations of radionuclides in the marine environment resulting from radioactive discharges such that by 2020 they add close to zero to historic levels.

The report stated that due to the diverse nature of other minor sources of radioactive discharges, no discharge profile or target was set for this industrial sector, presuming that these discharges would continue to be tightly controlled and reduced wherever practicable.

Information on work in progress within the OSPAR Convention can be found on the OSPAR website (www.ospar.org). In addition, a recent report from the Radioactive Substances Committee covers issues relating to reporting of discharges, environmental measurements, standards and quality assurance (OSPAR, 2004). Progress by contracting parties with the implementation of controls on radioactive discharges has also been published (OSPAR, 2003).

A UK technical report has assessed key marine indicators for study within the OSPAR context (Smith, 2002). The UK has also undertaken a modelling study to provide information to support implementation of the discharge strategy (Jones *et al*., 2003). The European Commission (EC) has recently published a full assessment of the radiological exposure of the European Community from radioactivity in North European marine waters (Commission of the European Communities, 2002).

The importance of taking an integrated approach to stewardship of the marine environment has been recognised in the UK and the strategy to achieve this aim has been published (Department for Environment, Food and Rural Affairs, Scottish Executive and Welsh Assembly Government, 2002). The report “Safeguarding Our Seas” considers conservation and sustainable development of the marine environment and sets out how the UK is addressing those issues in relation to radioactive and other substances and effects. The UK is committed to completion of a fully integrated assessment of the marine environment by 2004 and the report considering environmental quality aspects is available (Department for Environment, Food and Rural Affairs, 2004a).

The UK has ratified the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (International Atomic Energy Agency, 1997). This agreement aims to ensure that individuals, society and the environment are protected from harmful effects of ionising radiation as a result of the management of spent nuclear fuel and radioactive waste. A recent report explains how the UK has responded to the objectives of the Joint Convention (Department for Environment, Food and Rural Affairs, 2004b).

The UK Government has introduced legislation to radically alter the existing arrangements for managing civil public sector nuclear clean up. The Energy Act 2004, which was enacted on 22nd July 2004, will enable the establishment of the Nuclear Decommissioning Authority (NDA). The NDA will take responsibility for nuclear sites currently operated by British Nuclear Fuels (BNFL), including ownership of its assets and liabilities, and United Kingdom Atomic Energy Authority (UKAEA). It will be responsible for developing and implementing an overall strategy for cleaning up the civil public sector nuclear legacy safely, securely and in ways that protect the environment. The NDA is expected to become fully operational in April 2005. The legislation also provides for improvements to the Radioactive Substances Act 1993, by speeding up the regulatory processes for transferring radioactive waste discharge authorisations on nuclear sites.

1.2.3 Radioactive waste disposal at sea

In the past, disposals of packaged solid waste of low specific activity were mainly made to an area of the deep Atlantic Ocean. The last such disposal was in 1982. The UK Government announced the permanent cessation of disposal of such material at sea at the OSPAR Ministerial meeting in 1998. At that meeting, Contracting Parties agreed that there would no longer be any exception to a prohibition on the dumping of radioactive substances, including wastes (OSPAR, 1998). The environmental impact of the deep ocean disposals was predicted by detailed mathematical modelling and has been shown to be negligible (Organisation for Economic Co-operation and Development, Nuclear Energy Agency, 1985). Disposals of small amounts of waste also took place from 1950 to 1963 in a part of the English Channel known as the Hurd Deep. The results of environmental monitoring of this area in 2003 are presented in Section 9. They confirm that the radiological impact of these disposals was insignificant.

In the UK, Defra, Department of the Environment for Northern Ireland, Scottish Executive and National Assembly for Wales issue licences to operators for the disposal of dredge material under the Food and Environment Protection Act (FEPA), 1985 (United Kingdom - Parliament, 1985). The protection of the marine environment is considered before a licence is issued. Since dredge material will contain radioactivity from natural and man-made sources at varying concentrations, assessments are undertaken when appropriate for assurance that there is no significant foodchain or other risk from the disposal. In all cases these have shown that the impact of the radioactivity associated with disposal operations has been very low, below 'de minimis'* levels of exposure. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 1999). IAEA have recently published a system of assessment which can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003).

1.2.4 Other sources of radioactivity

There are several other sources of radioactivity that may affect the marine food chain and the environment. These include disposals of material from offshore installations, transport incidents, satellite re-entry, releases from overseas nuclear installations and the operation of nuclear powered submarines. Submarine berths in the UK are monitored by the MOD (DSTL, 2003). General monitoring of the British Isles is undertaken as part of the programmes described in this report. This would detect any gross effects from the sources above. No such effects were found in 2003. Low levels of

***** *'De minimis' relates to doses of the order of 0.010 mSv or less (Internal Atomic Energy Agency, 1999a).*

radionuclides were detected in the marine environment around the Channel Islands (Section 9) and these may be partly due to discharges from the nuclear fuel reprocessing plant at Cap de la Hague.

The contribution of aerial radioactive discharges from UK installations to radionuclide concentrations in the marine environment has been studied (Department for Environment, Food and Rural Affairs, 2004c). The main conclusion was that aerial discharges do not make a significant contribution to levels in the marine environment. Tritium and carbon-14 were predicted to be at concentrations which were particularly high in relation to measured values in the Irish Sea. However, the study suggested that this was due to unrealistic assumptions being made in the assessment. On occasion, the effects of aerial discharges are detected in the aquatic environment, and conversely the effects of aquatic discharges are detected in the terrestrial environment. Where this is found, appropriate comments are made in this report.

1.2.5 Food irradiation

Food irradiation is a processing technique where food is exposed to ionising radiation in a controlled manner. The ionising radiation produces free radicals, which react within the food to produce the desired effect. It does not make the food radioactive. The ionising radiation is either generated by machine, as is the case for electron beams or x-rays, or produced by the radioactive decay of caesium-137 or cobalt-60 (both unstable isotopes that produce gamma radiation).

Irradiation may be used to eliminate or reduce food borne pathogenic organisms, extend shelf life by retarding food spoilage and inhibit ripening, germination or sprouting of certain food products. Irradiation may also be used as a phytosanitary measure to rid plants or plant products of harmful organisms.

Food irradiation has been permitted in the UK for over 10 years, and UK legislation was amended in 2000 to implement two European Directives on food irradiation (Commission of the European Communities, 1999a and b).

In the UK, one facility in England is licensed to irradiate a range of dried herbs and spices and it is inspected regularly by the Food Standards Agency. Several other irradiation facilities are approved to irradiate food; most are located in Member States of the EU. Details of food irradiation facilities are available on the Internet at:

http://europa.eu.int/comm/food/food/biosafety/irradiation/comm_legisl_en.htm.

Although few foods are irradiated in the UK, there is an increased interest in the technique in other countries, particularly in the USA. A Food Standards Agency survey identified a surprisingly high proportion of dietary supplements as irradiated and in breach of legislation (Food Standards Agency, 2002a). There were no immediate food safety concerns arising from this survey, however approval for the irradiation of dietary supplements had not been sought and none of the offending products were correctly labelled as “irradiated” or “treated with ionising radiation”.

The Agency’s food irradiation research programme was reviewed in 2003 and a revised programme of research is planned. More details are available on the Internet at:

http://www.food.gov.uk/science/research/researchinfo/choiceandstandardsresearch/foodirradiation1/.

2. METHODS OF SAMPLING, MEASUREMENT, PRESENTATION AND ASSESSMENT

This Section explains the scope of the monitoring programmes presented in this report and summarises the methods and data used to measure and assess radioactivity in food and the environment.

2.1 Sampling programmes

The primary purpose of the programmes is to check on levels of radioactivity in food and the environment. The results are used to ensure that the safety of people is not compromised and that doses, as a result of discharges of radioactivity, are below the dose limit. The scope extends throughout the UK and the Insular States (the Channel Islands and the Isle of Man) and is undertaken independently of the industries which discharge wastes to the environment. Samples of food, water and other materials are collected from the environment and analysed in specialist laboratories. *In situ* measurements of radiation dose rates and contamination are also made and the results of the programme are assessed in terms of limits and trends in this report. Subsidiary objectives for the programmes are:

- to provide information to assess the impact on non-human species
- to enable indirect confirmation of compliance with authorisations for disposal of radioactive wastes
- to determine whether undisclosed releases of radioactivity have occurred from sites
- to establish a baseline from which to judge the importance of accidental releases of radioactivity should they occur

Sampling is focused on nuclear sites licensed by the HSE under the Nuclear Installations Act, 1965 (United Kingdom - Parliament, 1965) since these generally discharge more radioactivity and have a greater impact on the environment. The programmes also serve to provide information to assist the environment agencies to fulfil statutory duties under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993). Additional sampling is carried out in areas remote from nuclear sites to establish the general safety of the food chain, drinking water and the environment. Results from this sampling generate data that are used as background levels to compare with results from around nuclear sites and to show the variation in levels across the UK. Levels in the environment can be affected by disposals of radioactive waste from nuclear sites abroad and show the legacy of atmospheric fallout from past nuclear weapons testing and the nuclear reactor accident in 1986 at Chernobyl in the Ukraine.

The programme can be divided into three main sectors largely on the basis of the origin of radioactivity in the environment:

1. Nuclear sites discharging gaseous and liquid radioactive wastes
2. Industrial and landfill sites and
3. Chernobyl and regional monitoring

2.1.1 Nuclear sites

Nuclear sites are the prime focus of the programme as they are responsible for the largest individual discharges of radioactive waste. Sampling and direct monitoring is carried out close to each of the sites shown in Figure 1.1. Because some radionuclides discharged in liquid effluent from BNFL Sellafield can be detected in the marine environment in many parts of north-European waters, the programme for this site extends beyond national boundaries.

The frequency and type of measurement and the materials sampled vary from site to site and are chosen to be representative of existing exposure pathways. Knowledge of such pathways is gained from surveys of local peoples' diets and way of life. As a result the programme varies from site to site and from year to year. Detailed information on the scope of the programme at individual sites is given in the tables of results. The routine programme is supplemented by additional monitoring when necessary, for example, in response to incidents or reports of unusual or high discharges of radioactivity with the potential to get into the food chain or the environment. The results of both routine and additional monitoring are included in this report.

The main aim of the programme is to monitor the environment and diet of people who live or work near nuclear sites in order to estimate exposures for those small groups of people who are most at risk from disposals of radioactive waste (the critical group). The pathways that are the most relevant to discharges of liquid wastes are the ingestion of seafood and freshwater fish, drinking water and external exposure from contaminated materials. For gaseous wastes, the effects are due to the ingestion of terrestrial foods, inhalation of airborne activity and external exposure from material in the air and deposited on land. Inhalation of airborne activity and external exposure from airborne material and surface deposition are difficult to assess by direct measurement but can be assessed using environmental models. The main thrust of the monitoring is therefore directed at a wide variety of foodstuffs and measurements of external dose rates on the shores of seas, rivers and lakes. The programme also includes some key environmental indicators, in order that levels can be put in an historic context.

2.1.2 Industrial and landfill sites

Whilst the main focus of the programme is the nuclear industry, a watching brief is kept on other activities which may have a radiological impact on people and the food chain. This part of the programme considers the impact of disposals of natural and man-made radionuclides from non-nuclear industries and of disposal into landfill sites other than at Dounreay. The distribution of sites considered in 2003 is shown in Figure 2.1.

Industrial sites are chosen because either they are known from previous research to have a measurable radiological impact on people and the food chain or they represent a potential to do so. These sites do not require licensing under the Nuclear Installations Act. Examples considered in the past are hospitals, incinerators, steel works and radiochemical manufacturers. In 2003, the sites studied were:

- Avonmouth, Avon (radiolabelling)
- Beckenham, Kent (pharmaceutical research)
- Chilton, Oxfordshire (radiological protection)
- Norwich, Norfolk (food research)
- Southampton, Hampshire (hospital)
- Torbay, Devon (hospital)
- Whitehaven, Cumbria (chemical manufacturer)

In the case of the Whitehaven site, the survey was directed at fish and shellfish consumption. At other sites monitoring of plants, soil or animals took place because the main interest was the terrestrial food chain.

About fifty landfill sites were monitored in England, Scotland and Wales. They were studied to assess the extent, if any, of the contamination leaching from the site and re-entering the terrestrial environment in leachates collected in surface waters close to the sites. The most important site is the engineered facility operated by BNFL at Drigg in Cumbria.

2.1.3 Chernobyl fallout and regional monitoring

Monitoring of the effects of the 1986 Chernobyl accident was undertaken in relation to the continuing restrictions on the movement, sale and slaughter of sheep in parts of Cumbria, north Wales and Scotland. Monitoring of other foodstuffs is now at a much-reduced rate as levels have declined significantly since the accident, but there remains a small-scale survey of radiocaesium in freshwater fish taken from a small number of upland lakes.

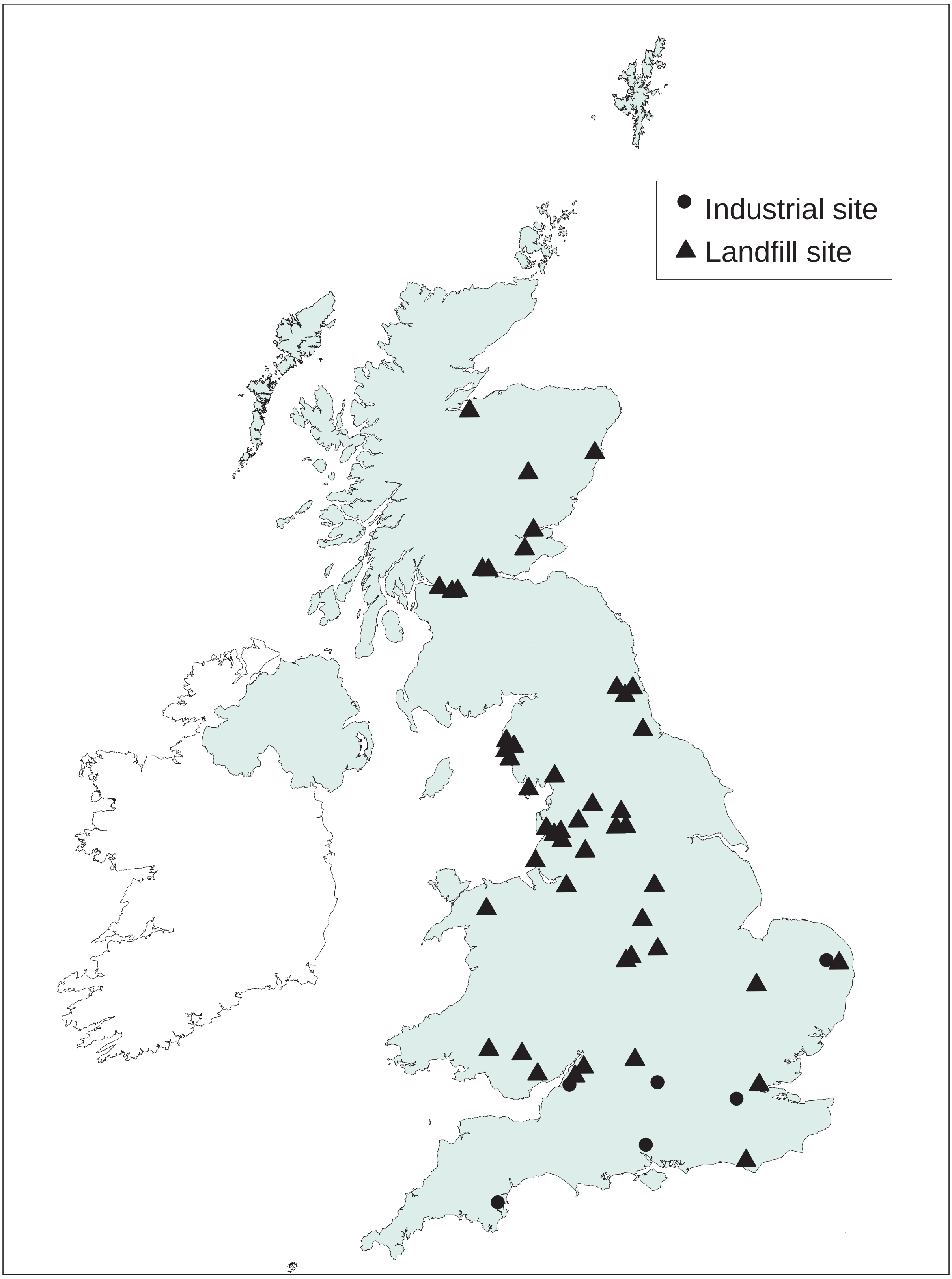

Figure 2.1 Industrial and landfill sites monitored in 2003

2. Sampling, measurement, presentation and assessment

The programme of regional monitoring considers the levels of radionuclides in the environment in areas away from specific sources as an indication of general contamination of the food supply and the environment. The component parts of this programme are:

- monitoring of the Channel Islands, the Isle of Man and Northern Ireland
- dietary surveys
- sampling of milk, crops, bread and meat
- drinking water, rain and airborne particulates
- seawater surveys.

Channel Islands, Isle of Man and Northern Ireland

The programmes for the Insular States and Northern Ireland are designed to complement that for the rest of the UK and to take account of the possibility of long-range transport of radionuclides.

Channel Islands monitoring is carried out on behalf of the Channel Island States. It consists of sampling and analysis of seafood and indicator materials as a measure of the potential effects of UK and French disposals into the English Channel and historic disposal of solid waste in the Hurd Deep.

Monitoring on the Isle of Man for terrestrial foodstuffs is carried out on behalf of the Department of Local Government and the Environment. Sampling is undertaken of a range of foodstuffs that are analysed for Chernobyl, Sellafield and Heysham related radionuclides. Monitoring of seafood is primarily directed at the effects of disposals from Sellafield.

The Northern Ireland programme is directed at the far-field effects of disposals of liquid radioactive wastes into the Irish Sea. Dose rates are monitored on beaches and seafood and indicator materials are collected from a range of coastal locations including marine loughs.

General diet

The purpose of the general diet surveys is to provide information on radionuclides in the food supply to the whole population, rather than to those in the vicinity of particular sources of contamination such as the nuclear industry. This programme provides background information that is useful in interpreting site-related measurements and also helps ensure that all significant sources of contamination form part of the site-related programme. As part of the Total Diet Study (TDS), representative mixed diet samples are collected from towns throughout the UK (see Section 9). Normal culinary techniques are used in preparing samples (e.g. removal of outer leaves of leafy vegetables if necessary) and samples are combined in amounts that reflect the relative importance of each food in the average UK diet. Some samples are analysed for a range of contaminants including radionuclides. Part of this data is also supplied to the European Commission in support of the Euratom Treaty*. The EC compile data into a report of results from all Member States. At the time of writing, the last report covered data for 1995 (Joint Research Centre, 2001). The TDS was supplemented with a study of canteen meals in 2003. Together they account for the ‘dense’ and ‘sparse’ network (Commission of the European Communities, 2000) required by the EC.

Specific foods, freshwater, rain and airborne particulates

Further background information on the relative concentrations of radionuclides is gained from the sampling and analysis of foods, particularly milk, crops, bread and meat. Freshwater, rain and airborne particulates are also analysed to add to the understanding of radionuclide intakes by the population via ingestion and inhalation and as general indicators of the state of the environment.

**The treaty establishing the European Atomic Energy Community (EURATOM) was signed in Rome on 25th March 1957.*

Milk sampling took place at dairies throughout the UK in 2003. Samples were taken monthly and some of the results are reported to the EC to allow comparison with those from other Member States. At the time of writing, the last report covered data for 1995 (Joint Research Centre, 2001).

Other food sampling complements the regional dairy programme described above. Crop samples were taken from locations throughout the UK. Bread and meat samples were also taken in Scotland. The results are used to give an indication of background levels of radioactive contamination from natural and man-made sources (nuclear weapon tests and Chernobyl fallout) for comparison with samples collected from around nuclear sites.

Freshwater used for the supply of drinking water was sampled throughout England, Scotland and Wales (Figure 9.2). Regular measurements of radioactivity in air and rain water were also made. Both programmes are partially sponsored by Defra and provide information to the EC under Article 36 of the Euratom Treaty. Similarly, in Northern Ireland, EHS funds analysis of freshwater used for drinking water. These data are sent to the EC under Article 36 of the Euratom Treaty.

Seawater surveys

Seawater surveys are carried out in the seas around the UK on behalf of Defra to provide information on radionuclide levels and fluxes in the coastal seas of northern Europe. Such information is used to support international studies of the health of the seas under the aegis of the Oslo and Paris Conventions (OSPAR, 2000b), to which the UK is a signatory and in support of research on the fate of radionuclides discharged to sea. These surveys are mounted using government research vessels and are supplemented by a programme of spot sampling of seawater at coastal locations.

2.2 Methods of measurement

There are two basic types of measurement made: (i) samples collected from the environment are analysed for their radionuclide content in a laboratory; and (ii) dose rates are measured directly in the environment.

2.2.1 Sample analysis

The analyses carried out on samples vary according to the nature of the radionuclide under investigation. The types of analysis can be broadly categorised in two groups: (i) gamma-ray spectrometry; and (ii) radiochemical methods. The former is a cost-effective method of detecting a wide range of radionuclides commonly found in radioactive wastes and is used for most samples. The latter comprise a range of analyses involving chemical separation techniques to quantify the alpha and beta emitting radionuclides under study. They are sensitive but more labour intensive. They are, therefore, only used when there is clear expectation that information is needed on specific radionuclides that are not detectable using gamma-ray spectrometry (see Section 2.4 for discussion on limits of detection).

Six laboratories analysed samples in the programmes described in this report. Their main responsibilities were as follows

- CEFAS Centre for Environment, Fisheries and Aquaculture Science,
  analysis of food related aquatic samples in England, Wales, Northern Ireland, Isle of Man and the Channel Islands

- SL Scientifics Ltd.,
  analysis of environment related samples in England and Wales

- IC Imperial College, University of London,
  total uranium analysis of terrestrial samples in England, Wales and the Channel Islands

- NRPB National Radiological Protection Board,
  gamma-ray spectrometry and radiochemistry of samples from Scotland, Total Diet, canteen meals and industrial samples from England and Wales and freshwater for Northern Ireland

- VLA Veterinary Laboratories Agency,
  gamma-ray spectrometry and radiochemistry (excluding total uranium analysis) of food related terrestrial samples in England, Wales, the Channel Islands and the Isle of Man

- WELL Winfrith Environmental Level Laboratory (NNC Ltd.)
  gamma-ray spectrometry and radiochemistry of air and rain samples in England, Wales, Northern Ireland and the Shetland Islands

Each laboratory operates quality control procedures to the standards required by the environment agencies and the Food Standards Agency. In most cases, contractors are third-party assessed for their operating procedures, i.e. they are accredited by an agency such as the United Kingdom Accreditation Service. Regular calibration of detectors is undertaken and intercomparison exercises are held with participating laboratories. The quality assurance procedures and data are made available to the UK environment agencies and the Food Standards Agency for auditing. The methods of measurement include alpha and gamma spectrometry, beta and Cherenkov scintillation counting and alpha and beta counting using proportional detectors.

Corrections are made for the radioactive decay of short-lived radionuclides between the time of sample collection and measurement in the laboratory. This is particularly important for sulphur-35 and iodine-131. Where bulking of samples is undertaken, the date of collection of the bulked sample is assumed to be in the middle of the bulking period. Otherwise the actual collection date for the sample is used. In a few cases where short-lived radionuclides are part of a radioactive decay chain, the additional activity ('in-growth') produced as a result of radioactive decay of parent radionuclides after sample collection is also considered. Corrections to the activity present at the time of measurement are made to take this into account for the radionuclides protactinium-233 and thorium-234.

The analysis of foodstuffs is carried out on that part of the sampled material that is normally eaten, for example, the shells of shellfish and the pods of legumes are discarded before analysis. Foodstuff samples are prepared in such a way so as to minimise losses of activity during the analytical stage. Most shellfish samples are boiled soon after collection to minimise losses from the digestive gland. For a few radionuclides, some activity may be lost in the cooking process during sample preparation. These losses generally reflect the effects of the normal cooking process for the foodstuff.

2.2.2 Measurement of dose rates and contamination

Measurements of gamma dose in air over intertidal and other areas are normally made at 1 m above the ground using Mini Instruments* environmental radiation meters type 680 and 690 with compensated Geiger-Muller tubes type MC-71. For certain key public activities, for example for people living on houseboats or for wildfowlers lying on the ground, measurements at other distances from the ground may be made. External beta doses are measured on contact with the source, for example fishing nets, using Berthold* LB 1210B or Mini 900/EP 15* contamination monitors. These portable instruments are calibrated against recognised reference standards and the inherent instrument background is subtracted. There are two quantities that can be presented as measures of external gamma dose rate, total gamma dose rate or terrestrial gamma dose rate. Total gamma dose rate includes all sources external to the measuring instrument. Terrestrial gamma dose rate excludes cosmic sources of radiation but includes all

* *The reference to proprietary products in this report should not be construed as an official endorsement of these products, nor is any criticism implied of similar products which have not been mentioned.*

others. In this report we have presented the total gamma dose rate. NRPB reports terrestrial gamma dose rates to SEPA. Terrestrial gamma dose rate is converted to total gamma dose rate by the addition of 0.037 $\mu Gy\ h^{-1}$ which is an approximation of the contribution made by cosmic radiation (Her Majesty's Inspectorate of Pollution, 1995).

Beta/gamma monitoring of contamination on beaches or river banks is undertaken using similar instrumentation to that for measurements of dose rates. In England and Wales, a Mini Instruments series 900 mini monitor with a beach monitoring probe is used. The aim is to cover a large area including strand-lines where radioactive debris may become deposited. Any item found with activity levels in excess of the action levels is removed for analysis. An action level of 100 counts per second (equivalent to 0.01 $mSv\ h^{-1}$) is used in England and Wales. During 2003, no items were found above the action level at any site in England and Wales. At Dounreay, in Scotland, special monitoring procedures are in place due to the known presence of radioactive fragments. Further information regarding Dounreay is provided in Section 4.

2.3 Presentation of results

The tables of monitoring results that follow contain summarised values of observations obtained during the year under review. The data are generally rounded to two significant figures. Values near to the limits of detection will not have the precision implied by using two significant figures. Observations at a given location for radioactivity levels and dose rates may vary throughout the year. This variability may be due to changes in rates of discharge, different environmental conditions and uncertainties arising from the methods of sampling and analysis.

The method of presentation of the summarised results allows the data to be interpreted in terms of public radiation exposures for comparison with agreed safety standards. The appropriate period for comparison with recommended limits is one year. Standard practice is to combine annual rates of consumption or occupancy of the small group of people, usually living close to the site, who are expected to be the most exposed (the critical group) with the arithmetic means of observed radioactivity concentrations or dose rates, respectively, during the year at the appropriate locations. This procedure is followed for assessing the impact of contamination of seafood, air, drinking water, beaches and nets.

For milk samples, the most appropriate quantity for use in assessments is the arithmetic mean in the year at the farm where the highest concentration is observed. This is labelled 'max' in the tables of results to distinguish it from the values that are averaged over a range of farms. For other terrestrial foods, an alternative approach is adopted since it is recognised that the possible storage of foods harvested during a particular time of the year has to be taken into account. Greater public exposures would be observed when foods are harvested at times when levels of contamination are high. For such foods, we have presented the maximum concentration observed of each radionuclide at any time in 2003 as well as the mean value. The maximum is labelled 'max' in the tables and forms the basis for the assessment of dose.

Results are presented for each location or source of supply where a sample is taken or a measurement is made. Sample collectors are instructed to obtain samples from the same location during the year. Spatial averaging is therefore not generally undertaken though it is inherent in the nature of some samples collected. A fish may move some tens of kilometres in an environment of changing concentrations in seawater, sediments and lower trophic levels. The resulting level of contamination therefore represents an average over a large area. Similarly cows providing milk at a farm may feed on grass and other fodder collected over a distance of a few kilometres of the farm. In the case of dose rate measurements, the position where the measurement is carried out is within a few metres of other measurements made within a year. Each observation consists of the mean of a number of instrument readings at a given location.

The numbers of farms that were sampled to provide information on activities in milk at nuclear sites are indicated in the tables of results. Milk samples collected weekly or monthly are generally bulked to provide four quarterly samples for analysis each year. For some radionuclides weekly, monthly or annual bulks are taken for analysis. Otherwise, the number of sampling observations in the tables of concentrations refers to the number of samples that were prepared for analysis during the year. In the case of small animals such as molluscs, one sample may include several hundred individual animals.

The number of sampling observations does not necessarily indicate the number of individual analyses carried out for a specific radionuclide. In particular, determinations by radiochemical methods are sometimes carried out less frequently than those by gamma-ray spectrometry. However, the results are often based on bulking of samples such that the resulting determination remains representative.

2.4 Detection limits

There are two main types of result presented in the tables: (i) positively detected values above the detection limits and (ii) 'less than' values which include data at the limit of detection (LoD) or minimum reporting level (MRL). There are also a few results quoted as 'not detected' (ND) by the methods used. 'Less than' values are only reported when the radionuclide is one which is likely to be discharged from the nuclear site under study, or when a positive result is detected in any other sample presented in the table in 2003.

Limits of detection are governed by various factors relating to the measurement method used and these are described in earlier reports (Ministry of Agriculture, Fisheries and Food, 1995). The MRL is a quantity related to the radiological significance of a particular concentration of activity. In certain cases, whilst a LoD may be relatively low, the requirements for reporting from analytical laboratories are defined at a higher level, that is the MRL. The concepts and values of MRLs are discussed further in earlier reports (e.g. Ministry of Agriculture, Fisheries and Food, 1995).

2.5 Additional information

The main aim of this report is to present all the results of routine monitoring from the programmes described previously. However, it is necessary to carry out some averaging for clarity and to exclude some basic data that may be of use only to those with particular research interests. Full details of the additional data are available from the environment agencies and the Food Standards Agency. Provisional results of concentrations of radionuclides in food samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries through the internet (www.food.gov.uk).

The main categories of additional data are:

- data for individual samples prior to averaging
- uncertainties in measurements
- data for very short-lived radionuclides supported by longer-lived parents
- data which are not relevant to a site's discharges for natural radionuclides and for artificial radionuclides below detection limits
- measurements carried out as part of the research programme described in Section 10.

Very short-lived radionuclides such as yttrium-90, rhodium-103m, rhodium-106m, barium-137m and protactinium-234m which are formed by decay of, respectively, strontium-90, ruthenium-103, ruthenium-106, caesium-137 and thorium-234 are taken into account when calculations of exposure are made. They are not listed in the tables of results. As a first approximation, their concentrations can be taken to be the same as those of their respective parents.

2.6 Radiation protection standards

The monitoring results in this report are interpreted in terms of radiation exposures of the public, commonly termed ‘doses’. This Section describes the dose standards that apply in ensuring protection of the public.

Current UK practice relevant to the general public is based on the recommendations of the ICRP as set out in ICRP Publication 60 (International Commission on Radiological Protection, 1991). The dose standards are embodied in national policy on radioactive waste (United Kingdom – Parliament, 1995b) and in guidance from the IAEA in their Basic Safety Standards for Radiation Protection (International Atomic Energy Agency, 1996). Legislative dose standards are contained in the Basic Safety Standards Directive 96/29/Euratom (Commission of the European Communities, 1996) and subsequently incorporated into UK law in the Ionising Radiations Regulations 1999 (United Kingdom – Parliament, 1999). In order to implement the Basic Safety Standards Directive, Ministers have provided the Environment Agency and SEPA with Directions concerning radiation doses to the public and their methods of estimation and regulation for all pathways (Department of the Environment, Transport and the Regions, 2000 and Scottish Executive, 2000). The methods and data used in this report are consistent with the Directions.

The relevant dose limits for members of the public are 1 mSv (millisievert) per year for whole-body (more formally ‘committed effective dose’) and 50 mSv per year specifically for skin. The latter limit exists to ensure that specific effects on skin due to external exposure are prevented. It is applicable, for example, in the case of handling of fishing gear. The dose limits are for use in assessing the impact of direct radiations and controlled releases (authorised discharges) from radioactive sources.

The mean dose received by the ‘critical group’ is compared with the dose limit. The critical group represents those who are most exposed to radiation and in this report are generally people who eat large quantities of locally grown food (high-rate consumers) or who spend long periods of time in areas where radioactive contamination may exist. The limits apply to all age groups. Children may receive higher doses than adults because of their physiology, anatomy and dietary habits. Consequently doses have been assessed to different age groups, i.e. adults, 10-year-old children and 1-year-old infants, and from this information it is possible to determine which of these age groups forms the critical group.

For drinking water, the World Health Organisation (WHO) has provided screening levels to compare with the results of measurements of total alpha and beta activity (WHO, 1993). The EC has prepared a directive on the quality of water intended for human consumption, which sets parameters for tritium and total indicative dose (Commission of the European Communities, 1998). The screening levels are 0.1 and 1.0 Bq l^{-1}, respectively, and are based on consideration of the dose that would result from radium-226 (alpha) and strontium-90 (beta) intakes. These were chosen as representative of the most radiotoxic radionuclides likely to be present in significant quantities. The values represent concentrations below which water can be considered potable without any further radiological examination. Similarly the Commission of the European Communities (CEC) has set a reference value of 100 Bq l^{-1} for tritium in drinking water (Commission of the European Communities, 1998).

Accidental releases may be judged against EU and ICRP standards in emergency situations (Commission of the European Communities, 1989 and International Commission on Radiological Protection, 1993). In addition, it is Government policy that EU food intervention levels will be taken into account when setting discharge limits. The IAEA has requested that the Codex Alimentarius Commission (CAC) considers producing guidelines for long-term use and revise or amend the current guideline levels for radionuclides in foods following accidental nuclear contamination for use in international trade. The Codex Committee on Food Additives and Contaminants has considered draft guidelines at its meeting in March 2004 (CODEX Alimentarius Commission, 2004). The committee agreed a draft text that has been forwarded to the CAC for preliminary adoption. The new draft guideline levels will apply to radionuclides contained in foods for human consumption and traded internationally.

The main focus of this report and radiological regulation and monitoring more generally is towards protection of man. The Habitats Directive (Commission of the European Communities, 1992) requires a 3-stage approach to the assessment of the impact of radioactive discharges on sensitive habitats. The environment agencies have completed initial assessments using the methods and data in Copplestone *et al*. (2001). Further research is being undertaken to provide methods and data to enable more complete and systematic assessments to be made in the UK (Commission of the European Communities, 2004).

2.7 Assessment methods and data

Calculations of exposures of members of the public from waste disposals are primarily based on the environmental monitoring data for 2003. The methods used are compatible with the principles endorsed by the UK National Dose Assessment Working Group (National Dose Assessment Working Group, 2004). The data provide information on two main pathways:

- ingestion of foodstuffs and
- external exposure from contaminated materials in the aquatic environment.

In addition, atmospheric dispersion models are used to estimate doses for gaseous discharges from a few sites where monitoring is not an effective method of establishing concentrations and dose rates in the environment. Full details are given in Appendix 2. Monitoring data are also used to assess doses from pathways which are generally of lesser importance:

- drinking water
- inadvertent ingestion of water and sediments and
- inhalation of resuspended soil and sediment

This Section describes how the data are chosen for each assessment of dose. For pathways involving intakes of radionuclides, the data required are:

- concentrations in foodstuffs, drinking water, sediments or air
- the amounts eaten, drunk or inhaled
- the dose coefficients that relate an intake of activity to a dose.

For external radiation pathways, the data required are:

- the dose rate from the source, for example a beach or fishermens' nets, and
- the time spent near the source.

In both cases, the assessment estimates exposures from these pathways for potential critical groups, that is the groups of people who are likely to be most exposed.

2.7.1 Radionuclide concentrations in foodstuffs, drinking water, sediments and air

In nearly all cases, the radionuclide concentrations are determined by monitoring and are given later in this report. The Sellafield, Drigg and Isle of Man terrestrial assessments are supplemented by information from foodchain models (see Appendix 2). The concentrations chosen for the assessment are intended to be representative of the intakes of the most exposed consumers in the population. All of the positively determined concentrations tabulated are included irrespective of the origin of the radionuclide. In some cases, this means that the calculated exposures include contributions due to disposals from other sites as well as from weapon test fallout and activity deposited following the Chernobyl accident. Where possible, corrections for background concentrations of natural radionuclides are made in the calculations of dose.

For aquatic foodstuffs, drinking water, sediments and air, the assessment is based on the mean concentration near the site in question. For milk, the mean concentration at a nearby farm with the highest individual result is used in the dose assessment. This procedure 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.

For other foodstuffs, the maximum concentrations are selected for the assessment. This allows for the possibility of storage of food harvested at a particular time when the peak levels in a year may have been present in the environment.

The tables of concentrations include ‘less than’ values as well as positive determinations. This is particularly evident for terrestrial foodstuffs. Where a result is presented as a ‘less than’ value, the dose assessment methodology treats it as if it were a positive determination in two situations: (i) when that radionuclide is specified in the relevant authorisation or (ii) when a positive determination for that radionuclide is found in another sample from the site. Although this approach may produce an overestimation of dose, particularly at sites where levels are low, it ensures that estimated exposures are unlikely to be understated.

2.7.2 Consumption, drinking and inhalation rates

In the assessment of the effects of disposals of liquid effluents, the amounts of fish and shellfish consumed are determined by site-specific dietary habit surveys. Data are collected primarily by direct interviews with potential high-rate consumers who are often found in fishing communities. Children are rarely found to eat large quantities of seafood and their resulting doses are invariably less than those of adults. The calculations presented in this report are therefore representative of adult seafood consumers.

In assessments of terrestrial foodstuffs, the amounts of food consumed are derived from national surveys of diet and are defined for three ages: adults, 10-year-old children and 1-year-old infants (based on Byrom *et al.*, 1995). For each food type, consumption rates at the 97.5 th percentile of consumers have been taken to represent the people who consume a particular foodstuff at a high level (the ‘critical group’ consumption rate).

Drinking and inhalation rates are general values for the population, adjusted according to the times spent in the locations being studied.

The consumption, drinking and inhalation rates are given in Appendix 4. Estimates of dose are based on the most up to date information available at the time of writing the report. Where appropriate, the data from site-specific surveys are averaged over a period of 5 years following the recommendation of the report of the Consultative Exercise on Dose Assessments (CEDA) (Food Standards Agency, 2001b).

The assessment of terrestrial foodstuffs is based on two assumptions: (i) that the foodstuffs eaten by the most exposed individuals are those that are sampled for the purposes of monitoring; and (ii) that the consumption of such foodstuffs is sustained wholly by local sources. The two food groups resulting in the highest dose are taken to be consumed at ‘high level’ consumption rates, while the remainder are consumed at mean rates. The choice of two food groups at the higher consumption rates is based on statistical analysis of national diet surveys. This shows that only a very small percentage of the population were critical rate consumers in more than two food groups (Ministry of Agriculture, Fisheries and Food, 1996). Locally grown cereals are not considered in the assessment of exposures as it is considered highly unlikely that a significant proportion of cereals will be made into locally consumed (as opposed to nationally consumed) foodstuffs, notably bread.

2.7.3 Dose coefficients

Dose calculations for intakes of radionuclides by ingestion and inhalation are based on dose coefficients taken from ICRP Publication 72 (International Commission on Radiological Protection, 1996a). These coefficients (often referred to as 'dose per unit intake') relate the committed dose received to the amount of radioactivity ingested or inhaled. The dose coefficients used in this report are provided in Appendix 5 for ease of reference.

Calculations are performed for three ages: adults, 10-year-old children and 1-year-old infants as appropriate to the pathways being considered. ICRP and the HSE have also published dose coefficients for the foetus (International Commission on Radiological Protection, 2001 and Phipps *et al*., 2001). The ratio of foetal to adult dose coefficients for the public is generally less than 1 (Stather *et al*., 2002). However there are some radionuclides notably tritium, carbon-14, sulphur-35 and strontium-90 where the ratio is greater, up to 2:1 for strontium-90. The implication for assessments in this report is that some doses for comparison with limits could be underestimated by excluding the foetal age group, however the likelihood of this happening is low since the main group of assessments that may be affected are those for terrestrial foods which tend to result in relatively low doses. Our assessments confirm that in no case would foetal doses approach the dose limit. The NRPB is planning to issue guidance in relation to assessments of foetal doses. The assessments procedure in RIFE will be reviewed and revised as necessary when the guidance is made available.

The dose assessments include the use of appropriate gut uptake factors (proportion of radioactivity being absorbed from the digestive tract). Where there is a choice of gut uptake factors for a radionuclide, we have generally chosen the one that results in the highest predicted exposure. In particular where results for total tritium are available, we have assumed that the tritium content is wholly in an organic form. However, we have also taken into account specific research work of relevance to the foods considered in this report. This affects the assessments for polonium, plutonium and americium radionuclides as discussed in Appendix 5.

2.7.4 External exposure

In the assessment of external exposure, there are two factors to consider: (i) the dose rate from the source and (ii) the time spent near the source. In the case of external exposure to penetrating gamma radiation, uniform whole body exposure has been assumed. The radiation as measured is in terms of the primary quantity known as 'air kerma* rate', a measure of the energy released when the radiation passes through air. This has been converted into exposure using the factor 1 milligray = 0.85 millisievert (International Commission on Radiological Protection, 1996b). This factor applies to a rotational geometry with photon energies ranging from 50 keV to 2 MeV. This is appropriate for the instrument used whose sensitivity is much reduced below 50 keV, and to the geometry of deposits of artificial radionuclides. Applying an isotropic geometry gives a value of 0.70 Sv Gy^{-1} which would be more appropriate for natural background radiation. The choice of 0.85 will therefore tend to overestimate dose rates for the situations considered in this report which include both artificial and natural radiation.

For external exposure of skin, the measured quantity is contamination in Bq cm^{-2}. In this case, dose rate factors in Sv y^{-1} per Bq cm^{-2} are used which are calculated for a depth in tissue of 7 mg cm^{-2} (Kocher and Eckerman, 1987). The times spent near sources of external exposure are determined by site-specific habits surveys in a similar manner to consumption rates of seafood. The occupancy and times spent handling fishing gear are given in Appendix 4.

2.7.5 Subtraction of 'background' levels

When assessing internal exposures due to ingestion of carbon-14 and radionuclides in the uranium and thorium decay series in seafood, concentrations due to natural background levels are subtracted. Background carbon-14 concentrations in terrestrial foods are also subtracted. The estimates of background concentrations are given in Appendix 6. When assessing the man-made effect on external

* *Air kerma is the quotient of the sum of the kinetic energies of all the charged particles liberated by indirectly ionising particles in a specified mass of air.*

exposures to gamma radiation, dose rates due to background levels are subtracted. On the basis of measurements made previously as part of the programmes reported here, the gamma dose rate backgrounds in the aquatic environment are taken to be 0.05 µGy h^{-1} for sandy substrates, 0.07 µGy h^{-1} for mud and salt marsh and 0.06 µGy h^{-1} for other substrates. These data are compatible with those presented by McKay *et al*. (1995). However, where it is difficult to distinguish the result of a dose rate measurement from natural background, the method of calculating exposures based on the concentrations of man-made radionuclides in sediments is used (Hunt, 1984). Estimates of external exposures to beta radiation include a component due to natural (and un-enhanced) sources because of the difficulty in distinguishing between natural and man-made contributions. Such estimates are therefore conservative when compared with the relevant dose limit that excludes natural sources of radiation.

2.7.6 Summation of doses from different pathways

The dose standards formally require the summation of contributions from all practices under control. In the context of this report, individual members of the public will be exposed to disposals from the nuclear site under study and, in the case of widespread contamination, from other sites. However, they may also be exposed to other controlled practices such as the transportation of radioactive materials, the use of consumer products containing radioactivity (e.g. some smoke detectors and tritium lights) and direct radiation from nuclear sites and other sources.

The environmental data and the individuals affected that are assessed in this report naturally fall into two separate groups: those affected by liquid waste disposal and those by gaseous waste disposal. We have therefore calculated doses separately in these two cases and within each group we have summed contributions from the different pathways involved. The simple further addition of ‘liquid’ and ‘gaseous’ doses will overestimate the dose received at that location due to radioactive waste disposal because the population groups most affected by atmospheric and liquid discharges tend to be different. An individual is unlikely to consume both aquatic and terrestrial foods at such high rates. With the benefit of new habits survey information gained for all pathways of significance, an assessment of the total dose at specific nuclear sites is provided in Appendix 7. Direct radiation from nuclear sites is considered with the benefit of information provided by the HSE.

2.7.7 Uncertainties in dose assessment

Various methods are used to reduce the uncertainties in the process of dose estimation for critical groups from monitoring programmes. These address the following main areas of concern:

- programme design
- sampling and *in situ* measurement
- laboratory analysis
- description of pathways to man
- radiation dosimetry
- calculational and presentational error

Quantitative estimation of uncertainties in doses is beyond the scope of this report. However, independent assessments are undertaken by industry (e.g. BNFL, 2004)

3. NUCLEAR FUEL PRODUCTION AND REPROCESSING

The main sites discharging radioactive wastes in the UK associated with nuclear fuel production and reprocessing are at Capenhurst (uranium enrichment), Sellafield (reprocessing) and Springfields (fuel manufacture). British Nuclear Fuels (BNFL) plc holds the main authorisations for waste disposal at these sites though small amounts of gaseous wastes are discharged by Urenco (Capenhurst) Ltd. at Capenhurst and UKAEA at Sellafield. The low-level waste repository at Drigg operated by BNFL is discussed in Section 8.1

3.1 Capenhurst, Cheshire

The main functions undertaken on the Capenhurst site are enrichment of uranium and dismantling of redundant plant. The enrichment facility is operated by Urenco (Capenhurst) Ltd. Radioactive waste arisings consist of tritium, uranium plus its daughter products, technetium-99 and neptunium-237 (from recycled fuel). In 2003, BNFL had authorisations to dispose of small amounts of radioactivity in gaseous wastes via stacks and in liquid wastes to the Rivacre Brook. Urenco (Capenhurst) Ltd. also had a gaseous discharge authorisation. An environmental monitoring programme for foodstuffs, water, dose rates and indicator materials was carried out to investigate the different pathways that could be of radiological significance. These were ingestion of locally grown food and occupancy near the Rivacre Brook.

Results for 2003 are presented in Tables 3.1(a) and (b). Concentrations of radionuclides in samples from the land and from the Rivacre Brook were generally similar to those for 2002. Gamma dose rates were difficult to distinguish from natural background. The concentrations of artificial radionuclides in marine samples are consistent with values expected at this distance from Sellafield. The critical group for liquid discharges from the site is considered to be children who play near the Brook and may inadvertently ingest water and sediment from the Brook. Taking pessimistic assumptions about their ingestion rates and allowing for a small increase in gamma dose rates, the dose to the group was less than 0.009 mSv in 2003 (Table 3.2). The dose to high-rate seafood consumers would be less than the dose to children ingesting Rivacre Brook water and sediment.

The main effect of the site operations was detected in soils and grass containing technetium-99. However, the consequential levels in foodstuffs were very low. The dose to the critical group of terrestrial food consumers was less than 0.005 mSv in 2003.

3.2 Sellafield, Cumbria

Operations and facilities at Sellafield include fuel element storage, the Magnox and oxide fuel reprocessing plants, mixed oxide fuel manufacture, decommissioning and clean-up of some nuclear facilities, and the Calder Hall Magnox nuclear power station. Calder Hall ceased electricity production in March 2003 and is now preparing for decommissioning. Radioactive waste discharges include a very minor contribution from the UKAEA Windscale site, which includes facilities operated by AEA Technology. The most significant discharges are made from the BNFL fuel element storage ponds and the reprocessing plants, which handle irradiated Magnox and oxide fuel from the UK nuclear power programme, and some fuel from abroad.

No changes to the limits specified in the authorisations to discharge radioactivity were made in 2003. In June 2003, the HSE announced its decision to give permission to BNFL to re-route the future production of Medium Active Concentrate (MAC) at Sellafield (Health and Safety Executive and Environment Agency, 2003). The modification to re-route new MAC was a requirement specified in the Environment Agency's decision on the future regulation of technetium-99 discharges from Sellafield published in September 2001. In response, BNFL has, since July 2003, re-routed MAC to storage and subsequent vitrification. The re-routing of new MAC will have the effect of eliminating the discharge of technetium-99 and other radionuclides to the Irish Sea from this source. However, discharges from the site will not reduce until after the existing MAC in storage, which is chemically unsuitable for vitrification, has been treated in the Enhanced Actinide Removal Plant (EARP).

In April 2004, further progress in reducing technetium-99 discharges was announced by the Environment Agency and HSE (Environment Agency, 2004d). As a result of a separate requirement of the Agency's decision on technetium-99, a trial of the use of TPP (tetraphenylphosphonium bromide) in EARP was carried out by BNFL in 2003 to remove technetium-99 from the MAC already in store at the time of the re-routing. The trial was assessed by the Environment Agency and HSE and was very successful and BNFL has subsequently implemented the new technique. As a result of this and of the earlier MAC diversion, discharges of technetium-99 will be reduced by around 90% from 2002 levels. A review of other authorisation requirements at BNFL Sellafield has been completed and the Environment Agency's proposed decision, including a significantly strengthened and more comprehensive authorisation was forwarded to Ministers in August 2002. Following the agreement of Ministers, the Environment Agency has updated its proposals for the Sellafield authorisation, which came into force on 1st October 2004. The Environment Agency has also begun a review of disposals from the UKAEA Windscale site (Environment Agency, 2002b).

Current monitoring of the site reflects both historic and present day activities and, in view of its importance, is considered in depth in this report. The discussion is provided in two sub-sections, one relating to the effects of liquid discharges, the other to gaseous wastes.

The Commission of the European Communities inspected the Sellafield site in March 2004 under terms of the Euratom Treaty (Article 35). The inspection was to establish the adequacy of monitoring and reporting undertaken by both the site operators and the regulatory bodies. Submissions were made by BNFL, the Environment Agency and the Food Standards Agency and the outcome of the Inspection will be summarised in subsequent RIFE reports when it is made available by the CEC.

3.2.1 The effects of liquid discharges

Discharges from the Sellafield pipelines during 2003 are summarised in Appendix 1. Total alpha and beta discharges were 0.407 and 83.3 TBq, respectively (2002: 0.35 and 112 TBq, respectively). Most of the reduction in total beta discharge was due to technetium-99. Discharges of it decreased from 85.4 TBq in 2002 to 37.0 TBq in 2003 and are now much lower than the peak reached in 1995 of 192 TBq. The reduction of technetium-99 was due to the trial use of TPP in October-November 2003 (see above). There were small increases for carbon-14 and ruthenium-106 linked to the highest throughput of Magnox fuel reprocessing in the last ten years, necessary to ensure all Magnox reprocessing ceases in 2012 as required by the UK strategy for radioactive discharges. No discharges exceeded the limits set in the authorisation.

Regular monitoring of the marine environment near Sellafield continued during 2003. Important radiation exposure pathways were consumption of fish and shellfish and external exposure to gamma rays and beta particles from human occupancy over sediments. Other pathways were kept under review and in particular, the potential for sea-to-land transfer at the Ravenglass estuary to the south of the site. In 2003, as in previous recent years, there was no harvesting of *Porphyra* seaweed in west Cumbria for manufacture of laverbread but monitoring continued because the pathway remains potentially important. Smith *et al*. (2004) gives a review of changes in discharges and effects from the site. The monitoring locations for seafood, water, environmental materials and dose rates near the Sellafield site are shown in Figures 3.1 and 3.2.

Following international and local concerns, and given the importance of the fish farming industry in Scotland, a special survey was carried out in March-May 2003 of radioactivity in farmed salmon from Scotland and Northern Ireland. The results have been published and are included in this report (see Table 3.3) for completeness (Food Standards Agency, 2003a).

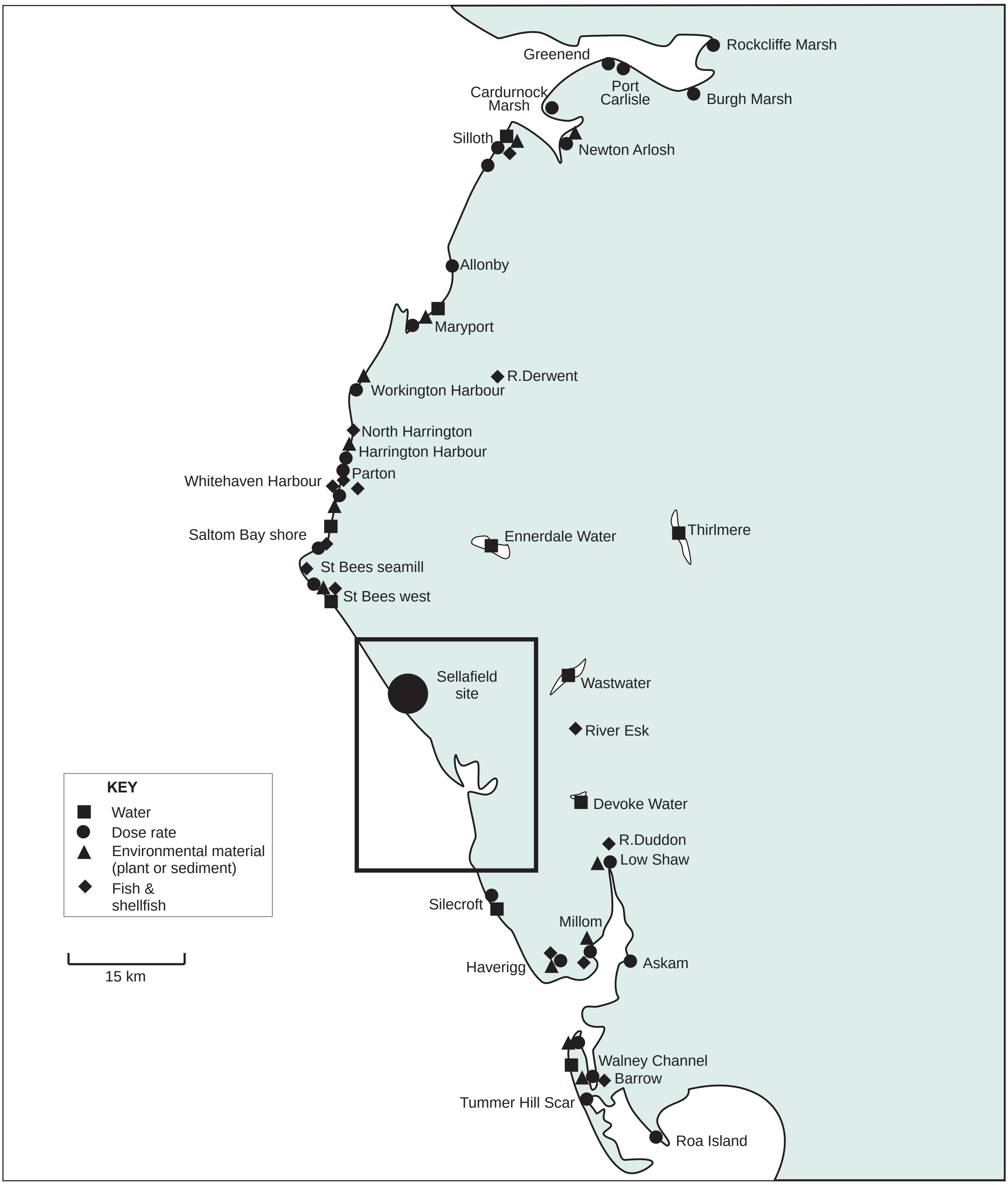

Figure 3.1 Monitoring locations in Cumbria (excluding farms)

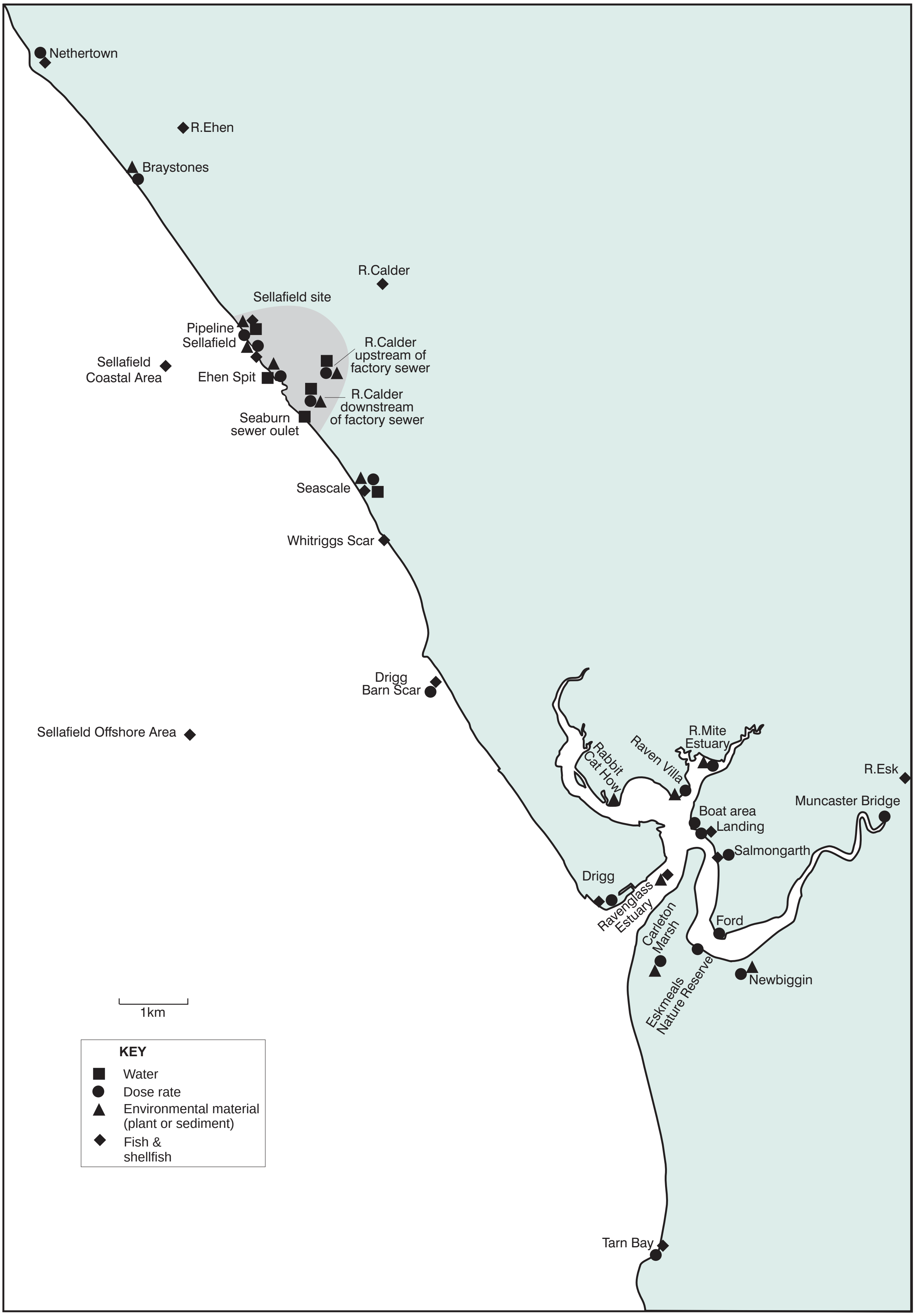

Figure 3.2 Monitoring locations at Sellafield (excluding farms)

The fish and shellfish consumption pathway
Concentrations of radionuclides

Concentrations of beta/gamma activity in fish from the Irish Sea and from further afield are given in Table 3.3. Concentrations in 2003 were generally similar to those in 2002. However, small increases were observed for carbon-14 and ruthenium-106 due to the discharge trends noted above. Data are listed by location of sampling or landing point, in approximate order of increasing distance from Sellafield. Samples taken near other nuclear establishments that reflect Sellafield discharges are given later in this report. The ‘Sellafield Coastal Area’ extends 15 km to the north and to the south of Sellafield, from St Bees Head to Selker and 11 km offshore; most of the fish and shellfish consumed by the local critical group is taken from this area. Specific surveys are carried out in the smaller ‘Sellafield Offshore Area’ where experience has shown that good catch rates may be obtained. This area consists of a rectangle, one nautical mile (1.8 km) wide by two nautical miles (3.6 km) long, situated south of the pipelines with the long side parallel to the shoreline; it averages about 5 km from the pipeline outlet.

The results for radiocaesium generally reflect progressive dilution with increasing distance from Sellafield. However, the rate of decline of radiocaesium concentrations with distance is not as marked, as was the case some years ago, when significant reductions in discharges were achieved. There is therefore a greater contribution from historical sources. Radiocaesium in fish from the Baltic is not due to Sellafield discharges but is substantially from the Chernobyl accident. Concentrations of radiocaesium in fish known to have been caught in Icelandic waters remained typical of those from weapon test fallout, at a value of about 0.2 Bq kg^{-1} for caesium-137 in cod. Data for the Barents Sea are similar. Data for cod from the ‘Offshore Area’ have been used to give a general indication of trends in fish (Figures 3.3 - 3.8) though some variability between fish species can be found.

Low concentrations of man-made radioactivity were found in fishmeal which is fed to farmed fish, poultry, pigs, cows and sheep. A theoretical study has established that any indirect onward transmission of radioactivity into human diet as a result of this pathway is unlikely to be of radiological significance (Smith and Jeffs, 1999). A detailed survey was undertaken in 2003 to confirm these findings and the results are reported in Table 3.3. Samples were obtained from 14 fish farms in Scotland and 3 in Northern Ireland. They demonstrate radionuclide concentrations are indeed very low, most being less than the limits of detection, and the few that were positively determined were all less than 1Bq kg^{-1} (Food Standards Agency, 2003a).

Concentrations of most other beta/gamma emitting radionuclides in fish tend to be lower. However, with an expected carbon-14 concentration being about 25 Bq kg^{-1} from natural sources, the data suggest there is a local enhancement of carbon-14 due to discharges from the site. The highest concentrations of radioactivity in marine fish are found for tritium at about 100 Bq kg^{-1}. Similar concentrations are found from determinations of organically associated tritium in the fish. Concentrations of tritium in local seawater at St Bees are less than 30 Bq l^{-1} (Table 9.17). This indicates that some bioaccumulation of tritium is taking place. However, its extent is much smaller than observed in the Severn Estuary near Cardiff (see Section 7). The radiotoxicity of tritium is very low, and the radiological importance of these concentrations, as determined later in this report, is much less than that of other radionuclides.

For shellfish, a wide range of radionuclides contributes to radiation exposure of consumers owing to generally greater uptake of radioactivity in these organisms than in fish. Table 3.4 lists concentrations of beta/gamma-emitting nuclides (except plutonium-241) and total beta activity in shellfish from the Irish Sea and further afield. Crustaceans and molluscs are of particular radiological importance to the critical group near to Sellafield, as described later in this section. In addition to sampling by CEFAS, supplies of winkles, mussels and limpets were obtained from consumers who collected them in the Sellafield coastal area.

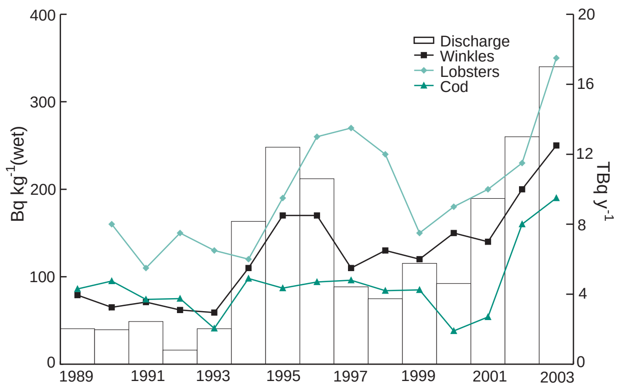

Figure 3.3 Carbon-14 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

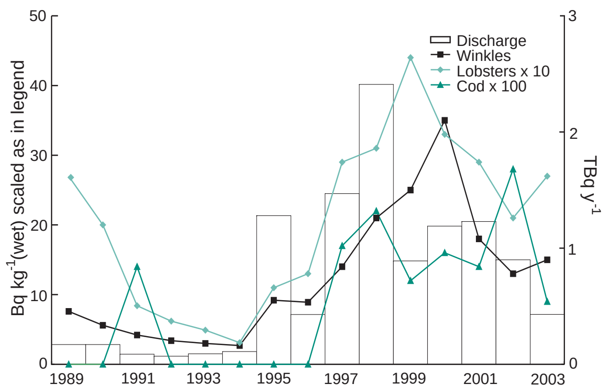

Figure 3.4 Cobalt-60 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

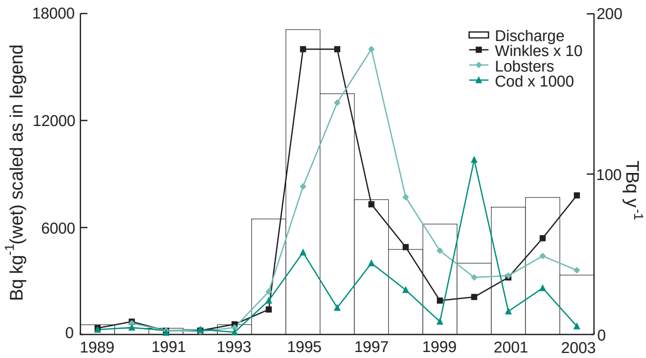

Figure 3.5 Technetium-99 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

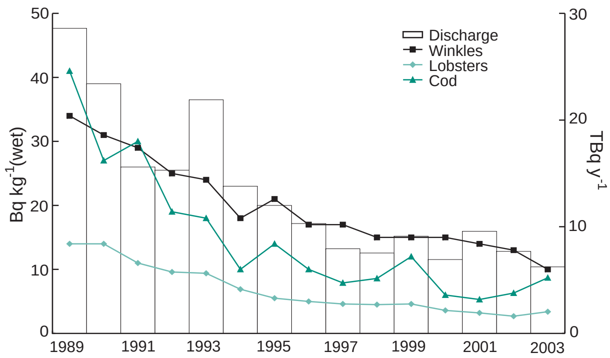

Figure 3.6 Caesium-137 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

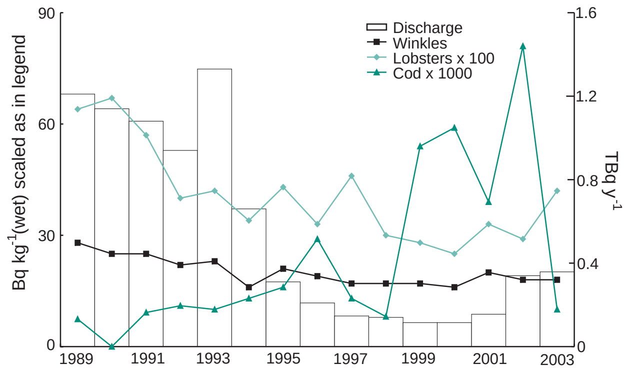

Figure 3.7 Plutonium-239/240 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

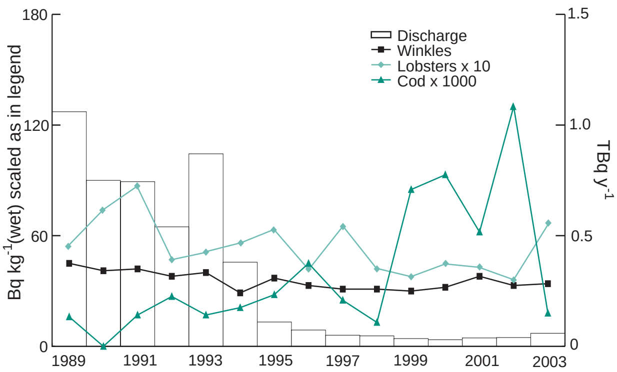

Figure 3.8 Americium-241 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

Concentrations of artificial radionuclides in shellfish, as with fish, generally diminish with increasing distance from Sellafield. There can be substantial variations between species: for example, lobsters tend to concentrate more technetium-99 in comparison with crabs (see also Knowles *et al.*, 1998; Swift and Nicholson, 2001). However, as a general rule, molluscs tend to contain higher levels of radionuclides than crustaceans, which in turn tend to contain more than fish. The highest concentrations due to Sellafield discharges are found for tritium, carbon-14 and technetium-99. When comparing 2002 and 2003 data across a wide range of sampling locations and shellfish species, few major changes in concentrations were found. Some increases in carbon-14 and ruthenium-106 were detected, as noted earlier. Tritium levels in molluscs collected close to the site were slightly higher when compared to 2002 levels. Technetium-99 levels were largely unchanged despite a reduction in discharges. This is thought to be due to a 1 or 2 year lag effect. Seaweeds are a sensitive indicator of technetium-99 and further information from samples collected throughout the UK is given later in this Section.

Analyses for transuranic radionuclides such as plutonium (except plutonium-241, which is measured using beta counting), americium, neptunium and curium are often labour-intensive because they involve chemical separation techniques to quantify the alpha-emitting radionuclides and they are counted for a long time in order to detect the very low levels present. Therefore a specific selection of samples of fish and shellfish, chosen mainly on the basis of potential radiological significance, were analysed for these nuclides. The data for 2003 are presented in Table 3.5. Transuranics are less mobile than radiocaesium in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranics in shellfish compared with fish and a rapid reduction with distance from Sellafield in concentrations of transuranics, particularly in shellfish. Concentrations in shellfish in 2003 were generally similar to those in 2002 (Figures 3.7 and 3.8). Levels of transuranics in samples from the north-eastern Irish Sea were the highest found in foodstuffs in the UK. The anomalous high concentrations in offshore cod found in 2002 were not repeated in 2003.

The longer term changes in concentrations in seafood are shown in Figures 3.3 - 3.8 with the corresponding discharge profiles. In general, concentrations have increased and decreased in response to changes in discharges albeit on occasion with a certain time lag. However, there have been irregular results, particularly for fish and this is probably due to their migratory nature.

Concentrations of natural radionuclides in fish and shellfish in the Sellafield area are presented in Section 8.

Individual dose from seafood consumption

Table 3.6 summarises doses in 2003 from radionuclides in fish and shellfish.

The dose to the local critical group of high-rate consumers from artificial radionuclides was 0.21 mSv. This dose includes a contribution due to external exposure of radiation. The consumption and occupancy rates of the local critical group were reviewed in 2003; changes were found in the mix of species consumed and increases were found in the consumption of crustaceans. The small increase in dose from 0.19 mSv reported for 2002 (based on a five year average of habits surveys data 1998 – 2002) (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2003) is largely due to changes in some of the consumption rates of the local critical group. Most of the dose from the ingestion of seafood and external irradiation due to Sellafield was from historic discharges. Recent and current discharges of technetium-99 contributed about 15% of the dose to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose were plutonium-239/240 and americium-241. The increases in concentrations of carbon-14 and ruthenium-106 noted previously had a minor effect contributing less than 10% of the dose from artificial radionuclides.

The dose estimates are based on a five-year average of critical group habits in an attempt to provide a more direct measure of the effects of changing concentrations in food and the environment, as opposed to changes in the diet and habits of consumers. This approach follows the recommendation of the report of the Consultative Exercise on Dose Assessment (Food Standards Agency, 2001b). The period of averaging chosen for the 2003 dose assessment was 1999-2003 and the data are provided in Appendix 4. A dose assessment for the Sellafield fishing community based on consumption rates and habits survey data for 2003 is provided in Table 3.6 for comparison with the same group using the five year average habit survey data.

Data for natural radionuclides in fish and shellfish are discussed in Section 8. However, the effects on the Sellafield critical group from controlled discharges of natural radionuclides from another west Cumbrian source, Rhodia Consumer Specialties Ltd., Whitehaven, are also considered here. The increase in natural radionuclide concentrations is difficult to determine above a variable background (see Appendix 6). However, using maximising assumptions for the dose coefficients, the dose to the local group of seafood consumers due to the enhancement of concentrations of natural radionuclides in the Sellafield area in 2003 was estimated to be 0.41 mSv. Most of this was due to the polonium-210 and lead-210 content of shellfish. Taken with the 0.21 mSv dose from artificial radionuclides from Sellafield this gives a total dose to the critical group of 0.62 mSv. These doses may be compared with an average dose of approximately 2.2 mSv y^{-1} to members of the UK public from all natural sources of radiation (Hughes, 1999) and to the annual dose limit to members of the public of 1 mSv.

Exposures of groups representative of the wider communities associated with fisheries in Whitehaven, Dumfries and Galloway, the Morecambe Bay area, Fleetwood, Northern Ireland, north Wales and the Isle of Man have been kept under review (Table 3.6). Where appropriate the dose from consumption of seafood has been summed with a contribution from external exposure over intertidal areas. The doses received by all these groups are significantly less than that for the local Sellafield group because of the lower concentrations observed further afield. There were small changes in the doses in each area when compared with those in 2002 (see following text table and Figure 3.9). It is expected that there will be fluctuations in concentrations due to normal sampling variability. Whilst there have been changes in the concentrations of some radionuclides in seafood, their effect is relatively minor. All doses were well within the dose limit for members of the public of 1 mSv.

The dose from artificial radionuclides, equivalent to a consumption rate of 15 kg $year^{-1}$ of fish from landings at Whitehaven and Fleetwood, is also given in Table 3.6. This consumption rate represents an average for typical fish-eating members of the public. Their dose was very low, less than 0.005 mSv in 2003.

Doses from artificial radionuclides in the Irish Sea

Group	Dose, mSv	
	2002	2003
Isle of Man	0.007	0.006
Northern Ireland	0.012	0.013
Dumfries and Galloway	0.045	0.036
Whitehaven	0.026	0.031
Sellafield	0.19	0.21
Morecambe Bay	0.066	0.075
Fleetwood	0.018	0.018
North Wales	0.014	0.012

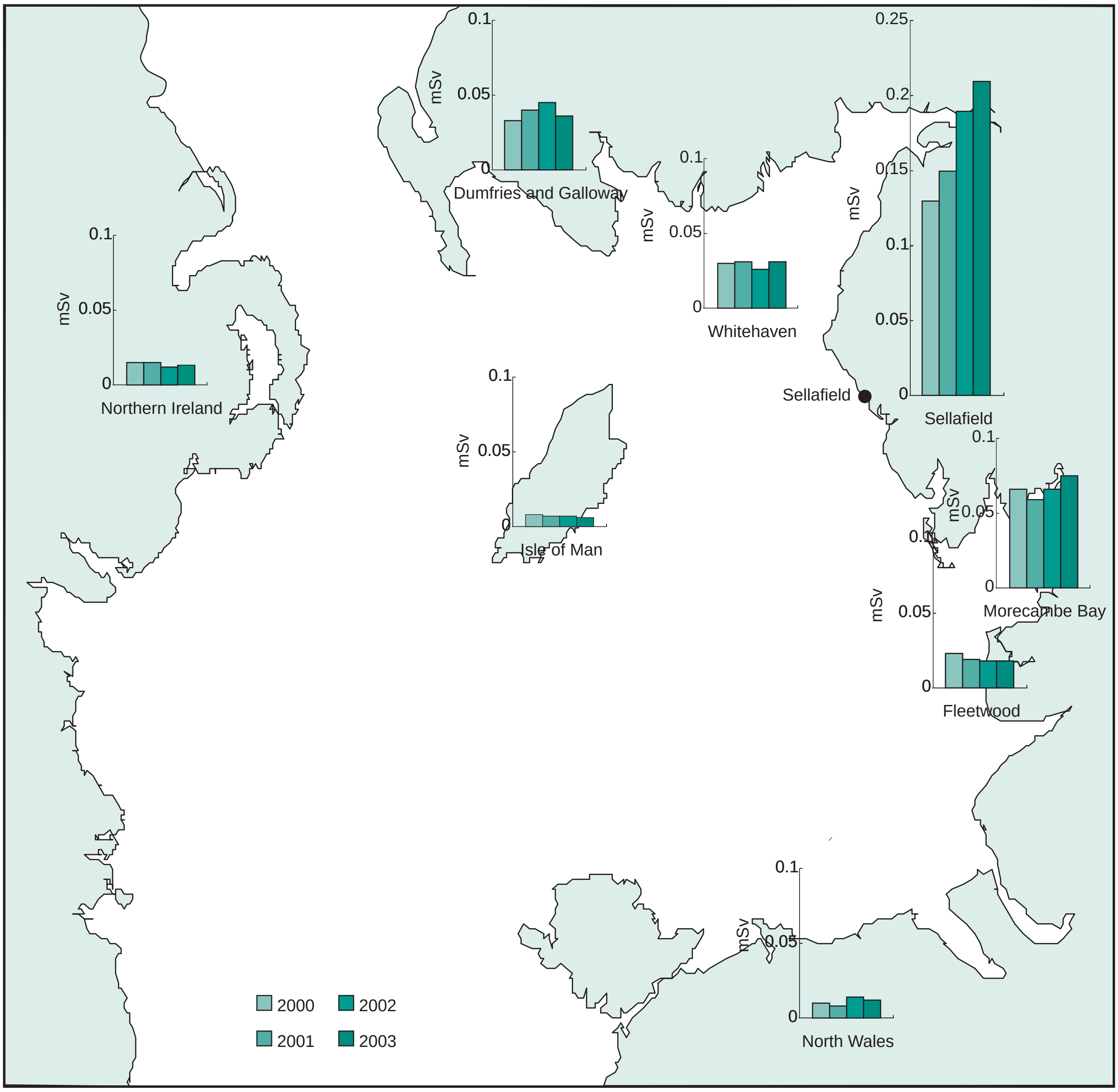

Figure 3.9 Individual radiation exposures to seafood consumers from artificial radionuclides in the Irish Sea, 2000-2003

The exposure of potential consumers of trout from a tarn at a local farm was not considered, as there was no consumption of trout from the lake in 2003.

External exposure from gamma emitting radionuclides

A further important pathway leading to radiation exposure as a result of Sellafield discharges arises from uptake of gamma-emitting radionuclides by intertidal sediments in areas frequented by the public. These exposures can make a significant contribution to the dose received by members of the public in coastal communities throughout the Irish Sea but particularly in Cumbria and Lancashire. In general, it is the fine-grained muds and silts prevalent in estuaries and harbours, rather than the coarser-grained sands to be found on open beaches, which adsorb the radionuclides more readily. Gamma dose rates currently observed in intertidal areas are mainly due to radiocaesium and natural radionuclides.

A range of coastal locations is regularly monitored, both in the Sellafield vicinity and further afield, using environmental radiation meters. Table 3.7 lists the locations monitored by the environment agencies and the Food Standards Agency together with the dose rates in air at 1 m above ground. Dose rates on Irish Sea shorelines, near other nuclear establishments that reflect Sellafield discharges, are given later in this report. The gamma dose rates measured above mud and salt marsh fluctuate quite markedly, disguising the general decrease with increasing distance from Sellafield (see Figure 3.10). Dose rates over intertidal areas throughout the Irish Sea in 2003 were similar to those data for the same locations in 2002 (Environment Agency, Environment and Heritage Service, Food Standards Agency, Scottish Environment Protection Agency, 2003). The relatively high result found in Whitehaven Yacht Basin was determined because, unusually, the Basin was not covered with seawater because the lockgates were not operational for a period. The result is consistent with earlier measurements made before the Basin was provided with gates. The longer term reduction of gamma dose rates since the 1980s can be seen in Figure 3.11; this has occurred primarily as a result of the reduction of gamma emitting radionuclides from Sellafield.

Gamma dose rate data taken from the banks of the River Calder, which flows through the Sellafield site, showed a significant excess above natural background. This is likely to be due to monitoring equipment detecting direct radiation from the Calder Hall power station (which was permanently shut down in 2003). However, there may also be a contribution due to small patches of sediments in the river. The occupancy by members of the public, for example anglers, of this section of the river is low. It is unlikely that more than a few tens of hours per year are spent near the sediment patches and, on this basis, the resulting exposures were much less than those of intertidal areas discussed later in this Section.

Concentrations of radionuclides in surface sediments are also regularly monitored, both because of relevance to dose rates and in order to keep under review distributions of adsorbed radioactivity. Concentrations of beta/gamma emitting radionuclides and transuranics, taken mostly at the same locations as the dose rate measurements, are given in Table 3.8.

The trends over the last two decades of discharges from Sellafield and concentrations in mud from Ravenglass are shown in Figures 3.12 – 3.15. The concentrations of many radionuclides have generally decreased over the past 20 years in response to decreases in discharges. There have been progressive and sustained reductions in discharges of caesium-137 and plutonium isotopes and these are reflected in the changes in concentrations of these radionuclides at Ravenglass. In recent years, discharges have been similar and there has been more variability in the concentrations of caesium-137, plutonium isotopes and americium-241. This is probably due to either remobilisation of historical sediments containing higher activity concentrations or increased presence of finer-grained sediments with higher activity concentrations. For americium-241, there is also an additional contribution due to ingrowth from plutonium-241 in the environment. Overall, concentrations in sediments in 2003 were similar to those in 2002 (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2003).

The results of the assessment of external exposure pathways are shown in Table 3.6. The highest whole body exposures due to external radiation resulting from Sellafield discharges, past and present, are received by people who live in houseboats in the Ribble estuary in Lancashire. In 2003, their dose was 0.079 mSv or about 8% of the dose limit for members of the public. This was less than the value of 0.12 mSv in 2002 due to reduced dose rates in the local vicinity of the houseboats (Environment Agency, Environment and Heritage Service, Foods Standards Agency, Scottish Environment Protection Agency, 2003). A small contribution due to inadvertent ingestion of sediments and inhalation of resuspended sediments is included. Their dose is dominated by those due to external exposure because of the long times spent over muddy areas. Other groups received lower doses in 2003. The most important of these were found in the Ravenglass estuary where critical group exposures over salt marsh or mud were up to 0.041 mSv for the nature warden. Doses from recreational use were 0.035 mSv. The dose for a typical occupancy of a sandy beach close to Sellafield was estimated to be much less than 0.005 mSv.

Inhalation of resuspended beach sediments and inadvertent ingestion of the same material give rise to only minor radiation exposures compared with seafood consumption and the external radiation pathway.

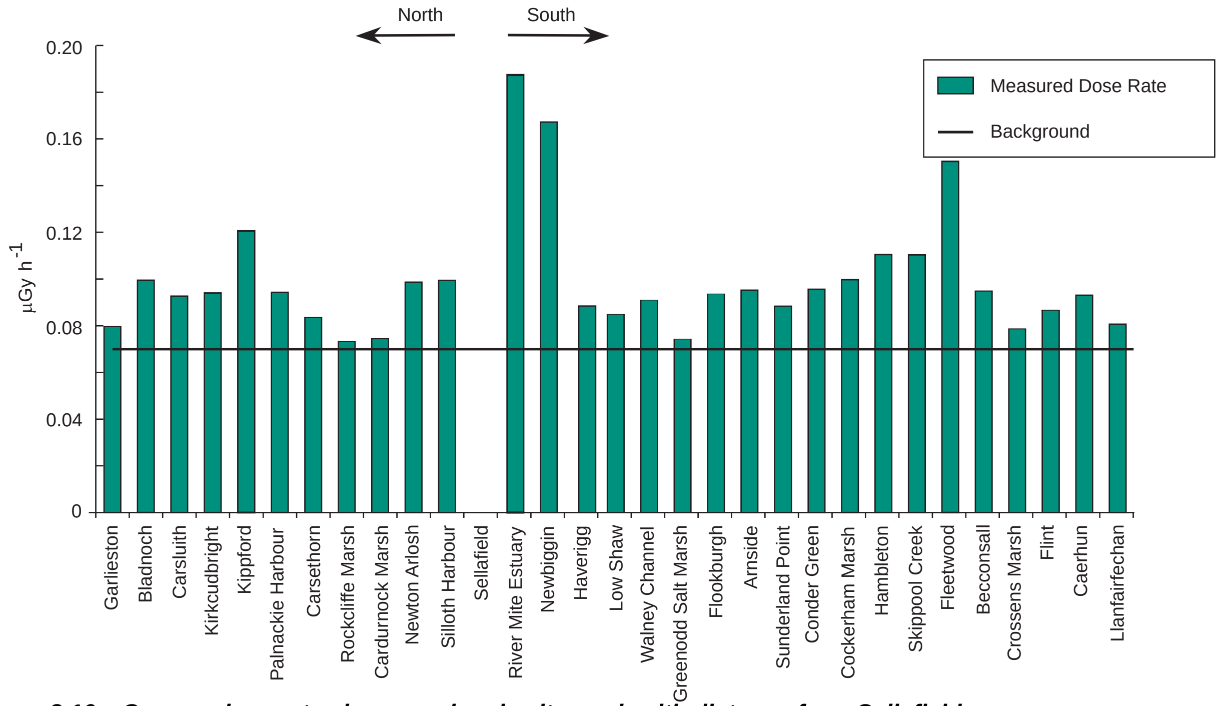

Figure 3.10 Gamma dose rate above mud and salt marsh with distance from Sellafield

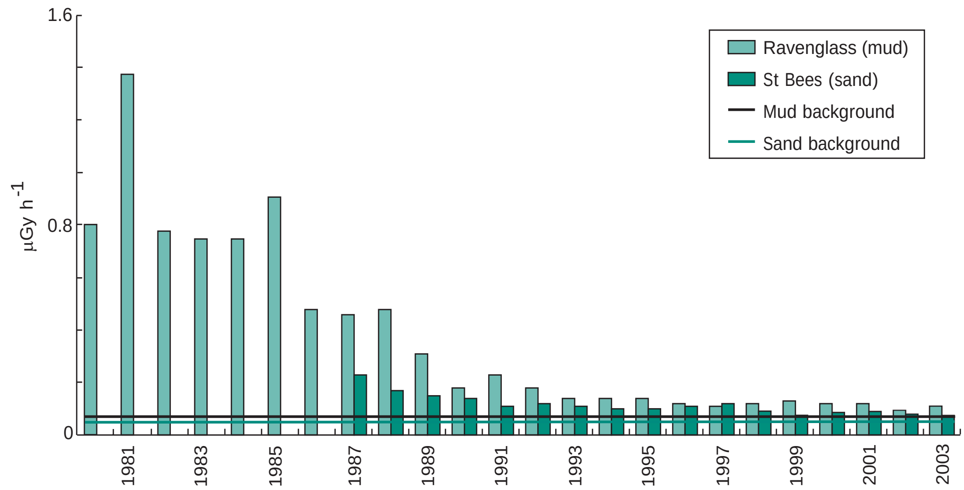

Figure 3.11 Gamma dose rate at Ravenglass and St Bees (data prior to 1988 are from BNFL surveys)

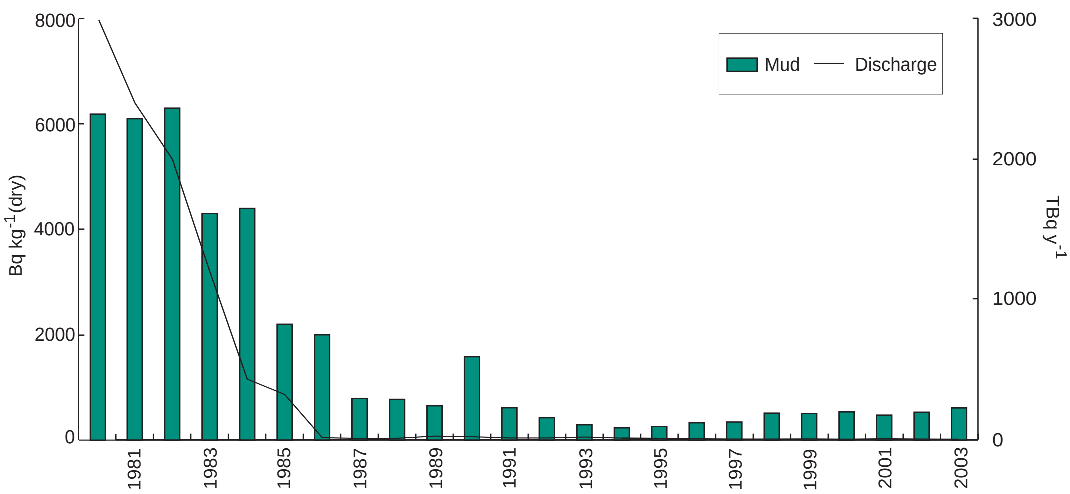

Figure 3.12 Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)

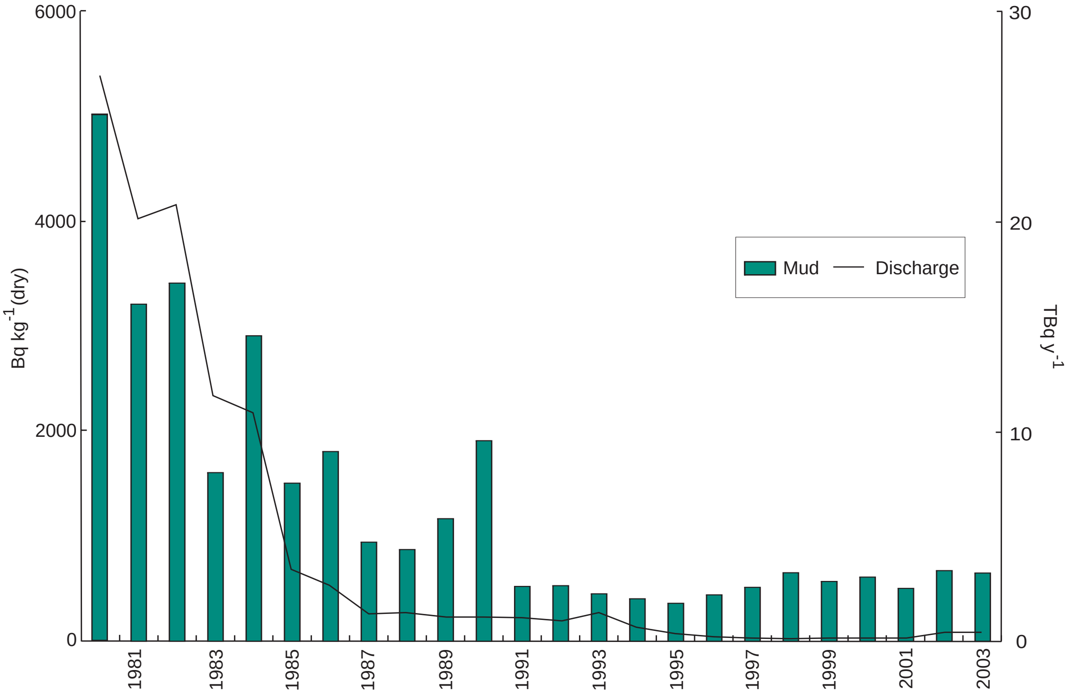

Figure 3.13 ***Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass*** ***(data prior to 1988 are from BNFL surveys)***

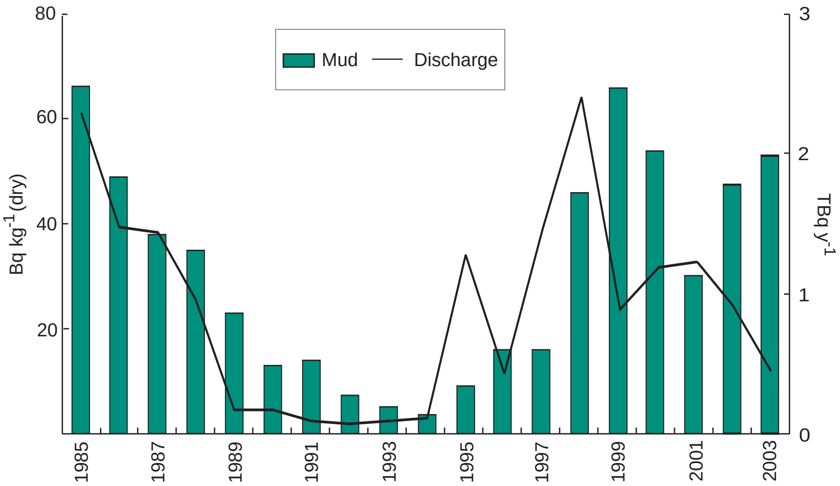

Figure 3.14 ***Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass*** ***(data prior to 1988 are from BNFL surveys)***

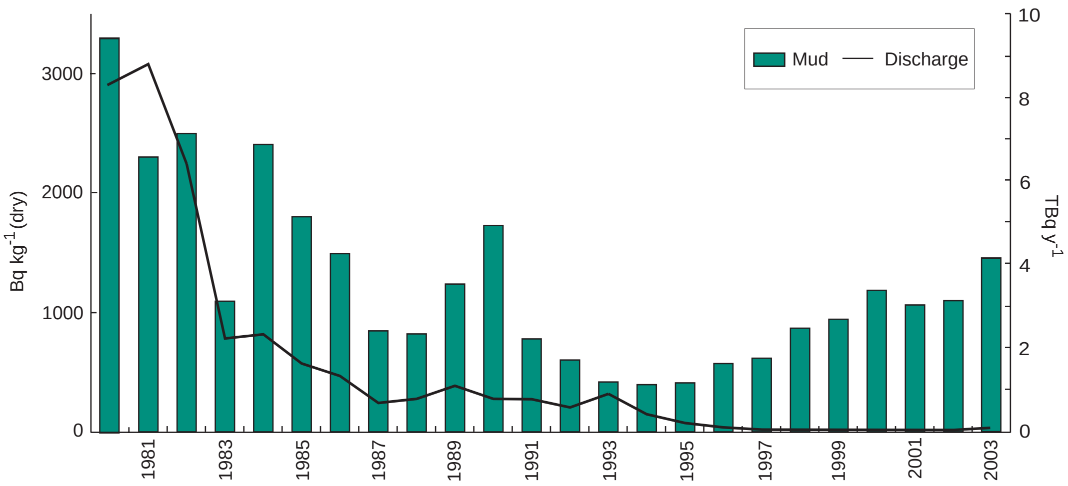

Figure 3.15 ***Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass*** ***(data prior to 1988 are from BNFL surveys)***

Fishing gear

During immersion in seawater, fishing gear may entrain particles of sediment on which radioactivity is adsorbed. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Fishing gear is regularly monitored using surface contamination meters. Results for 2003 are presented in Table 3.9. Measured dose rates were generally similar to those for 2002. Habits surveys keep under review the amounts of time spent by fishermen handling their gear; for those most exposed, a time handling nets and pots of 730 h $year^{-1}$ was appropriate. The skin dose from handling of fishing gear in 2003, including a component due to natural radiation, was 0.11 mSv, which was less than 1% of the appropriate dose limit of 50 mSv specifically for skin. Handling of fishing gear is therefore a minor pathway of radiation exposure.

Contact dose-rate monitoring of intertidal areas

A routine programme of measurements of beta dose rates from shoreline sediments continued in 2003 to allow the contribution to effective dose to be estimated for people who handle sediments regularly, and to estimate their exposures for comparison with the skin dose limit of 50 mSv. The results of the measurements made using contamination monitors are presented in Table 3.10. The skin dose to anglers who dig bait and to mollusc collectors, based on a time handling sediment of 1000 h $year^{-1}$, was 0.21 mSv in 2003 which was less than 1% of the skin dose limit.

In addition, more general beta/gamma monitoring of contamination on beaches continued in 2003. About 50 km of beach is surveyed close to the discharge point, in the Ravenglass estuaries and further afield to establish whether there are any localised ‘hot spots’ of activity, particularly in strand lines and beach debris. No material was found in excess of the action levels equivalent to 0.01 mSv h^{-1} in 2003 and no material was therefore removed. BNFL’s own monitoring located a radioactive particle (0.3 mSv h^{-1} at contact) on 24 July 2003 on the beach just north of the pipeline. The particle was removed and analysed. The analysis found it was a flat, mineralised particle, approximately 0.4 mm in diameter containing 0.2 MBq of caesium-137.

As part of the management of the legacy wastes and old plant at Sellafield, BNFL is removing three redundant sea discharge pipelines. Two of the pipes are of steel construction and one of plastic. An intermediate stage of the work in 2003 involved the temporary storage of cut sections on the seabed in secure stillages. During bad weather in November 2003 the contents of one stillage containing plastic pipes were lost and many of the sections were washed up on local beaches. The plastic pipe had been used to discharge surface water from the Sellafield site and therefore would have had negligible levels of radioactive contamination. The great majority of the lost pieces were recovered but there is a possibility that a few remain unaccounted for. Nearly all the pieces recovered were monitored and found to be clean, apart from one found on a beach in the Isle of Man, which had a small patch of light contamination.

Beta/gamma monitoring was carried out by the Environment Agency along the strandline between Nethertown and Seascale beach to check for any contamination in the vicinity of the washed up sections of pipe. None was found.

Water

Evidence of the effects of liquid discharges from Sellafield on concentrations of radionuclides in seawater is determined by sampling from research vessels and the shore. The results of the seawater programme are presented in Section 9.

Small amounts of activity are discharged under authorisation via the factory sewer outfall onto the beach near the River Calder. There was some evidence of tritium at the outfall (Table 3.11). However the waters are not potable and the low concentrations are of no radiological significance.

Table 3.11 shows the results of the analysis of samples of surface water taken from Ehen Spit (see Figure 3.2) near Sellafield where water issues from the ground at low tide. This release is not due to authorised discharges of liquid wastes but to ground water migration. The water is brackish so it will not be used as drinking water and therefore the only consumption would be inadvertent. Enhanced total beta concentrations were observed with levels similar to previous years. The concentrations of tritium and caesium-137 during 2003 were of the same order as those reported in 2002. The dose from inadvertent consumption of water from Ehen Spit has been shown to be insignificant (Environment Agency, 2002a).

Sampling of rivers and lakes in West Cumbria is included here for completeness though the results are not necessarily indicative of the effects of liquid waste discharges. Some of the sources provide public drinking water. All concentrations were below the LoD. The levels of total beta activity were below the WHO recommended value of 1.0 Bq l^{-1}.

Seaweeds and related pathways

Seaweeds are useful environmental indicator materials; they concentrate particular radionuclides, so they greatly facilitate measurement and assist in the tracing of these radionuclides in the environment. Table 3.12 presents the results of measurements in 2003 of seaweeds from shorelines of the Cumbrian coast and further afield. Although small quantities of samphire, *Porphyra* and *Rhodymenia* (a red seaweed) may be eaten, concentrations of radioactivity were of negligible radiological significance.

Fucus seaweeds are useful indicators, particularly of fission product radionuclides other than ruthenium-106; samples of *Fucus vesiculosus* seaweed were collected both in the Sellafield vicinity and further afield to show the extent of Sellafield contamination in north European waters. These clearly showed the effects of discharges of technetium-99 from Sellafield. There was a small increase in technetium-99 in *Fucus vesiculosus* in 2003 but the highest concentrations which are found near Sellafield are now much less than those in the mid 1990s (Figure 3.16). The spatial extent of the technetium-99 from Sellafield is clearly evident in this figure, but there is a large reduction in levels as the effect of Sellafield becomes less pronounced in moving from the eastern Irish Sea, to the rest of the Irish Sea, to Scottish Waters and on to the North Sea. Movement southwards from Sellafield into the English Channel is less significant (Hunt *et al*., 2002).

Seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a continuing research study in 2003. The results are shown in Table 3.13. The study comprises a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and assessments of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added (Camplin *et al.,* 2000). In 2003, seaweed harvesting in the Sellafield area continued to be rare. However, several plots of land fertilised by seaweed were identified and investigated further. Samples of soil were analysed for a range of radionuclides by gamma-ray spectrometry and for technetium-99. The soil and compost data show enhanced levels of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Various vegetable samples that had been grown in the soils from these plots were obtained. The technetium-99 concentrations in vegetables ranged from 3 to 270 Bq kg^{-1} in the edible parts. Small concentrations of gamma-emitting radionuclides were found in some vegetables.

Pessimistically assuming that high-rate vegetable consumers obtain all of their supplies from these plots, the annual dose was estimated to be 0.026 mSv. Exposures of consumers further afield in Northern Ireland, Scotland and north Wales will be much less. The seaweed/vegetable pathway will be kept under review but it is likely that the doses due to direct consumption of seafood and external radiation from intertidal areas will remain more important.

The potential transfer of technetium-99 to milk, meat and offal from animals grazing tide-washed pasture was considered using a modelling approach in the report for 1997 (Ministry of Agriculture, Fisheries and

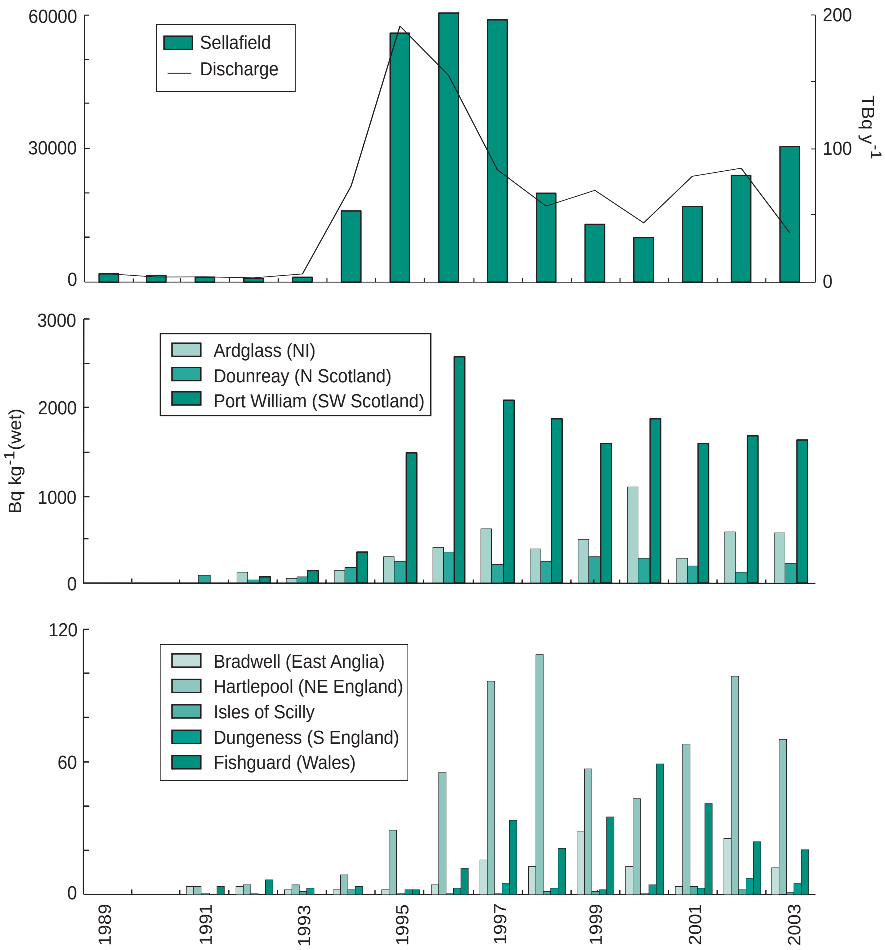

Figure 3.16 Technetium-99 liquid discharge from Sellafield and concentration in seaweed, Fucus vesiculosus

Food and Scottish Environment Protection Agency, 1998). The maximum potential dose was calculated to be 0.009 mSv at that time. Follow up sampling of tide-washed pastures at Newton Arlosh, Cumbria and Hutton Marsh, Lancashire in 2003 suggests that this dose estimate remains valid (Table 3.13). In the Scottish islands, seaweed may be eaten directly by sheep grazing on the foreshore. Our investigations show that this does not take place to a significant extent in the Sellafield area. Nevertheless, for reassurance purposes the Food Standards Agency undertook an assessment of the potential dose to a high-rate consumer of meat and liver from sheep grazing the seaweed using data relevant to the Shetlands and Orkneys. This showed that doses would have been well within the dose limit of 1mSv per year for members of the public in 1998 when concentrations of technetium-99 would have been at substantially higher levels than in 2003 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999).

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2003; this pathway has therefore remained essentially dormant. However, monitoring of *Porphyra* has continued in view of its potential importance, historical significance and the value of *Porphyra* as an environmental indicator material. Samples of *Porphyra* are regularly collected from selected locations along UK shorelines of the Irish Sea. Results of analyses for 2003 are presented in Table 3.12. Samples of laverbread from the major manufacturers are regularly collected from markets in south Wales and analysed. Results for 2003 are also presented in Table 3.12. The dose to critical laverbread consumers in south Wales was 0.005 mSv, confirming the low radiological significance of this exposure pathway.

Ravenglass

The main purpose of the monitoring of terrestrial foodstuffs in the Ravenglass area was to determine whether there was a significant transfer of radionuclides from sea to land in this area. In order to investigate this, samples of milk, crops, fruit, livestock and environmental indicator materials were collected and analysed for radionuclides which were released in liquid effluent discharges from Sellafield. In addition, analyses for sulphur-35, from gaseous releases, were also undertaken to compare with results for the immediate area around Sellafield.

The results of measurements in 2003 are presented in Table 3.14. In general, the data are similar to those for 2002 and show lower concentrations than are found in the direct vicinity of Sellafield. The evidence for sea-to-land transfer is limited. A small amount of technetium-99 was detected in lettuce, sheep meat and grass but the concentrations were very low. Concentrations of transuranic radionuclides were also very low but the observed isotopic ratio of $^{239+240}Pu$:^{238}Pu of 2:1 in honey is characteristic of what would result from Sellafield discharges. A ratio of $^{239+240}Pu$:^{238}Pu of about 40:1 would be expected for fallout. The only other indication of the effects of Sellafield discharges is the detection of sulphur-35 in some samples. These may have been due to gaseous discharges from the site.

The exposure due to consumption of terrestrial foods from Ravenglass in 2003 is given in Table 3.6. The 1-year-old age group received the highest exposures. Their dose, including contributions from Chernobyl and weapon test fallout, was calculated to be 0.019 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv and is similar to 2002. Sea-to-land transfer therefore is not of radiological importance in the Ravenglass area.

3.2.2 The effects of gaseous discharges and other sources of exposure

The effects of gaseous discharges from Sellafield are considered here with other minor sources of exposure near Sellafield unrelated to the liquid discharge route.

Discharges of gaseous wastes from Sellafield are summarised in Appendix 1. There were significant reductions for some radionuclides when compared with 2002, notably sulphur-35, argon-41 and cobalt-60. These were largely due to the cessation of power production at Calder Hall in March 2003. Total alpha and beta discharges increased in 2003 (alpha, 4.1 10^{-5} TBq in 2002 to 1.2 10^{-4} TBq in 2003; beta, 7.2 10^{-4} TBq in 2002 to 1.2 10^{-3} TBq in 2003) and there were associated increases of particular radionuclides. These were largely related to Magnox fuel reprocessing and storage activities.

The routine sampling programme for terrestrial foods in the vicinity of Sellafield was the most extensive of those for the nuclear sites in the UK in order to reflect the scale of the operations on the site. A wide range of foodstuffs was sampled including milk, fruit, vegetables, meat and offal, game, cereals and environmental materials such as grass and soil. Samples were obtained from different locations around the site in order to encompass the possible variations in activity levels due to the influence of meteorological conditions on the dispersal of gaseous discharges. The analyses undertaken included gamma-ray spectrometry and specific measurements for tritium, carbon-14, sulphur-35, strontium-90, technetium-99, iodine-129, radiocaesium, uranium and transuranic radionuclides.

The results of routine monitoring in 2003 are presented in Table 3.15. The concentrations of all radionuclides were low and there was no indication of widespread contamination from the site. Concentrations in terrestrial foodstuffs were generally similar to those in 2002 though there were significant reductions in concentrations of sulphur-35. These correspond to the reductions in discharges from Calder Hall.

Levels of activity in meat and offal from cattle and sheep continued to be analysed in 2003. Concentrations of radionuclides were low with limited evidence of the effects of Sellafield derived activity in data for tritium, carbon-14 and sulphur-35. Plutonium concentrations were much lower than those found in seafood.

A wide range of fruit and vegetables were sampled in 2003 including apples, blackberries, broccoli, cabbage, carrots, cauliflower, elderberries, potatoes, runner beans, sprouts, swede and turnips. The results were similar to those found in previous years excepting those for sulphur-35, which were lower. In common with meat and offal samples, limited evidence for the effects of Sellafield discharges was found in data for tritium, carbon-14 and sulphur-35. Concentrations of transuranic radionuclides were very low.

The dose received by the critical group who consume terrestrial food and are exposed to external and inhalation pathways from gaseous releases was calculated using the methods and data presented in Section 2 and Appendix 2. The results are presented in Table 3.6. Calculations were performed for three ages (adults, 10y and 1y) and the doses received by 1-year-olds were found to be the highest, at 0.034 mSv (Adult: 0.021; 10y: 0.022). The most significant contributions to the 1-year-old's dose were from strontium-90 and ruthenium-106. The most important foodstuff was milk, which accounted for more than 50% of the dose.

The assessed dose due to high-rate food consumption by infants in 2003 (0.031 mSv) was similar to the corresponding dose in 2002 (0.033 mSv). Doses as a result of environmental non-food pathways were lower in 2003 due to the reduced discharges of argon-41 from Calder Hall.

Previous reports in this series have dealt with the issue of contamination associated with feral pigeons in the vicinity of Sellafield. Internal contamination, mainly of caesium-137, in birds sampled by Ministry of Agriculture, Fisheries and Food (MAFF) in 1998 was found up to 0.11 MBq kg^{-1} and consuming the breast meat of 20 birds contaminated at the highest level would have resulted in a dose of 1 mSv. The advice issued by MAFF on 14th February 1998 remains in place as a precaution. People were advised not to handle, slaughter or consume pigeons within a 10 mile radius of the site. A full review of the incident was published in 1999 (Copeland Borough Council *et al.*, 1999). Since then, BNFL have undertaken remedial measures, including a substantial cull of pigeons in the area and preventing access to the loft spaces in buildings on the Sellafield site. Results of the analysis of wood pigeon samples collected in 2003 are included in Table 3.15. The concentrations were similar to those for other meat collected in the Sellafield area and would add little to the exposure of local consumers. In view of the limited numbers of feral pigeons now on the site, the Food Standards Agency will be reviewing the need for the precautionary advice to continue.

Sediments from road drains

Sediments from road drains (gully pots) in Seascale and Whitehaven have been sampled and analysed since 1998 following the discovery of contaminated feral pigeons at a bird sanctuary at Seascale. Gully pots in road drains collect sediments washed off road surfaces. Samples were taken from one drain at Whitehaven and four drains in Seascale village, two near the bird sanctuary. The results of analyses in 2003 are shown in Table 3.16. Levels of caesium-137 and americium-241 were enhanced in the drains nearest the bird sanctuary, but are now about one hundred times lower than they were in 1998 when remedial measures were taken.

3.3 Springfields, Lancashire

This establishment is mainly concerned with the manufacture of fuel elements for nuclear reactors and the production of uranium hexafluoride. Radioactive liquid waste arisings consist mainly of thorium and uranium and their decay products; liquid discharges are made by pipeline to the Ribble estuary. Discharges of beta-emitting radionuclides, which result in the greatest contribution to the radiological impact due to Springfields, decreased from 106 TBq (2002) to 97 TBq in 2003 (see Appendix 1). Discharges of gaseous effluents remained very low at a similar level to those for 2002. In December 2003, the Environment Agency began public consultation on a revised authorisation which proposed a decrease in discharges to the River Ribble (Environment Agency, 2003b).

Public radiation exposure in this vicinity, as a result of site discharges, is relatively low; there is, however, a contribution in the estuary due to Sellafield discharges. The most important marine pathway is external exposure, due to adsorption of radioactivity on the muddy areas of river banks and in salt marshes. The programme is therefore targeted mainly at *in situ* measurement of dose rates and analysis of sediments. However, habits surveys have confirmed the existence of high-rate consumers of seafood, particularly fish and shrimps, and they are also considered as a potential critical group in this report. Locally obtained fish, shellfish and samphire continued to be sampled. A study carried out by Rollo *et al.*, (1994) showed exposures due to airborne radionuclides that may have come from discharges to the estuary were negligible.

Monitoring of terrestrial foods included sampling of milk, fruit and vegetables. Environmental materials including grass and soil were also sampled. Water was sampled from the vicinity of Ulnes Walton where low-level solid wastes from Springfields used to be disposed of in landfill. Disposal ceased in 1983. The local monitoring locations are shown in Figure 3.17.

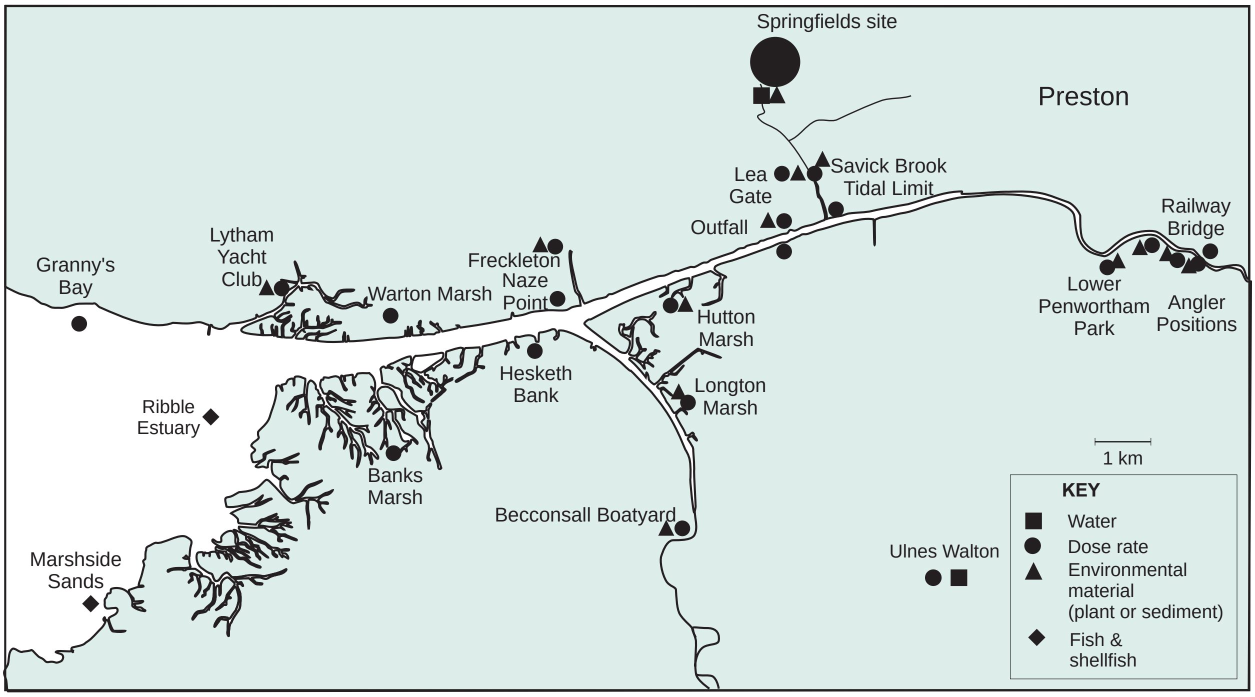

Figure 3.17 Monitoring locations at Springfields (excluding farms)

Results for 2003 are shown in Tables 3.17(a) and (b). Radionuclides detected which were partly or wholly due to Springfields discharges were isotopes of thorium, uranium and their decay products. Total beta measurements were dominated by the presence of thorium-234. The high concentrations observed throughout the estuary are transient, being influenced by the short half-life of thorium-234, variations in discharges from Springfields, tidal movements and river flow. There are large variations in the observed concentrations but the annual means are similar to those observed in recent years (Figure 3.18). Elevated concentrations of caesium-137 and americium-241 originating from Sellafield are also found in sediments of the estuary. These concentrations were similar to those in recent years.

Gamma dose rates throughout the estuary are enhanced above levels expected due to natural background. This is largely due to the historic effects of discharges from Sellafield. The results in 2003 were generally similar to those for 2002. Doses for the most exposed people from external pathways have been taken to be represented by four groups: people living on houseboats, anglers spending time on

Figure 3.18 Total beta liquid discharge from Springfields and concentration in sediment at Savick Brook

the banks of the upper estuary, children playing in muddy areas and fishermen handling nets. The dose from the houseboat pathway is estimated to be the highest because of the relatively large amount of time spent over mud. In 2003, the dose to houseboat dwellers was 0.079 mSv including a small contribution from inhalation of resuspended sediments and inadvertent ingestion of sediments (Table 3.2). This represents a reduction from the value in 2002 of 0.12 mSv, largely due to a reduction in dose rate measured over local sediments.

The exposures of anglers and children playing were of lesser importance. In 2003, their doses were 0.009 mSv and <0.005 mSv, respectively, similar to the values for 2002.

Beta dose rates on nets were also enhanced above those expected due to natural background. However, the skin dose for fishermen handling nets was estimated to be 0.67 mSv or less than 2% of the relevant dose limit for members of the public.

Concentrations of radionuclides in seafood and measurements in other materials from the estuary were similar to those for 2002. The dose for the seafood consumption group was 0.019 mSv or less than 2% of the 1 mSv dose limit. The majority of the dose is attributable to Sellafield discharges transferred to the Springfields area with only a small percentage resulting from discharges from the Springfields site itself.

In 2003, the critical group of terrestrial food consumers was adults consuming vegetables at high rates. Their dose was less than 0.005 mSv; this includes a contribution due to weapons testing and Chernobyl fallout and natural sources.

Concentrations of uranium isotopes in grass and soil are variable around the site. Similar levels to those found in 2002 were detected. Concentrations in fresh water and sediment in Deepdale Brook, a small stream that passes through the site, were also unchanged. Freshwater from the vicinity of Ulnes Walton showed similar levels of uranium isotopes to those found in Deepdale Brook.

Table 3.1(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2003

Material	Location	No. of sampling observations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{60}Co	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs	^{155}Eu	^{233}Pa	^{234}Th	^{234}U
Aquatic samples												
Flounder	Liverpool Bay	2	<25									
Flounder	Mersey Estuary	2	<25									
Shrimps	Wirral	2	<25	<0.05	3.6	<0.48	<0.13	1.9	<0.14			
Mussels	Liverpool Bay	2	<25									
Mussels	Mersey Estuary	2	<25									
Cockles	Dee Estuary	4		0.17	13	<0.40	<0.20	1.9	<0.10	*	11	
Prickly cockle	Liverpool Bay	1		1.1		1.4	<0.16	5.8	<0.11		29	
Elodea canadensis	Rivacre Brook	2		<0.08	8.6	<0.80	<0.18	0.48	<0.25	0.12	13	8.8
Mud	Rivacre Brook	2		<0.39	82	<4.2	<1.2	4.6	<1.9	10	38	31
Sediment	Rivacre Brook	1[E]			360			7.4				180
Sediment	Rivacre Brook (1.6 km downstream)	2[E]			120			3.2				56
Sediment	Rivacre Brook (3.1 km downstream)	2[E]			63			0.95				22
Sediment	Rossmore (4.3 km downstream)	2[E]			91			6.6				120
Freshwater	Rivacre Brook	2	3.0	<0.11	<0.022	<1.0	<0.30	<0.11	<0.25			0.023
Freshwater	Rivacre Brook	2[E]	<5.5		<0.10							0.045
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	<4.0		<2.4							0.027
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<4.0		<2.2							0.021
Freshwater	Rossmore (4.3 km downstream)	2[E]	<4.0		<2.0							0.015
Freshwater	EA Technology Pond	1[E]	<4.0		<0.10							<0.0060
Freshwater	Dunkirk Lane Pond	2[E]	<4.0		2.3							<0.0065

Material	Location	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{235}U	^{238}U	^{237}Np	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Aquatic samples											
Shrimps	Wirral	2						<0.16			
Cockles	Dee Estuary	4				0.16	0.88	2.3	0.0037		
Prickly cockle	Liverpool Bay	1						16			
Elodea canadensis	Rivacre Brook	2	0.41	5.0	0.19			<0.28			150
Mud	Rivacre Brook	2	1.3	19	1.6			<2.3			
Sediment	Rivacre Brook	1[E]	8.7	93	3.4					370	2500
Sediment	Rivacre Brook (1.6 km downstream)	2[E]	2.4	38	4.8					350	1100
Sediment	Rivacre Brook (3.1 km downstream)	2[E]	0.80	15	<1.6					130	680
Sediment	Rossmore (4.3 km downstream)	2[E]	4.9	42	3.9					500	1200
Freshwater	Rivacre Brook	2	0.00043	0.011	0.000025				<0.14		
Freshwater	Rivacre Brook	2[E]	<0.0050	0.024	<0.055					0.06	0.26
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	<0.0050	0.014	<0.055					<0.032	0.38
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<0.0050	0.0090	<0.055					<0.041	0.26
Freshwater	Rossmore (4.3 km downstream)	2[E]	<0.0050	0.0080	<0.055					<0.027	0.26
Freshwater	EA Technology Pond	1[E]	<0.0050	<0.0050	<0.10					0.06	0.51
Freshwater	Dunkirk Lane Pond	2[E]	<0.0050	<0.0055	<0.55					<0.11	2.6

Table 3.1(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			$^{3}H^{c}$	^{99}Tc	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples								
Milk		5	<2.4	<0.0065				<0.0065
Milk	max		<2.5					
Lettuce		1		<0.029	<0.022	0.0012	0.0017	<0.026
Potatoes		1		<0.029				<0.026
Strawberries		1		<0.028				<0.024
Grass		8		<0.019				<0.053
Grass	max			0.026				0.14
Silage		4						0.37
Silage	max				0.082	0.0044	0.096	0.53
Soil		4						54
Soil	max				10	0.61	10	62
Grass/herbage	North of Ledsham	1[E]		1.6	0.30	<0.042	0.27	
Soil	North of Ledsham	1[E]		7.7	18	<1.1	18	
Grass/herbage	South of Capenhurst	1[E]		6.2	0.034	<0.023	<0.026	
Soil	South of Capenhurst	1[E]		65	21	0.90	21	
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		3.0	0.094	<0.026	0.070	
Soil	Off lane from Capenhurst to Dunkirk	1[E]		45	22	1.0	25	
Grass/herbage	East of station	1[E]		51	0.61	<0.11	0.45	
Soil	East of station	1[E]		280	21	<0.59	21	

* *Not detected by the method used*

[a] *Except for milk and water where units are Bq l^{-1}, and for soil and sediment where dry concentrations apply*

[b] *Data are arithmetic means unless stated as 'Max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean is also the maximum.*

[c] *In distillate fraction of sample*

[d] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 3.1(b). Monitoring of radiation dose rates near Capenhurst, 2003

Location	Material or ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Rivacre Brook Plant outlet	Rock	1	0.095
Rivacre Brook Plant outlet	Concrete	1	0.093
Rivacre Brook 1.5km downstream	Grass	2	0.080
Rivacre Brook 3.1km downstream	Mud and forest cover	1	0.078
Rivacre Brook 3.1km downstream	Forest leaf litter	1	0.076
Rossmore Road West 4.3km downstream	Grass	2	0.078

Table 3.2. Individual radiation exposures – Capenhurst and Springfields, 2003

Site	Exposed population group[a]	Exposure mSv				
		Total	Seafood	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water
Capenhurst	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
	Children playing at Rivacre Brook[d]	0.009	-	-	0.008	<0.005
Springfields	Seafood consumers	0.019	0.019	-	-	-
	Houseboat occupants	0.079	-	-	0.075	<0.005
	Fishermen handling nets or pots[c]	0.67	-	-	0.67	-
	Children playing at Savick Brook[d]	<0.005	-	-	<0.005	<0.005
	Anglers	0.009	-	-	0.009	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-

[a] *Adults are the most exposed group unless otherwise stated*
[b] *Children aged 1y*
[c] *Exposure to skin for comparison with the 50 mSv dose limit*
[d] *Children aged 10y*

Table 3.3. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2003

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}												
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Sellafield coastal area	Cod	7				<0.17		<0.26	<0.23		<1.0	<0.17	8.1	<0.44	210
Sellafield coastal area	Plaice	4	110	130		<0.13		<0.23	<0.24		<0.79	<0.10	5.0	<0.50	160
Sellafield coastal area	Bass	1				<0.13		<0.30	<0.29		<1.1	<0.14	8.1	<0.47	
Sellafield coastal area	Pollack	1				<0.11		<0.20	<0.19		<0.83	<0.11	13	<0.45	170
Sellafield coastal area	Mullet	1				<0.09		<0.24	<0.21		<0.92	<0.09	6.2	<0.54	
Sellafield offshore area	Cod	1			190	<0.09	0.081	<0.17	<0.13	0.46	<0.59	0.16	8.7	<0.31	
Sellafield offshore area	Plaice[a]	2			150	0.09	0.078	<0.09	<0.08	22	<0.35	<0.04	4.2	<0.17	
Sellafield offshore area	Dab	2				<0.14		<0.27	<0.25		<0.97	<0.11	8.1	<0.53	
Sellafield offshore area	Sole	1				<0.15		<0.41	<0.40		<1.6	<0.15	4.0	<0.77	
Sellafield offshore area	Red gurnard	1				<0.17		<0.69	<0.95		<1.8	<0.19	5.0	<1.0	
Sellafield offshore area	Lesser spotted dogfish	2				<0.09		<0.26	<0.35		<0.80	<0.10	12	<0.45	
River Ehen	Sea trout	1				<0.22		<1.2	<2.4		<2.6	<0.23	1.6	<1.3	
River Calder	Salmon	1				<0.13		<0.25	<0.20	0.081	<1.3	<0.13	0.20	<0.47	
Ravenglass	Cod	6				<0.16		<0.22	<0.21		<0.69	<0.12	7.3	<0.37	
Ravenglass	Plaice	4	94	130		<0.15		<0.21	<0.19		<0.83	<0.10	4.6	<0.44	
Whitehaven	Cod	4			100	<0.09	0.055	<0.21	<0.18		<0.77	<0.09	5.6	<0.45	
Whitehaven	Plaice	4				<0.10	0.048	<0.21	<0.19		<0.83	<0.09	4.8	<0.46	
Whitehaven	Ray	4				<0.14		<0.63	<0.98		<1.5	<0.15	6.6	<0.71	
Parton	Cod	4				<0.11		<0.24	<0.30		<0.70	<0.11	8.1	<0.38	
Morecambe Bay (Flookburgh)	Flounder	4			120	<0.10		<0.30	<0.31		<0.92	<0.10	10	<0.52	
Morecambe Bay (Morecambe)	Plaice	4	<37	<45		<0.11	0.033	<0.29	<0.30	2.0	<0.99	<0.11	5.1	<0.45	
Morecambe Bay (Morecambe)	Bass	2				<0.07		<0.36	<0.65		<0.75	<0.08	14	<0.47	
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.09	0.13	<0.30	<0.33		<0.87	<0.10	5.1	<0.55	
River Duddon	Sea trout	1				<0.21		<0.62	<0.64		<2.2	<0.21	1.9	<0.77	
River Kent	Sea trout	1				<0.06		<0.21	<0.28		<0.58	<0.06	5.6	<0.31	
River Derwent	Sea trout	1				<0.08		<0.35	<0.53		<0.86	<0.09	3.5	<0.56	
Fleetwood	Cod	4			59	<0.10	0.038	<0.34	<0.45	0.90	<0.94	<0.10	4.3	<0.42	
Fleetwood	Plaice	4				<0.07		<0.22	<0.25		<0.61	<0.07	3.0	<0.27	
Isle of Man	Cod	4				<0.09		<0.32	<0.45		<0.81	<0.09	2.1	<0.42	
Isle of Man	Herring	4				<0.09		<0.33	<0.46		<0.85	<0.09	0.76	<0.49	
Inner Solway	Plaice	4				<0.11		<0.35	<0.44		<1.0	<0.11	1.4	<0.67	
Inner Solway	Flounder	4		<6.9	98	<0.11	0.10	<0.45	<0.67	3.3	<0.98	<0.11	13	<0.63	
Inner Solway	Lemon sole	4				<0.12		<0.45	<0.61		<1.0	<0.12	1.2	<0.67	
Inner Solway	Salmon	1		22		<0.10		<0.24	<0.33		<0.47	<0.10	0.66	<0.34	
Inner Solway	Sea trout	1		9.2		<0.10		<0.33	<0.47		<0.67	<0.10	2.9	<0.45	
North Solway coast	Cod	1	<25	29	50	<0.07	0.051	<0.26	<0.35	1.4	<0.71	<0.07	3.6	<0.46	
Kirkcudbright	Plaice	2				<0.13		<0.53	<0.77		<1.2	<0.13	2.0	<0.75	
North Anglesey	Ray	4				<0.13		<0.65	<1.4		<1.4	<0.13	0.92	<0.69	
North Anglesey	Plaice	2	<25	<25	30	<0.05		<0.14	<0.15		<0.43	<0.05	1.9	<0.21	
Ribble Estuary	Flounder	1				<0.06		<0.23	<0.27		<0.63	<0.07	4.6	<0.39	
Ribble Estuary	Salmon	1				<0.11		<0.34	<0.37	0.72	<1.1	<0.11	0.22	<0.52	
Ribble Estuary	Bass	1				<0.07		<0.24	<0.29		<0.63	<0.07	7.7	<0.32	
Ribble Estuary	Sea trout	1				<0.07		<0.22	<0.22	1.5	<0.73	<0.08	6.7	<0.44	
Ribble Estuary	Mullet	1				<0.16		<1.4	<3.7		<1.9	<0.18	2.4	<1.1	

Table 3.3. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Liverpool Bay	Flounder	2	<25										
Mersey Estuary	Flounder	2	<25										
Northern Ireland	Cod	6		40	<0.10		<0.41	<0.29		<0.98	<0.10	1.7	<0.48
Northern Ireland	Haddock	6			<0.10		<0.47	<0.83		<1.0	<0.10	1.1	<0.51
Northern Ireland	Whiting	6			<0.05		<0.15	<0.19		<0.43	<0.05	2.6	<0.23
Northern Ireland	Herring	4			<0.09		<0.35	<0.48		<0.86	<0.10	0.54	<0.40
Northern Ireland	Spurdog	8			<0.12		<0.52	<0.87		<1.2	<0.12	1.8	<0.58
Northern Ireland	Saithe	2			<0.06		<0.17	<0.18		<0.62	<0.07	2.6	<0.38
Northern Ireland	Farmed salmon	3			<0.06		<0.10	<0.07	<0.12	<0.52	<0.06	0.64	<0.27
West of Scotland	Mackerel	1			<0.06		<0.29	<0.42		<0.67	<0.07	0.14	<0.45
West of Scotland	Farmed salmon	1			<0.05		<0.20	<0.22		<0.57	<0.06	0.29	<0.35
Shetland - East coast	Farmed salmon	1			<0.10		<0.23	<0.18	<0.090	<0.87	<0.10	<0.12	<0.58
Shetland - West coast	Farmed salmon	1			<0.20		<0.46	<0.36	<0.070	<1.7	<0.19	<0.30	<0.97
Orkney - Scapa Flow	Farmed salmon	1			<0.14		<0.33	<0.27	<0.090	<1.2	<0.14	0.35	<0.89
North west Sutherland	Farmed salmon	1			<0.21		<0.38	<0.26	0.050	<1.6	<0.18	0.34	<1.0
Loch Broom	Farmed salmon	1			<0.14		<0.32	<0.27	<0.070	<1.3	<0.12	<0.22	<0.82
East Harris	Farmed salmon	1			<0.22		<0.43	<0.33	0.050	<1.9	<0.20	0.84	<1.1
Torridon	Farmed salmon	1			<0.14		<0.27	<0.18	<0.25	<1.2	<0.12	0.19	<0.71
Isle of Raasay	Farmed salmon	1			<0.20		<0.42	<0.32	<0.070	<1.7	<0.18	0.42	<0.98
Western Minch	Farmed salmon	1			<0.18		<0.36	<0.27	<0.10	<1.5	<0.17	0.20	<1.1
Loch Linnhe	Farmed salmon	2			<0.17		<0.45	<0.41	0.085	<0.60	<0.17	0.33	<0.86
Loch Fyne	Farmed salmon	1			<0.20		<0.44	<0.31	<0.060	<1.7	<0.19	0.50	<0.98
Loch Striven	Farmed salmon	1			<0.17		<0.37	<0.30	<0.080	<1.3	<0.15	0.47	<0.88
Arran	Farmed salmon	1			<0.17		<0.36	<0.27	<0.070	<1.5	<0.18	0.20	<1.1
Minch	Herring	2			<0.08	<0.027	<0.31	<0.39		<0.80	<0.09	0.22	<0.51
Minch	Mackerel	1		67	<0.10		<0.39	<0.60		<0.87	<0.09	0.11	<0.45
Shetland	Fish meal	4			<0.17	0.080	<0.42	<0.39		<1.5	<0.16	0.53	<0.76
Shetland	Fish oil	4			<0.08		<0.14	<0.09		<0.68	<0.08	<0.07	<0.38
Northern North Sea	Cod	4			<0.06	<0.022	<0.18	<0.18		<0.58	<0.06	0.22	<0.26
Northern North Sea	Plaice	4			<0.09		<0.30	<0.38		<0.91	<0.09	<0.12	<0.45
Northern North Sea	Haddock	4		23	<0.09		<0.30	<0.36		<0.90	<0.09	<0.17	<0.38
Mid North Sea	Cod	4		24	<0.05	<0.027	<0.21	<0.30		<0.51	<0.05	0.36	<0.24
Mid North Sea	Plaice	4		32	<0.05	<0.027	<0.17	<0.21		<0.47	<0.05	0.21	<0.25
Southern North Sea	Cod	2			<0.05	<0.026	<1.1	<0.10		<0.39	<0.04	0.37	<0.17
Southern North Sea	Plaice	1			<0.03	0.017	<0.08	<0.07		<0.33	<0.04	0.43	<0.21
Southern North Sea	Sole	1			<0.06		<0.16	<0.18		<0.47	<0.05	0.30	<0.24
Southern North Sea	Herring	2			<0.05		<0.12	<0.11		<0.48	<0.05	0.33	<0.23
English Channel-East	Cod	4			<0.04		<0.11	<0.10		<0.39	<0.04	0.20	<0.20
English Channel-East	Plaice	4			<0.05		<0.15	<0.15		<0.47	<0.05	<0.11	<0.21
English Channel-West	Mackerel	4			<0.07		<0.25	<0.32		<0.64	<0.07	0.19	<0.29
English Channel-West	Plaice	4		28	<0.07		<0.38	<0.70		<0.83	<0.08	<0.11	<0.46
English Channel-West	Whiting	4			<0.05		<0.21	<0.33		<0.47	<0.05	0.30	<0.24
Gt Yarmouth (retail shop)	Cod	4			<0.04		<0.11	<0.11		<0.38	<0.04	1.3	<0.20
Gt Yarmouth (retail shop)	Plaice	4			<0.05		<0.14	<0.15		<0.46	<0.05	0.32	<0.22
River Tyne	Salmon	1			<0.07		<0.13	<0.09	0.20	<0.60	<0.07	0.20	<0.29
River Tyne	Sea trout	1			<0.06		<0.09	<0.07	0.36	<0.45	<0.05	0.42	<0.21
Skipsea	Sea trout	1			<0.06		<0.13	<0.10	0.25	<0.56	<0.07	0.50	<0.35
Skagerrak	Cod	3			<0.12		<0.49	<0.66		<1.2	<0.12	0.20	<0.49
Skagerrak	Herring	3			<0.08		<0.31	<0.44		<0.74	<0.08	0.41	<0.41
Iceland area	Cod	2			<0.05		<0.19	<0.20		<0.52	<0.06	0.16	<0.30
Iceland processed	Cod	1		16	<0.04		<0.15	<0.18		<0.43	<0.05	0.08	<0.27
Barents Sea	Cod	2			<0.13		<0.79	<0.75		<1.3	<0.14	<0.19	<0.60
Baltic Sea	Cod	4			<0.18		<1.0	<0.51		<1.8	<0.19	8.6	<0.94
Baltic Sea	Herring	4			<0.10		<1.0	<0.19		<1.2	<0.12	6.9	<0.70
Norwegian Sea	Cod	1			<0.15		<0.55	<0.70		<1.6	<0.16	0.18	<0.82
Norwegian Sea	Herring	1			<0.09		<0.42	<0.64		<1.0	<0.10	0.22	<0.68
Norwegian Sea	Saithe	1			<0.23		<0.86	<1.3		<2.1	<0.22	0.23	<0.73
Norwegian Sea	Mackerel	1			<0.13		<0.56	<0.92		<1.2	<0.12	<0.13	<0.55
Celtic Sea	Cod	4		45	<0.08	0.022	<0.26	<0.32		<0.76	<0.10	<0.81	<0.34
Celtic Sea	Plaice	1			<0.05		<0.12	<0.10		<0.42	<0.05	0.16	<0.26
Celtic Sea	Lemon sole	1			<0.13		<0.31	<0.28		<1.2	<0.11	0.11	<0.46
Celtic Sea	Whiting	2			<0.09		<0.30	<0.35		<0.91	<0.09	0.39	<0.36

[a] *The concentrations of ^{129}I and ^{147}Pm were <0.27 and <0.051 Bq kg^{-1} respectively*

Table 3.4. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2003

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Sellafield coastal area	Crabs[a]	8			180	<0.07	2.8	<0.31	0.76	<0.27	<0.45	86
Sellafield coastal area	Lobsters	8			350	<0.10	2.7	<0.52	0.45	<0.41	<0.78	3600
Sellafield coastal area	*Nephrops*	2				<0.12	<0.32	<0.31		<0.40	<0.47	1100
Sellafield coastal area[b]	Winkles	4			180	<0.13	4.9	<0.32	0.70	<0.36	<0.45	820
Sellafield coastal area[b]	Mussels	4				<0.11	7.7	<0.38	1.7	<0.35	<0.45	
Sellafield coastal area[b]	Limpets	4			100	<0.10	2.9	<0.29	3.7	<0.29	<0.31	1300
Sellafield coastal area	Whelks	2			120	<0.09	1.3	<0.24	0.14	<0.35	<0.48	63
St Bees	Winkles[c]	4			210	<0.08	11	<0.31	2.2	<0.20	<0.22	530
St Bees	Mussels	4				<0.08	4.9	<0.36		<0.30	<0.53	
St Bees	Limpets	4				<0.12	3.5	<0.32		<0.32	<0.35	
Nethertown	Winkles	12	<46	<33	250	<0.15	15	<0.40	4.4	<0.40	<0.50	780
Nethertown	Mussels	4	180	190	310	<0.09	9.5	<0.53		<0.34	<0.53	1500
Whitriggs	Shrimps	1				<0.17	0.55	<0.43		<0.61	<0.79	
Drigg	Winkles	4			250	<0.14	11	<0.39		<0.37	<0.43	410
Ravenglass	Crabs	4				<0.08	1.6	<0.21	0.54	<0.31	<0.49	46
Ravenglass	Lobsters	6				<0.10	1.1	<0.26	0.21	<0.35	<0.47	2200
Ravenglass	Winkles	2				<0.09	6.6	<0.24		<0.26	<0.31	
Ravenglass	Cockles	4			370	<0.11	13	<0.37	1.0	<0.26	<0.24	65
Ravenglass	Mussels	4		83		<0.09	5.5	<0.27		<0.24	<0.25	2000
Tarn Bay	Winkles	2				<0.12	8.2	<0.28		<0.28	<0.27	
Saltom Bay	Winkles	4				<0.11	7.1	<0.28		<0.27	<0.28	
Whitehaven	*Nephrops*	4			87	<0.08	<0.15	<0.23	0.11	<0.24	<0.27	590
Whitehaven	Whelks	2			120	<0.11	1.1	<0.32		<0.29	<0.31	
Silloth	Mussels	4		<25		<0.10	1.1	<0.24		<0.37	<0.51	
Parton	Crabs	5				<0.13	0.95	<0.36		<0.46	<0.62	
Parton	Lobsters	4				<0.09	0.50	<0.25		<0.25	<0.28	
Parton	Winkles	4				<0.14	5.9	<0.35		<0.39	<0.47	
Haverigg	Cockles	2				<0.08	4.3	<0.18		<0.18	<0.15	
Millom	Mussels	2				<0.05	1.2	<0.14		<0.14	<0.12	
Barrow	Lobsters	2				<0.06	0.41	<0.15		<0.19	<0.25	1700
Red Nab Point	Winkles	4				<0.10	0.99	<0.18		<0.23	<0.27	
Morecambe Bay (Flookburgh)	Shrimps	4			120	<0.08	<0.11	<0.22		<0.26	<0.27	12
Morecambe Bay (Morecambe)	Mussels	4	<38	<62	120	<0.05	0.82	<0.13		<0.16	<0.18	900
Morecambe Bay (Flookburgh)	Cockles	4			110	<0.06	1.2	<0.14	0.60	<0.16	<0.18	37
Morecambe Bay (Middleton Sands)	Cockles	2				<0.05	1.3	<0.12		<0.15	<0.15	

Table 3.4. continued

Location	Material	No. of sampling observ- ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	Total beta
Sellafield coastal area	Crabs[a]	8	5.5	1.5	1.0	<0.07	1.9	<0.48	0.77	<0.18	<0.14	170
Sellafield coastal area	Lobsters	8	<4.3	5.4	<0.76	<0.10	3.4	<0.56	1.2	<0.27	<0.23	2100
Sellafield coastal area	*Nephrops*	2	<1.2	<0.23	<0.43	<0.12	5.5	<0.60		<0.34	<0.26	
Sellafield coastal area[b]	Winkles	4	15	1.1	2.1	<0.13	5.0	<0.69	0.38	<0.33	<0.31	
Sellafield coastal area[b]	Mussels	4	44	<0.21	3.3	<0.11	3.6	0.90		<0.29	<0.24	
Sellafield coastal area[b]	Limpets	4	18	1.5	5.0	<0.11	7.1	<0.74		<0.32	<0.25	
Sellafield coastal area	Whelks	2	<1.4	0.69	0.51	<0.09	1.2	<0.55		<0.23	<0.24	
St Bees	Winkles[c]	4	43	4.9	4.3	<0.08	7.1	1.3	1.6	<0.25	<0.17	
St Bees	Mussels	4	40	<0.17	2.8	<0.09	3.0	3.0		<0.30	<0.30	
St Bees	Limpets	4	29	2.3	6.7	<0.12	5.7	1.1		<0.35	<0.36	
Nethertown	Winkles	12	65	6.9	5.1	<0.16	10	<2.1		<0.42	<0.33	950
Nethertown	Mussels	4	65	<0.20	5.3	<0.10	3.8	3.4	10	0.37	<0.26	1100
Whitriggs	Shrimps	1	<1.7	<0.34	<0.41	<0.17	2.7	<0.68		<0.47	<0.24	
Drigg	Winkles	4	45	5.3	3.8	<0.15	5.0	<0.87	1.5	<0.36	<0.40	530
Ravenglass	Crabs	4	<1.5	0.57	<0.40	<0.08	1.4	<0.39		<0.21	<0.16	130
Ravenglass	Lobsters	6	<2.0	1.7	<0.43	<1.1	2.3	<0.90		<0.25	<0.52	1400
Ravenglass	Winkles	2	15	2.6	2.3	<0.09	5.5	<0.73		<0.25	<0.25	
Ravenglass	Cockles	4	24	<0.22	1.7	<0.12	4.0	<1.1		<0.29	<0.30	260
Ravenglass	Mussels	4	31	<0.19	2.9	<0.10	1.9	<0.94		<0.24	<0.21	
Tarn Bay	Winkles	2	47	1.8	3.1	<0.12	9.6	<1.0		<0.26	<0.26	
Saltom Bay	Winkles	4	29	1.4	9.0	<0.12	10	<1.1		<0.31	<0.29	
Whitehaven	*Nephrops*	4	<0.85	<0.17	<0.27	<0.09	4.1	<0.45		<0.28	<0.20	500
Whitehaven	Whelks	2	3.4	0.60	<0.47	<0.11	1.2	<0.53		<0.34	<0.26	190
Silloth	Mussels	4	3.1	<0.18	0.93	<0.10	3.9	<0.47		<0.26	<0.20	
Parton	Crabs	5	<2.0	<0.55	<0.45	<0.13	1.6	<0.57		<0.37	<0.25	
Parton	Lobsters	4	<0.91	0.58	<0.32	<0.10	2.5	<0.41		<0.29	<0.20	
Parton	Winkles	4	25	1.1	3.9	<0.14	11	<0.98		<0.37	<0.35	
Haverigg	Cockles	2	4.1	<0.15	0.66	<0.09	4.0	0.42		<0.24	<0.22	
Millom	Mussels	2	8.7	<0.11	1.0	<0.06	1.6	<0.34		<0.16	<0.14	
Barrow	Lobsters	2	<0.56	0.42	<0.18	<0.06	2.2	<0.32		<0.17	<0.15	1100
Red Nab Point	Winkles	4	3.9	<0.13	1.3	<0.07	5.0	<0.34		<0.20	<0.16	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.81	<0.16	<0.22	<0.09	5.1	<0.39		<0.25	<0.17	
Morecambe Bay (Morecambe)	Mussels	4	4.6	<0.09	0.92	<0.05	3.7	<0.27		<0.14	<0.12	
Morecambe Bay (Flookburgh)	Cockles	4	2.8	<0.11	0.59	<0.06	4.6	<0.28		<0.16	<0.13	
Morecambe Bay (Middleton Sands)	Cockles	2	1.1	<0.09	0.56	<0.05	3.3	<0.26		<0.14	<0.13	

Table 3.4. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Fleetwood	Squid	1			<0.05	<0.05	<0.14		<0.13	<0.12	
Fleetwood	Whelks	2		70	<0.08	<0.10	<0.23	0.038	<0.28	<0.36	15
Isle of Man	Lobsters	4			<0.06	<0.06	<0.16		<0.16	<0.15	170
Isle of Man	Scallops	4			<0.04	<0.04	<0.11		<0.13	<0.17	
Inner Solway	Shrimps	4	<12		<0.10	<0.10	<0.20	0.15	<0.25	<0.29	2.2
Southerness	Winkles	4	<15		<0.16	4.8	<0.38	0.57	<0.46	<0.52	460
Kirkcudbright	Scallops	8[F,S]			<0.07	<0.07	<0.12		<0.14	<0.18	
Kirkcudbright	Queens	8[F,S]			<0.08	<0.08	<0.13		<0.16	<0.22	
North Solway coast	Crabs	8[F,S]		93	<0.11	0.51	<0.27	0.46	<0.35	<0.43	33
North Solway coast	Lobsters	8[F,S]		78	<0.08	<0.19	<0.21	0.12	<0.23	<0.25	950
North Solway coast	Winkles	7[F,S]			<0.11	2.2	<0.30	0.25	<0.32	<0.37	660
North Solway coast	Cockles	7[F,S]	<29	91	<0.07	1.4	<0.13	0.72	<0.16	<0.18	32
North Solway coast	Mussels	8[F,S]	<18	79	<0.07	0.66	<0.10	0.53	<0.12	<0.13	310
Wirral	Shrimps	2	<25		<0.05	<0.05	<0.12		<0.13	<0.12	3.6
Wirral	Cockles	4			<0.04	0.17	<0.10		<0.12	<0.12	13
Liverpool Bay	Mussels	2	<25								
Liverpool Bay	Prickly cockle	1			<0.05	1.1	<0.12		<0.17	<0.21	
Mersey Estuary	Mussels	2	<25								
Ribble Estuary	Shrimps	2		59	<0.06	<0.07	<0.16		<0.15	<0.16	3.0
Ribble Estuary	Cockles	2			<0.09	0.57	<0.20		<0.22	<0.20	
Ribble Estuary	Mussels	1			<0.06	0.18	<0.13		<0.16	<0.17	
Knott End	Cockles	1			<0.15	1.8	<0.38		<0.56	<0.78	
North Anglesey	Crabs	2			<0.05	<0.06	<0.15		<0.16	<0.19	7.8
North Anglesey	Lobsters	2			<0.05	<0.06	<0.14		<0.15	<0.14	180
Conwy	Mussels	2		38	<0.04	<0.04	<0.09		<0.10	<0.09	
Northern Ireland	Crabs	2			<0.07	<0.08	<0.19		<0.26	<0.37	
Northern Ireland	Lobsters	7			<0.15	<0.15	<0.36		<0.53	<0.75	170
Northern Ireland	*Nephrops*	8			<0.10	<0.10	<0.27		<0.42	<0.65	50
Northern Ireland	Winkles	4			<0.15	<0.15	<0.36		<0.49	<0.63	
Northern Ireland	Mussels	2			<0.14	<0.13	<0.34		<0.65	<1.2	30
Western Irish Sea	Scallops	2			<0.05	<0.05	<0.14		<0.26	<0.55	
Skye	Lobster	1			<0.10	<0.10	<0.16		<0.48	<0.93	
Skye	Mussels	1			<0.10	<0.10	<0.12		<0.32	<0.92	
Islay	Crabs	1			<0.10	<0.10	<0.10		<0.10	<0.11	
Islay	Scallops	1			<0.10	<0.10	<0.16		<0.22	<0.31	
Lewis	*Nephrops*	1			<0.10	<0.10	<0.10		<0.18	<0.41	
Southern North Sea	Cockles	2			<0.02	<0.08	<0.06		<0.05	<0.04	
Southern North Sea	Mussels	4			<0.07	<0.06	<0.15		<0.23	<0.35	1.6
Southern North Sea	Cockles[d]	2			<0.04	<0.04	<0.08		<0.10	<0.09	1.5
Southern North Sea	Mussels[d]	2			<0.05	<0.05	<0.11		<0.12	<0.12	
The Wash	Mussels	1			<0.04	0.12	<0.09		<0.13	<0.14	
Cromer	Crabs	1			<0.04	<0.05	<0.10		<0.08	<0.05	
English Channel-East	Scallops	4		31	<0.05	<0.06	<0.15		<0.14	<0.14	
English Channel-West	Crabs	4		18	<0.11	<0.11	<0.27		<0.29	<0.30	
English Channel-West	Lobsters	4			<0.10	<0.10	<0.26		<0.35	<0.42	0.15
English Channel-West	Scallops	4		25	<0.04	<0.05	<0.12		<0.13	<0.14	

Table 3.4. continued

Location	Material	No. of sampling observ- ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	Total beta
Fleetwood	Squid	1	<0.44	<0.09	<0.11	<0.05	0.89	<0.22	<0.17	<0.11	
Fleetwood	Whelks	2	<0.80	<0.16	<0.20	<0.08	0.61	<0.35	<0.25	<0.15	
Isle of Man	Lobsters	4	<0.54	<0.11	<0.14	<0.06	0.36	<0.28	<0.19	<0.13	200
Isle of Man	Scallops	4	<0.37	<0.07	<0.09	<0.04	0.24	<0.21	<0.12	<0.09	
Inner Solway	Shrimps	4	<0.64	<0.12	<0.22	<0.10	3.7	<0.41	<0.11	<0.18	
Southerness	Winkles	4	<13	<0.81	1.9	<0.15	1.7	<0.79	<0.18	<0.33	
Kirkcudbright	Scallops	8[F,S]	<0.39	<0.09	<0.10	<0.07	<0.17	<0.22	<0.12	<0.10	
Kirkcudbright	Queens	8[F,S]	<0.44	<0.10	<0.12	<0.08	<0.15	<0.24	<0.13	<0.11	
North Solway coast	Crabs	8[F,S]	<0.97	<0.20	<0.26	<0.11	1.1	<0.52	<0.22	<0.22	
North Solway coast	Lobsters	8[F,S]	<0.71	<0.12	<0.23	<0.08	1.3	<0.43	<0.16	<0.19	
North Solway coast	Winkles	7[F,S]	<6.3	<0.52	1.6	<0.11	1.2	<0.62	<0.22	<0.28	
North Solway coast	Cockles	7[F,S]	1.9	<0.10	0.61	<0.07	5.2	<0.28	<0.13	<0.14	
North Solway coast	Mussels	8[F,S]	1.6	<0.09	0.52	<0.07	2.4	<0.23	<0.11	<0.12	
Wirral	Shrimps	2	<0.48	<0.09	<0.13	<0.05	1.9	<0.27	<0.15	<0.14	
Wirral	Cockles	4	<0.40	<0.08	<0.20	<0.05	1.9	<0.21	<0.12	<0.10	
Liverpool Bay	Prickly cockle	1	1.4	<0.11	<0.16	<0.05	5.8	<0.27	<0.15	<0.11	
Ribble Estuary	Shrimps	2	<0.56	<0.11	<0.15	<0.06	2.5	<0.26	<0.20	<0.13	
Ribble Estuary	Cockles	2	<0.94	<0.15	<0.28	<0.10	2.4	<0.57	<0.26	<0.31	
Ribble Estuary	Mussels	1	<0.60	<0.10	0.38	<0.06	1.3	<0.35	<0.15	<0.18	
Knott End	Cockles	1	<1.7	<0.28	1.0	<0.16	3.0	<0.84	<0.38	<0.34	
North Anglesey	Crabs	2	<0.54	<0.11	<0.14	<0.06	0.51	<0.30	<0.18	<0.15	
North Anglesey	Lobsters	2	<0.52	<0.10	<0.13	<0.06	0.30	<0.26	<0.17	<0.12	230
Conwy	Mussels	2	<0.39	<0.07	<0.11	<0.04	0.21	<0.21	<0.10	<0.10	
Northern Ireland	Crabs	2	<0.70	<0.13	<0.17	<0.07	0.26	<0.34	<0.22	<0.15	
Northern Ireland	Lobsters	7	<1.5	<0.26	<0.33	<0.14	<0.28	<0.71	<0.39	<0.30	
Northern Ireland	*Nephrops*	8	<1.0	<0.19	<0.24	<0.10	0.82	<0.50	<0.30	<0.21	
Northern Ireland	Winkles	4	<1.5	<0.26	<0.33	<0.15	<0.21	<0.59	<0.41	<0.24	
Northern Ireland	Mussels	2	<1.4	<0.24	<0.28	<0.13	0.35	<0.53	<0.33	<0.20	
Western Irish Sea	Scallops	2	<0.45	<0.09	<0.10	<0.05	0.30	<0.25	<0.14	<0.10	
Skye	Lobster	1	<0.48	<0.10	<0.11	<0.10	<0.10	<0.36	<0.10	<0.14	
Skye	Mussels	1	<0.33	<0.10	<0.10	<0.10	<0.10	<0.27	<0.10	<0.10	
Islay	Crabs	1	<0.22	<0.10	<0.10	<0.10	0.19	<0.16	<0.10	<0.10	
Islay	Scallops	1	<0.46	<0.10	<0.13	<0.10	0.15	<0.35	<0.10	<0.16	
Lewis	*Nephrops*	1	<0.23	<0.10	<0.10	<0.10	0.28	<0.17	<0.10	<0.10	
Southern North Sea	Cockles	2	<0.23	<0.04	<0.06	<0.03	0.15	<0.12	<0.07	<0.06	
Southern North Sea	Mussels	4	<0.63	<0.11	<0.14	<0.07	<0.11	<0.28	<0.18	<0.12	
Southern North Sea	Cockles[d]	2	<0.37	<0.07	<0.09	<0.04	0.11	<0.19	<0.11	<0.09	
Southern North Sea	Mussels[d]	2	<0.45	<0.08	<0.12	<0.05	<0.05	<0.23	<0.14	<0.11	30
The Wash	Mussels	1	<0.39	<0.07	<0.10	<0.04	0.19	<0.19	<0.11	<0.08	
Cromer	Crabs	1	<0.40	<0.08	<0.11	<0.05	0.07	<0.19	<0.15	<0.10	
English Channel-East	Scallops	4	<0.48	<0.10	<0.12	<0.05	0.08	<0.24	<0.18	<0.12	
English Channel-West	Crabs	4	<0.98	<0.19	<0.23	<0.11	<0.10	<0.42	<0.33	<0.19	
English Channel-West	Lobsters	4	<1.0	<0.18	<0.22	<0.10	<0.09	<0.40	<0.29	<0.15	
English Channel-West	Scallops	4	<0.43	<0.08	<0.11	<0.05	<0.05	<0.23	<0.15	<0.10	

[a] *The concentration of ^{129}I was <0.36 Bq kg^{-1}*
[b] *Samples collected by Consumer 971*
[c] *The concentration of ^{129}I was <0.59 Bq kg^{-1}*
[d] *Landed in Holland*
[F,S] *Samples collected on behalf of the Food Standards Agency and SEPA*

Table 3.5. Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2003

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$
Sellafield coastal area	Cod	2		0.0012	0.0053		0.0093	*	*
Sellafield coastal area	Plaice	1		0.0020	0.010		0.018	*	*
Sellafield coastal area	Bass	1					<0.12		
Sellafield coastal area	Pollack	1					<0.29		
Sellafield coastal area	Mullet	1					<0.25		
Sellafield coastal area	Crabs	2	0.0038	0.098	0.44	4.1	1.8	0.0042	0.0045
Sellafield coastal area	Lobsters	2	0.031	0.11	0.44	7.0	7.8	0.0040	0.015
Sellafield coastal area	*Nephrops*	1		0.064	0.34		2.2	*	0.0042
Sellafield coastal area[a]	Winkles	1	0.010	0.69	3.6	35	7.1	*	0.013
Sellafield coastal area[a]	Mussels	1		1.8	8.6	98	19	0.026	0.043
Sellafield coastal area[a]	Limpets	1		1.5	7.1	74	14	0.047	0.017
Sellafield coastal area	Whelks	1		0.29	1.4	14	2.9	*	0.0091
Sellafield offshore area	Cod	1		0.0023	0.010		0.018	*	*
Sellafield offshore area	Plaice	1	0.00015	0.0071	0.030		0.047	0.00013	0.00011
Sellafield offshore area	Dab	2					<0.37		
Sellafield offshore area	Sole	1					<0.33		
Sellafield offshore area	Red gurnard	1					<0.67		
Sellafield offshore area	Lesser spotted dogfish	2					<0.34		
St Bees	Winkles	1	0.014	1.6	8.3	81	15	*	0.047
St Bees	Mussels	2		1.5	6.6	85	14	<0.051	0.048
St Bees	Limpets	1		1.9	9.5		19	*	0.040
Nethertown	Winkles	4	0.035	3.6	18	190	34	<0.021	0.061
Nethertown	Mussels	4		2.7	12		24	<0.058	0.067
River Ehen	Sea trout	1					<0.46		
River Calder	Salmon	1					<0.10		
Whitriggs	Shrimps	1					0.12		
Drigg	Winkles	1	0.016	1.9	9.9	99	20	*	0.025
Ravenglass	Cod	1		0.00046	0.0021		0.0041	0.000047	0.000020
Ravenglass	Plaice	1		0.0034	0.0017		0.0029	*	*
Ravenglass	Crabs	1		0.058	0.27	2.8	1.4	0.0016	0.0029
Ravenglass	Lobsters	1		0.074	0.35	3.4	3.5	*	0.0071
Ravenglass	Winkles	2					16		
Ravenglass	Cockles	1		2.0	9.3	100	27	0.055	0.054
Ravenglass	Mussels	1		1.2	5.9	66	13	0.043	0.034
Tarn Bay	Winkles	1		2.1	11	110	22	*	0.037
Saltom Bay	Winkles	4					21		
Whitehaven	Cod	1		0.00087	0.0046		0.0079	0.000019	0.000011
Whitehaven	Plaice	1		0.0014	0.0079		0.015	0.000019	0.000031
Whitehaven	Ray	1		0.00026	0.0021		0.0019	*	*
Whitehaven	*Nephrops*	1		0.055	0.30		1.9	*	0.0019
Whitehaven	Whelks	4					2.1		
Silloth	Mussels	1		0.95	4.8		9.2	*	0.013
Parton	Cod	4					<0.12		
Parton	Crabs	5					1.2		
Parton	Lobsters	4					1.5		
Parton	Winkles	1		2.0	10	100	19	*	0.010
Haverigg	Cockles	1		1.1	5.8		16	*	0.037
Millom	Mussels	2					4.4		
Barrow	Lobsters	2					1.7		
Red Nab Point	Winkles	1		0.42	2.2		4.0	*	0.0053
Morecambe Bay (Flookburgh)	Flounder	1		0.0016	0.0094		0.017	*	*
Morecambe Bay (Flookburgh)	Shrimps	1		0.0044	0.024	0.27	0.037	*	0.000053
Morecambe Bay (Flookburgh)	Cockles	1		0.48	2.6	24	6.8	*	0.014
Morecambe Bay (Morecambe)	Plaice	4					<0.17		
Morecambe Bay (Morecambe)	Bass	2					<0.15		
Morecambe Bay (Morecambe)	Mussels	1		0.48	2.6		4.3	*	0.0085
Morecambe Bay (Sunderland Point)	Whitebait	1		0.033	0.21	1.6	0.35	*	0.00092
Morecambe Bay (Middleton Sands)	Cockles	1		0.35	1.9		5.3	*	0.0065

Table 3.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$
River Duddon	Sea trout	1					<0.15		
River Kent	Sea trout	1					<0.07		
River Derwent	Sea trout	1					<0.39		
Fleetwood	Cod	1		0.000079	0.00037		0.00076	0.000039	*
Fleetwood	Plaice	1		0.00021	0.0010		0.0017	*	*
Fleetwood	Squid	1					<0.14		
Fleetwood	Whelks	1		0.058	0.32	2.6	0.40	*	*
Isle of Man	Cod	1		0.00017	0.00078		0.0013	*	*
Isle of Man	Herring	1		0.000069	0.00037		0.00051	*	*
Isle of Man	Lobsters	4					<0.10		
Isle of Man	Scallops	1		0.014	0.075		0.025	*	0.00047
Inner Solway	Plaice	4					<0.16		
Inner Solway	Flounder	1		0.0089	0.052		0.088	<0.00064	<0.00064
Inner Solway	Lemon sole	4					<0.15		
Inner Solway	Salmon	1					<0.12		
Inner Solway	Sea trout	1		0.00016	0.00024		0.0011	<0.00067	<0.00067
Inner Solway	Shrimps	1		0.0037	0.015		0.035	<0.00036	<0.00036
North Solway coast	Cod	1		0.00039	0.0023		0.0041	0.000026	0.0000087
North Solway coast	Crabs	2[F,S]		0.037	0.18	1.8	0.73	<0.00037	<0.00090
North Solway coast	Lobsters	2[F,S]		0.016	0.089	0.85	0.63	<0.00055	<0.0013
North Solway coast	Winkles	2[F,S]		0.21	1.0	10	1.7	<0.00055	0.0047
North Solway coast	Cockles	5[F,S]		0.67	3.6	32	9.3	<0.00076	0.013
North Solway coast	Mussels	2[F,S]		0.57	3.1	24	5.4	<0.0011	0.0054
Kirkcudbright	Plaice	1		0.0012	0.0052		0.0092	<0.00029	<0.00029
Kirkcudbright	Scallops	2[F,S]		0.0070	0.036		0.046	<0.00010	<0.00010
Kirkcudbright	Queens	2[F,S]		0.0093	0.051		0.021	<0.000090	<0.000090
Southerness	Winkles	1		0.12	0.63		3.5	<0.00061	<0.00061
North Anglesey	Ray	1		0.00013	0.00073		0.00095	*	*
North Anglesey	Plaice	2					<0.10		
North Anglesey	Crabs	1		0.0037	0.022		0.089	*	*
North Anglesey	Lobsters	2					<0.13		
Conwy	Mussels	1		0.019	0.11		0.20	*	0.00038
Wirral	Shrimps	2					<0.16		
Wirral	Cockles	1		0.16	0.88		2.3	*	0.0037
Liverpool Bay	Prickly cockle	1					16		
Ribble Estuary	Flounder	1					<0.17		
Ribble Estuary	Salmon	1					<0.32		
Ribble Estuary	Bass	1					<0.08		
Ribble Estuary	Sea trout	1					<0.19		
Ribble Estuary	Mullet	1					<0.34		
Ribble Estuary	Shrimps	1	<0.00035	0.0015	0.0088		0.015	*	*
Ribble Estuary	Cockles	1		0.20	1.1		3.4	0.0042	0.0060
Ribble Estuary	Mussels	1					0.74		
Knott End	Cockles	1		0.46	2.5		6.9	0.011	0.0077
Northern Ireland	Cod	6					<0.18		
Northern Ireland	Haddock	6					<0.22		
Northern Ireland	Whiting	1		0.0019	0.00084		0.0014	*	*
Northern Ireland	Herring	4					<0.16		
Northern Ireland	Spurdog	8					<0.18		
Northern Ireland	Saithe	2					<0.25		
Northern Ireland	Farmed salmon	3					<0.14		
Northern Ireland	Crabs	2					<0.14		
Northern Ireland	Lobsters	7					<0.35		
Northern Ireland	*Nephrops*	1		0.0068	0.039		0.15	*	*
Northern Ireland	Winkles	1		0.023	0.13		0.13	*	0.00025
Northern Ireland	Mussels	2					<0.19		
Western Irish Sea	Scallops	2					<0.12		
West of Scotland	Mackerel	1					<0.17		
West of Scotland	Farmed salmon	1					<0.15		
Shetland - East coast	Farmed salmon	1					<0.15		
Shetland - West coast	Farmed salmon	1					<0.27		
Orkney - Scapa Flow	Farmed salmon	1					<0.23		
North west Sutherland	Farmed salmon	1					<0.30		
Loch Broom	Farmed salmon	1					<0.22		
East Harris	Farmed salmon	1					<0.30		
Torridon	Farmed salmon	1					<0.21		
Isle of Raasay	Farmed salmon	1					<0.26		

Table 3.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Western Minch	Farmed salmon	1				<0.28		
Loch Linnhe	Farmed salmon	2				<0.24		
Loch Fyne	Farmed salmon	1				<0.28		
Loch Striven	Farmed salmon	1				<0.24		
Arran	Farmed salmon	1				<0.28		
Skye	Lobster	1				<0.10		
Skye	Mussels	1				<0.10		
Islay	Crabs	1				<0.10		
Islay	Scallops	1				<0.15		
Lewis	*Nephrops*	1				<0.10		
Minch	Herring	1	0.000012	0.000047		0.000063	*	*
Minch	Mackerel	1				<0.26		
Shetland	Fish meal	1	0.00016	0.0013		0.00062	*	*
Shetland	Fish oil	4				<0.10		
Northern North Sea	Cod	1	0.000016	0.00011		0.00016	*	*
Northern North Sea	Plaice	4				<0.23		
Northern North Sea	Haddock	1	0.000022	0.00027		0.00014	0.000041	*
Mid North Sea	Cod	4				<0.12		
Mid North Sea	Plaice	4				<0.11		
Southern North Sea	Cod	2				<0.05		
Southern North Sea	Plaice	1				<0.10		
Southern North Sea	Sole	1				<0.14		
Southern North Sea	Herring	2				<0.06		
Southern North Sea	Cockles	1	0.0029	0.021		0.011	*	*
Southern North Sea	Mussels	1	0.0019	0.014		0.0051	*	*
Southern North Sea	Cockles[b]	1	0.0017	0.0070		0.0086	0.000092	0.00051
Southern North Sea	Mussels[b]	1	0.013	0.064		0.12	*	0.00030
The Wash	Mussels	1				0.70		
Cromer	Crabs	1				<0.05		
English Channel-East	Cod	4				<0.06		
English Channel-East	Plaice	4				<0.07		
English Channel-East	Scallops	1	0.00043	0.0022		0.00093	*	0.000047
English Channel-West	Mackerel	4				<0.10		
English Channel-West	Plaice	4				<0.17		
English Channel-West	Whiting	4				<0.09		
English Channel-West	Crabs	1	0.00014	0.00093		0.0016	*	0.000063
English Channel-West	Lobsters	4				<0.08		
English Channel-West	Scallops	1	0.00026	0.0041		0.0022	0.000017	0.000018
Gt Yarmouth (retail shop)	Cod	4				<0.08		
Gt Yarmouth (retail shop)	Plaice	4				<0.11		
River Tyne	Salmon	1				<0.20		
River Tyne	Sea trout	1				<0.06		
Skipsea	Sea trout	1				<0.29		
Skagerrak	Cod	3				<0.18		
Skagerrak	Herring	3				<0.20		
Iceland area	Cod	2				<0.20		
Iceland processed	Cod	1	0.000011	0.000057		0.000094	*	0.000011
Barents Sea	Cod	2				<0.30		
Baltic Sea	Cod	4				<0.52		
Baltic Sea	Herring	4				<0.34		
Norwegian Sea	Cod	1				<0.32		
Norwegian Sea	Herring	1				<0.45		
Norwegian Sea	Saithe	1				<0.15		
Norwegian Sea	Mackerel	1				<0.13		
Celtic Sea	Cod	4				<0.16		
Celtic Sea	Plaice	1				<0.22		
Celtic Sea	Lemon sole	1				<0.10		
Celtic Sea	Whiting	2				<0.08		

** Not detected by the method used*
[a] Samples collected by consumer 971
[b] Landed in Holland
[F,S] Samples collected on behalf of the Food Standards Agency and SEPA

Table 3.6. Individual radiation exposures, Sellafield, 2003

Exposed population group[a]	Exposure mSv						
	Total	Seafood (nuclear industry discharges)	Seafood (other discharges)	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways
Seafood consumers							
Local seafood consumers (1999-2003)[d]	0.62[f]	0.19	0.41	-	0.021	-	-
Local seafood consumers (2003)[d]	0.76[e]	0.26	0.48	-	0.018	-	-
Whitehaven seafood consumers	0.031	0.031	-	-	-	-	-
Dumfries and Galloway seafood consumers	0.036	0.016	-	-	0.019	-	-
Morecambe Bay seafood consumers	0.075	0.054	-	-	0.021	-	-
Fleetwood seafood consumers	0.018	0.018	-	-	-	-	-
Isle of Man seafood consumers	0.006	0.006	-	-	-	-	-
Northern Ireland seafood consumers	0.013	0.010	-	-	<0.005	-	-
North wales seafood consumers	0.012	0.007	-	-	0.005	-	-
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-
Other groups							
Ravenglass estuary, recreational use	0.035	-	-	-	0.033	<0.005	-
Ravenglass estuary, nature warden	0.041	-	-	-	0.036	0.005	-
Fishermen handling nets or pots[c]	0.11	-	-	-	0.11	-	-
Bait diggers and shellfish[c] collectors	0.21	-	-	-	0.21	-	-
Ribble estuary houseboats	0.079	-	-	-	0.075	<0.005	-
Average beach occupancy in Cumbria	<0.005	-	-	-	<0.005	-	-
Local consumers at Ravenglass[b]	0.019	-	-	0.019	-	-	-
Local consumers of vegetables grown on land with seaweed added	0.026	-	-	0.026	-	-	-
Consumers of laverbread in South Wales	0.005	-	-	0.005	-	-	-
Inhabitants and consumers of locally grown food [b]	0.034	-	-	0.031	-	-	<0.005
Average consumer of locally grown food	0.009	-	-	0.009	-	-	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*
[c] *Exposure to skin for comparison with the 50 mSv dose limit*
[d] *Doses are estimated for critical group habits representative of 2003 and a five year period, 1999 - 2003. Includes the effects of discharges from adjacent industrial site at Whitehaven*
[e] *The total dose due to nuclear industry discharges was 0.28 mSv*
[f] *The total dose due to nuclear industry discharges was 0.21 mSv*

Table 3.7. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2003

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, µGy h^{-1}
Cumbria			
Rockcliffe Marsh	Salt marsh	4^F	0.073
Burgh Marsh	Marsh	2	0.074
Port Carlisle 1	Grass and salt marsh	2	0.088
Port Carlisle 1	Salt marsh	2	0.090
Port Carlisle 2	Grass	2	0.10
Port Carlisle 2	Salt marsh	1	0.12
Greenend 1	Grass	1	0.081
Greenend 1	Grass and pebbles	1	0.087
Greenend 1	Pebbles	1	0.095
Greenend 1	Sand	1	0.086
Greenend 2	Grass	1	0.078
Greenend 2	Grass and salt marsh	1	0.083
Greenend 2	Pebbles and sand	1	0.098
Greenend 3	Grass	1	0.077
Greenend 3	Grass and salt marsh	1	0.082
Greenend 3	Pebbles and sand	1	0.096
Cardurnock Marsh	Grass	1	0.071
Cardurnock Marsh	Grass and salt marsh	1	0.078
Cardurnock Marsh	Salt marsh	2	0.074
Newton Arlosh	Salt marsh	4^F	0.11
Newton Arlosh	Grass and salt marsh	1	0.089
Newton Arlosh	Salt marsh	2	0.095
Silloth harbour	Mud and sand	1	0.099
Silloth harbour	Sand	1	0.082
Silloth harbour	Mud	2	0.099
Silloth silt pond	Grass	4	0.077
Allonby	Sand	1	0.088
Allonby	Sand and stones	1	0.094
Allonby	Pebbles and sand	2	0.097
Maryport harbour	Sand	2	0.090
Parton	Winkle bed	4^F	0.090
Workington harbour	Mud	1	0.099
Workington harbour	Pebbles and mud	1	0.10
Harrington harbour	Pebbles and sand	1	0.10
Harrington harbour	Sand	1	0.10
Whitehaven - outer harbour	Mud and sand	12^F	0.087
Whitehaven - outer harbour	Coal and sand	12^F	0.12
Whitehaven - outer harbour	Pebbles and sand	1	0.12
Whitehaven - outer harbour	Sand	3	0.10
Whitehaven - yacht basin	Mud	1^F	0.17
Saltom Bay	Winkle bed	4^F	0.099
St Bees	Sand	4^F	0.070
St Bees	Sand	4	0.077
Nethertown	Winkle bed	4^F	0.087
Nethertown beach	Rock	1	0.081
Nethertown beach	NA	1	0.085
Braystones	Pebbles	1	0.11
Braystones	Pebbles and sand	1	0.11
Sellafield	Sand	4^F	0.071
Sellafield beach	Grass and sand	2	0.098
Sellafield beach	NA	1	0.11
Sellafield beach	Sand	1	0.084
Pipeline on foreshore	NA	1	0.10
Pipeline on foreshore	Pebbles	1	0.10
Ehen spit seashore	Sand	1	0.084
River Calder downstream of factory sewer	Grass	2	0.29
River Calder upstream of factory sewer	Grass	2	0.096
Seascale	Grass	2	0.083
Seascale	Grass and tarmac	1	0.094
Seascale	Pebbles and sand	1	0.086
Seascale	Sand	2	0.087
Drigg Barn Scar	Mussel bed	4^F	0.086
Muncaster Bridge	Grass	1	0.13
Muncaster Bridge	Grass and salt marsh	1	0.12
Muncaster Bridge	Mud	1	0.12
Muncaster Bridge	NA	1	0.12

Table 3.7. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h-1
Cumbria (cont.)			
Ravenglass - Carleton Marsh	Salt marsh	4F	0.18
Ravenglass - Carleton Marsh	Salt marsh	2	0.18
Ravenglass - Carleton Marsh	Grass	1	0.10
Ravenglass - Carleton Marsh	Marsh and mud	1	0.16
Ravenglass - salmon garth	Mud, sand and stones	4F	0.11
Ravenglass - salmon garth	Sand and stones	4F	0.089
Ravenglass - salmon garth	Mussel bed	4F	0.085
Ravenglass - salmon garth	Pebbles and rock	1	0.097
Ravenglass - salmon garth	Pebbles and sand	1	0.12
Ravenglass - salmon garth	Pebbles and mud	1	0.11
Ravenglass - salmon garth	Sand	1	0.10
Ravenglass - boat area	Pebbles and mud	1	0.10
Ravenglass - boat area	Pebbles and sand	1	0.11
Ravenglass - boat area	Rock and sand	1	0.093
Ravenglass - boat area	Sand	1	0.092
Ravenglass - ford	Mud	2	0.11
Ravenglass - ford	Mud and sand	4F	0.096
Ravenglass - ford	Sand	1	0.11
Ravenglass - ford	Rock and sand	1	0.12
Ravenglass - River Mite estuary	Grass and salt marsh	1	0.20
Ravenglass - River Mite estuary	Grass, salt marsh and mud	1	0.16
Ravenglass - River Mite estuary	Salt marsh	2	0.20
Ravenglass - Raven Villa	Mud	11F	0.11
Ravenglass - Raven Villa	Mud and sand	1F	0.10
Ravenglass - Raven Villa	Salt marsh	12F	0.16
Ravenglass - Raven Villa	Grass, salt marsh and mud	1	0.16
Ravenglass - Raven Villa	Grass and salt marsh	1	0.13
Ravenglass - Raven Villa	Salt marsh	2	0.18
Ravenglass - Eskmeals Nature Reserve	Pebbles and sand	2	0.11
Ravenglass - Eskmeals Nature Reserve	Sand	2	0.075
Newbiggin/Eskmeals 1	Mud	2	0.19
Newbiggin/Eskmeals 1	Grass and salt marsh	1	0.17
Newbiggin/Eskmeals 1	Grass and mud	1	0.18
Newbiggin/Eskmeals 2	Mud	1	0.15
Newbiggin/Eskmeals 2	Grass, salt marsh and mud	1	0.17
Newbiggin/Eskmeals 2	Grass and mud	1	0.17
Newbiggin/Eskmeals 2	Mud and salt marsh	1	0.14
Tarn Bay	Sand	2F	0.062
Tarn Bay	Winkle bed	2F	0.079
Tarn Bay	Sand	2	0.089
Silecroft	Pebbles and sand	1	0.10
Silecroft	Sand	2	0.084
Haverigg	Mud	4F	0.088
Haverigg	Sand	4F	0.064
Haverigg	Sand	2	0.078
Millom	Mud and sand	4F	0.087
Millom	Mud	2	0.11
Low Shaw	Salt marsh	2	0.085
Askam	Sand	2	0.075
Tummer Hill Marsh	Salt marsh	2	0.14
Walney Channel, N of discharge point	Mud	2	0.091
Walney Channel, S of discharge point	Mud	1	0.092
Walney Channel, S of discharge point	Pebbles and mud	1	0.092
Roa Island	Pebbles	1	0.090
Roa Island	Mud and stones	1	0.095
Greenodd	Salt marsh	2	0.074
Sand Gate Marsh	Salt marsh	4F	0.091
Sand Gate Marsh	Grass and salt marsh	1	0.095
Sand Gate Marsh	Grass, mud and sand	1	0.098
Sand Gate Marsh	Salt marsh	2	0.092
Flookburgh	Mud and sand	4F	0.082
Flookburgh	Salt marsh	3	0.097
Flookburgh	Grass and salt marsh	1	0.089
High Foulshaw	Salt marsh	4F	0.083
High Foulshaw	Grass and salt marsh	1	0.075
High Foulshaw	Salt marsh	3	0.080
Arnside	Salt marsh	4F	0.093
Arnside	Mud and sand	4	0.077
Arnside	Salt marsh	4	0.096

Table 3.7. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Lancashire, Merseyside and North Wales			
Sunderland Point	Mud	1	0.087
Sunderland Point	Mud and sand	2	0.089
Sunderland Point	Sand	1	0.091
Sunderland	Mud	2	0.087
Sunderland	Mud and salt marsh	1	0.091
Sunderland	Grass and mud	1	0.10
Morecambe Central Pier	Mussel bed	4[F]	0.072
Morecambe Central Pier	Mud and sand	4[F]	0.074
Morecambe Central Pier	Mud	1	0.079
Morecambe Central Pier	Pebbles and mud	1	0.084
Half Moon Bay	Mud and sand	4[F]	0.075
Half Moon Bay	Sand	2	0.067
Middleton Sands	Mud	1	0.079
Middleton Sands	Sand	1	0.075
Colloway Marsh	Salt marsh	4[F]	0.14
Colloway Marsh	Salt marsh	4	0.10
Lancaster	Grass	4	0.083
Aldcliffe Marsh	Salt marsh	4[F]	0.10
Aldcliffe Marsh	Salt marsh	4	0.11
Conder Green	Mud	1[F]	0.094
Conder Green	Mud and sand	3[F]	0.092
Conder Green	Salt marsh	4[F]	0.11
Conder Green	Grass	1	0.093
Conder Green	Grass and mud	2	0.089
Conder Green	Salt marsh	1	0.090
Cockerham Marsh	Salt marsh	4[F]	0.10
Cockerham Marsh	Grass and salt marsh	2	0.10
Cockerham Marsh	Salt marsh	2	0.099
Heads - River Wyre	Salt marsh	2[F]	0.098
Heads - River Wyre	Grass and salt marsh	1	0.10
Heads - River Wyre	Salt marsh	2	0.10
Heads - River Wyre	NA	1	0.11
Height o' th' hill - River Wyre	Salt marsh	4[F]	0.11
Height o' th' hill - River Wyre	Grass and mud	1	0.11
Height o' th' hill - River Wyre	Salt marsh	3	0.11
Hambleton	Grass	1	0.11
Hambleton	Grass and mud	3	0.11
Knott End	Mud and sand	2[F]	0.075
Fleetwood shore 1	Pebbles and sand	1	0.073
Fleetwood shore 1	Sand	3	0.075
Fleetwood shore 2	Salt marsh	4	0.15
Skippool Creek 1	Grass	1	0.13
Skippool Creek 1	Grass and mud	3	0.11
Skippool Creek 2	Grass	2	0.10
Skippool Creek 2	Grass and mud	2	0.10
Skippool Creek 3	Mud and concrete	1	0.076
Skippool Creek 3	Wood	2	0.094
Skippool Creek boat 2 (boat cabin)	Mud and wood	1	0.090
Skippool Creek boat 2 (mud)	Grass	1	0.095
Skippool Creek boat 2 (mud)	Grass and mud	3	0.094
Blackpool	Sand	4	0.066
Crossens Marsh	Salt marsh	2	0.078
Crossens Marsh	Salt marsh and mud	1	0.080
Crossens Marsh	Grass and salt marsh	1	0.077
Ainsdale	Sand	4	0.059
New Brighton	Sand	4	0.062
West Kirby	Mud	3	0.067
West Kirby	Sand	1	0.068
Rock Ferry	Rock and sand	1	0.078
Rock Ferry	Sand	3	0.079
Little Neston Marsh 1	Grass, mud and sand	1	0.091
Little Neston Marsh 1	Grass and mud	1	0.093
Little Neston Marsh 2	Salt marsh	3	0.10
Little Neston Marsh 2	Salt marsh and sand	1	0.098
Flint 1	Mud	2	0.091
Flint 2	Salt marsh	4	0.081
Prestatyn	Concrete	1	0.082
Prestatyn	Sand	1	0.058

Table 3.7. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Lancashire, Merseyside and North Wales (cont.)			
Rhyl	Mud	1	0.072
Rhyl	Rock and concrete	1	0.072
Llandudno	Pebbles	1	0.091
Llandudno	Pebbles and rock	1	0.090
Caerhun	Grass and salt marsh	1	0.094
Caerhun	Salt marsh	1	0.091
Llanfairfechan	Grass, salt marsh and sand	1	0.080
Llanfairfechan	Sand	1	0.070
South-west Scotland			
Southerness	Winkle bed	4	0.079
Piltanton Burn	Salt marsh	4	0.059
Garlieston	Mud	4	0.079
Innerwell	Mud	6^F	0.088
Innerwell	Mud and sand	2^F	0.076
Bladnoch	Mud	4	0.099
Creetown	Salt marsh	4	0.099
Carsluith	Mud	4	0.092
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.088
Cumstoun	Salt marsh	4	0.087
Kirkcudbright	Salt marsh	4	0.094
Cutters Pool	Winkle bed	8^F	0.089
Rascarrel Bay	Winkle bed	8^F	0.12
Palnackie Harbour	Mud	4	0.094
Gardenburn	Salt marsh	4	0.10
Kippford - Slipway	Mud	4	0.11
Kippford - Merse	Salt marsh	4	0.13
Carsethorn	Mud	4	0.083
Glencaple Harbour	Mud and sand	4	0.093
Isle of Man			
Isle of Man	Sand	1	0.066
Northern Ireland			
Narrow Water	Mud	1	0.092
Rostrevor	Sand	1	0.13
Mill Bay	Mud	1	0.10
Greencastle	Sand	1	0.087
Cranfield Bay	Sand	1	0.085
Annalong	Sand	1	0.12
Newcastle	Sand	1	0.094
Dundrum	Mud	1	0.089
Tyrella	Sand	1	0.084
Rossglass	Sand	1	0.085
Killough	Mud	1	0.089
Ardglass	Mud	1	0.11
Kilclief	Sand	1	0.083
Strangford	Stones	1	0.10
Nickey's Point	Mud	1	0.087
Island Hill	Mud	1	0.086
Ards Maltings	Mud	1	0.084
Greyabbey	Sand	1	0.079
Kircubbin	Sand	1	0.088
Portaferry	Stones	1	0.094
Cloghy	Sand	1	0.070
Ballyhalbert	Sand	1	0.069
Ballywalter	Sand	1	0.070
Millisle	Sand	1	0.074
Groomsport	Sand	1	0.069
Helen's Bay	Sand	1	0.063
Belfast Lough	Sand	1	0.065
Carrickfergus	Sand	1	0.064
Whitehead	Sand	1	0.067
Larne	Sand	1	0.059
Drains Bay	Sand	1	0.055
Ballygally	Sand	1	0.059
Half Way House	Sand	1	0.058
Glenarm	Sand	1	0.055

Table 3.7. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Northern Ireland (cont.)			
Carnlough	Sand	1	0.061
Red Bay	Sand	1	0.071
Cushendall	Sand and stones	1	0.069
Cushendun	Sand	1	0.061
Ballycastle	Sand	1	0.061
Giant's Causeway	Sand	1	0.061
Port-Ballintrae	Sand	1	0.061
White Rocks	Sand	1	0.071
Portrush	Sand	1	0.072
Portstewart	Sand	1	0.062

NA Not available

[F] *Measurements are made on behalf of the environment agencies unless labelled "F". In that case the Food Standards Agency has also participated for quality control purposes.*

Table 3.8. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2003

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Cumbria												
Newton Arlosh	Turf	4[F]	<0.85	<2.9		<2.5	<2.3	<10	<4.3	<1.1	510	<6.2
Newton Arlosh	Sediment	3		3.5		<1.5	<0.85	<6.4	<4.0	<0.57	420	<4.0
Maryport Outer Harbour	Sediment	2		4.0	5.0	<2.1	<1.3	<11	<5.1	<0.84	130	<5.1
Workington Harbour	Sediment	2		13		<1.7	<1.6	<30	9.7	<0.94	280	<11
Harrington Harbour	Sediment	2		1.7		<1.2	<0.73	<3.7	<3.6	<0.41	160	<1.9
Whitehaven yacht basin	Mud	4[F]	<0.90	14		<2.0	<1.7	44	26	<1.2	850	<8.3
Whitehaven Outer Harbour	Sediment	3		<1.7	<1.1	<2.2	<2.0	<5.3	<6.0	<0.78	180	<3.6
St Bees	Sand	4[F]	<0.57	5.1		<2.2	<3.1	<6.7	<2.6	<0.64	80	<4.1
St Bees	Sediment	4		4.4		<1.6	<1.5	<4.5	<3.6	<0.44	81	<2.0
River Calder - upstream	Sediment	2		<0.66		<1.6	<0.99	<4.3	<3.6	<0.58	63	<3.2
River Calder - downstream	Sediment	1		<0.80		<1.7	<0.97	<4.4	<4.5	<0.60	65	<2.5
Sellafield	Sand	4[F]	<0.50	4.4		<2.0	<2.8	<8.5	<2.8	<0.60	70	<3.7
Ehen Spit	Sediment	2		4.5		<0.98	<0.50	<4.8	<3.0	<0.36	77	<1.5
Seascale beach	Sediment	4		2.9		<1.8	<1.7	<3.6	<2.3	<0.42	51	<1.8
Ravenglass - Carleton Marsh	Mud	4[F]	<0.87	24		<2.1	<1.9	130	18	<1.2	370	23
Ravenglass - Carleton Marsh	Sediment	4		26		<8.9	<7.0	<99	<24	<1.8	1200	<21
River Mite Estuary	Sediment	3		18	75	<5.1	<4.2	58	12	<1.3	410	<15
Ravenglass - Raven Villa	Mud and sand	4[F]	<0.75	39		<2.0	<2.4	160	27	<0.98	260	34
Ravenglass - Raven Villa	Sediment	3		24		<7.0	<7.5	<69	<24	<1.7	850	<28
Newbiggin (Eskmeals)	Sediment	4		53	<96	<4.8	<4.6	200	<30	<1.7	620	41
Low Shaw	Sediment	2		<2.1		<1.0	<0.50	<7.3	<3.9	<0.48	130	<4.2
Millom	Mud and sand	4[F]	<0.64	5.7		<1.5	<1.4	26	5.2	<0.77	120	<5.6
Millom	Sediment	2		11		<1.5	<0.82	<17	<6.9	<0.52	120	<4.6
Haverigg	Sediment	2		<0.81		<1.5	<0.94	<4.4	<3.2	<0.52	29	<3.9
Sand Gate Marsh	Turf	4[F]	<0.68	<1.7		<1.4	<1.1	<7.6	<2.7	<0.87	180	<4.5
Sand Gate Marsh	Sediment	4		<1.9		<2.9	<2.6	<6.0	<4.4	<0.58	180	<2.7
Flookburgh	Mud and sand	4[F]	<0.47	<0.49		<0.95	<0.75	<5.2	<1.9	<0.56	160	<4.0
Flookburgh	Sediment	4		<1.3		<3.6	<2.7	<9.9	<12	<1.1	650	<6.4
Walney Channel - west	Sediment	2		5.5		<1.1	<0.60	<10	4.6	<0.50	97	<3.5
Walney Channel - east	Sediment	2		8.3		<1.6	<1.6	<23	6.2	<0.59	120	<8.0
Lancashire and North Wales												
Morecambe	Mud and sand	4[F]	<0.74	<3.4		<1.5	<1.3	<20	7.4	<0.86	160	<4.6
Morecambe	Sediment	1		1.8							102	
Half Moon Bay	Mud and sand	4[F]	<0.90	6.5		<1.7	<1.4	<28	<7.2	<0.97	160	<5.9
Half Moon Bay	Sediment	2		<1.3							36	
Heysham pipelines	Sediment	2		<1.1							26	
Potts Corner	Sediment	2		<0.99							56	
Sunderland Point	Sediment	4		2.3		<2.1	<1.9	<6.1	<5.0	<0.64	100	<3.7
Conder Green	Turf	4[F]	<0.96	4.0		<1.9	<1.4	<11	<3.9	<1.2	320	<5.4
Conder Green	Sediment	4		<2.2		<2.0	<1.8	<6.2	<3.6	<0.58	160	<3.4
Hambleton	Sediment	4		5.1		<3.8	<3.3	<24	<12	<1.1	390	<4.9
Fleetwood	Sediment	4		<0.69		<2.4	<2.3	<3.7	<2.7	<0.48	21	<2.2
Skippool Creek	Sediment	4		4.6		<3.2	<2.5	<18	<10	<0.93	420	<4.5
Blackpool	Sediment	4		<0.41		<1.4	<1.4	<2.6	<1.6	<0.34	5.7	<1.4
Crossen Marsh	Sediment	4		<0.90		<4.9	<4.5	<7.3	<5.7	<0.99	130	<3.6
Ainsdale	Sediment	4		<0.42		<1.5	<1.7	<2.9	<2.0	<0.37	8.3	<1.7
New Brighton	Sediment	4		<0.61		<2.4	<2.3	<5.0	<3.0	<0.54	4.9	<2.8
Rock Ferry	Sediment	4		<0.52		<2.1	<1.9	<3.3	<2.6	<0.41	33	<2.5
Llandudno	Sediment	2		<0.25		<0.75	<0.60	<2.2	<1.0	<0.22	3.0	<0.86
Rhyl	Sediment	2		<1.7		<18	<36	<13	<11	<1.5	110	<7.4
Llanfairfechan	Sediment	2		<0.84		<2.6	<1.9	<6.1	<5.6	<0.82	89	<5.4
Caerhun	Sediment	2		<1.2		<3.4	<2.2	<8.6	<8.5	<1.0	330	<4.8

Table 3.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Cumbria												
Newton Arlosh	Turf	4[F]	<3.0	<3.0				280				
Newton Arlosh	Sediment	3	<2.2	<3.9				590			660	1200
Maryport Outer Harbour	Sediment	2	<3.6	<3.9	16	90	820	140			520	930
Workington Harbour	Sediment	2	<4.5	<4.7				190			1100	1900
Harrington Harbour	Sediment	2	<2.0	<1.7				69			310	930
Whitehaven yacht basin	Mud	4[F]	11	7.1				1100				2900
Whitehaven Outer Harbour	Sediment	3	<2.8	<2.5	9.6	52	540	92			330	1000
St Bees	Sand	4[F]	<1.8	<2.0				190				
St Bees	Sediment	4	<2.2	<1.5				310			310	620
River Calder - upstream	Sediment	2	<2.4	<2.6							260	1400
River Calder - downstream	Sediment	1	<3.1	<1.5							400	1600
Sellafield	Sand	4[F]	<1.6	<1.8				600				
Ehen Spit	Sediment	2	<1.8	<0.99				200			330	660
Seascale beach	Sediment	4	<2.0	<1.3				150			290	670
Ravenglass - Carleton Marsh	Mud	4[F]	7.5	<4.0				920				
Ravenglass - Carleton Marsh	Sediment	4	16	<6.4				3200			4200	4100
River Mite Estuary	Sediment	3	<7.6	<4.4	75	380	5200	800			1400	2300
Ravenglass - Raven Villa	Mud and sand	4[F]	7.5	<4.4				670				
Ravenglass - Raven Villa	Sediment	3	<12	<5.9				1700			2900	2100
Newbiggin (Eskmeals)	Sediment	4	12.0	<8.0	130	650	6200	1500			2100	2400
Low Shaw	Sediment	2	<2.4	<1.7				120			430	760
Millom	Mud and sand	4[F]	<2.2	<2.3				210				
Millom	Sediment	2	<2.4	<2.7				630			370	900
Haverigg	Sediment	2	<2.3	<2.4				34			100	510
Sand Gate Marsh	Turf	4[F]	<2.2	<2.4				91				
Sand Gate Marsh	Sediment	4	<2.6	<2.0				131			390	950
Flookburgh	Mud and sand	4[F]	<1.5	<2.1				51				
Flookburgh	Sediment	4	<4.5	<4.2				430			810	1500
Walney Channel - west	Sediment	2	<2.1	<1.7				150			340	800
Walney Channel - east	Sediment	2	<3.3	<2.6				170			600	1100
Lancashire and North Wales												
Morecambe	Mud and sand	4[F]	<2.1	<2.4				120				
Morecambe	Sediment	1						<77				
Half Moon Bay	Mud and sand	4[F]	<2.4	<2.5	16	87		150	0.15	0.23		
Half Moon Bay	Sediment	2						<36				
Heysham pipelines	Sediment	2						<24				
Potts Corner	Sediment	2						29				
Sunderland Point	Sediment	4	<2.5	<3.2				130			290	890
Conder Green	Turf	4[F]	<3.2	<2.9				200				
Conder Green	Sediment	4	<2.4	<2.1				210			510	900
Hambleton	Sediment	4	<3.8	<3.5				300			780	1400
Fleetwood	Sediment	4	<1.8	<1.5				27			<120	660
Skippool Creek	Sediment	4	<3.7	<3.4				310			790	1200
Blackpool	Sediment	4	<1.3	<0.84				5.0			<100	380
Crossen Marsh	Sediment	4	3.2	<1.9				110			430	840
Ainsdale	Sediment	4	<1.5	<0.94				5.3			<100	350
New Brighton	Sediment	4	<2.0	<1.3				2.8			<100	410
Rock Ferry	Sediment	4	<1.7	<1.4				16			140	800
Llandudno	Sediment	2	<0.84	<0.58							<100	390
Rhyl	Sediment	2	<6.3	<4.1				83			490	1000
Llanfairfechan	Sediment	2	<3.6	<4.3				70			440	1200
Caerhun	Sediment	2	<3.7	<3.5				47			520	1500

Table 3.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{54}Mn	^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Scotland											
Bladnoch	Mud	4	<0.13	5.9	<0.77	<1.3	8.8	3.5	<0.18	330	<1.2
Garlieston	Sediment	4	<0.10	0.40	<0.20	<0.20	<0.65	<0.69	<0.10	32	0.61
Innerwell	Mud	2[F]	<0.83	4.9	<2.1	<2.1	<9.3	<4.1	<1.0	150	<4.2
Innerwell	Sediment	4	<0.11	2.2	<0.31	<0.45	<2.5	1.8	<0.12	87	<1.0
Carsluith	Sediment	4	<0.10	2.4	<0.31	<0.38	<3.5	<1.9	<0.11	89	<0.91
Kippford Merse	Turf	4	<0.10	3.5	<0.57	<1.8	<2.7	1.4	<0.11	300	<1.0
Kippford Slipway	Sediment	4	<0.10	5.8	<0.46	<0.76	9.6	3.9	<0.15	220	<1.4
Palnackie Harbour	Sediment	4	<0.10	4.6	<0.48	<1.1	8.9	3.1	<0.15	170	<0.87
Carsethorn[a]	Sediment	2	<0.10	1.9	<0.21	<0.21	3.2	2.2	<0.10	73	<0.71
Kirkconnel Merse	Sediment	4	<0.11	1.3	<0.39	<0.45	<1.4	<1.8	<0.15	540	<1.0
Campbletown	Sediment	1	<0.10	<0.10	<0.17	<0.13	<0.63	<0.20	<0.10	8.4	<0.61
Dornoch Brow	Sediment	4	<0.10	2.1	<0.39	<0.29	4.1	2.9	<0.18	140	<0.94
Northern Ireland											
Lough Foyle	Mud	1[F]	<0.54	<0.37	<1.7	<2.1	<5.2	<1.4	<0.60	4.7	<4.2
Lough Foyle	Mud and sand	1[F]	<0.30	<0.26	<0.76	<0.54	<3.0	<0.82	<0.37	1.3	<2.3
Portrush	Sand	2[F]	<0.34	<0.32	<1.5	<2.5	<3.2	<0.77	<0.37	0.55	<2.1
Ballymacormick	Mud	2[F]	<0.50	<0.42	<3.3	<0.60	<4.7	<1.3	<0.57	24	<3.9
Strangford Lough- Nickey's point	Mud	2[F]	<0.63	<0.50	<3.7	<0.49	<5.7	<1.6	<0.69	33	<4.6
Dundrum Bay	Mud	2[F]	<0.56	<0.42	<3.6	<0.50	<4.9	<1.3	<0.57	5.2	<4.0
Carlingford Lough	Mud	2[F]	<0.87	<0.62	<5.2	<0.46	<7.8	<2.2	<1.0	55	<5.9
Oldmill Bay	Mud	2[F]	<0.51	<0.50	<1.4	<1.3	<4.9	<1.6	<0.62	35	<3.7
Isle of Man	Sediment	1		<0.77	<1.8	<1.1	<4.8	<3.9	<0.67	3.0	<2.2

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Scotland											
Bladnoch	Mud	4	2.5	1.6			340				
Garlieston	Sediment	4	<0.22	<0.38	3.5	19	20	0.024	0.029		
Innerwell	Mud	2[F]	<2.6	<2.3			170				
Innerwell	Sediment	4	0.86	1.2			100				
Carsluith	Sediment	4	0.99	<0.95	2.9	24	46	<0.17	<0.17	340	570
Kippford Merse	Turf	4	2.3	<1.2	41	220	350	<0.18	0.58		
Kippford Slipway	Sediment	4	1.9	1.2	20	120	210	<0.20	0.29		
Palnackie Harbour	Sediment	4	1.4	1.2	17	91	180	<0.21	0.29		
Carsethorn	Sediment	2	0.54	0.57			63				
Kirkconnel Merse	Sediment	4	1.9	1.9	17	106	179	<0.25	0.35		
Campbletown	Sediment	1	<0.15	0.45			1.3				
Dornoch Brow	Sediment	4	<0.69	<1.1	8.3	43	79	0.024	0.071		
Northern Ireland											
Lough Foyle	Mud	1[F]	<1.3	<2.0	0.15	0.88	1.4	0.0036	0.0011		
Lough Foyle	Mud and sand	1[F]	<0.82	<1.2			<1.3				
Portrush	Sand	2[F]	<0.97	<0.98			<0.96				
Ballymacormick	Mud	2[F]	<1.2	<1.7	1.7	9.2	15	*	0.019		
Strangford Lough- Nickey's point	Mud	2[F]	<1.6	<2.0	1.6	9.2	9.6	*	0.016		
Dundrum Bay	Mud	2[F]	<1.4	<1.7			<2.1				
Carlingford Lough	Mud	2[F]	<2.1	<3.3	2.1	12	9.0	*	0.0070		
Oldmill Bay	Mud	2[F]	<1.5	<1.9	2.2	12	20	*	0.031		
Isle of Man	Sediment	1	<3.4	<1.2						<100	330

* *Not detected by the method used*

[a] *The concentration of ^{3}H was <5.5 Bq kg^{-1}*

[F] *Measurements are made on behalf of the environment agencies unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 3.9. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2003

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, μSv h^{-1}
M	Nets	4	0.14
	Ropes	4	<0.070
S	Nets	4	<0.095
	Pots	1	*
T	Gill nets	4	<0.061
	Pots	3	0.28
W	Gill nets	2	0.17
	Pots	2	0.37
X	Gill nets	4	<0.046
	Pots	2	0.12
Z	Nets	4	0.13

** Not detected by the method used*

Table 3.10. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2003

Location	Ground type	No. of sampling observ-ations	μSv h^{-1}
Whitehaven - outer harbour	Mud and sand	2	0.22
St Bees	Sand	2	0.12
Nethertown	Winkle bed	2	0.34
Sellafield pipeline	Sand	2	0.13
Drigg Barn Scar	Mussel bed	2	0.21
Ravenglass - Raven Villa	Salt marsh	2	0.75
Ravenglass - salmon garth	Mussel bed	2	0.30
Tarn Bay	Sand	2	0.13

Table 3.11. Concentrations of radionuclides in surface waters from West Cumbria, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration Bq l^{-1}								
			^{3}H	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu + ^{240}Pu$	Total alpha	Total beta
Freshwater	Ehen Spit issue	4	430	<0.43	0.15	<0.41	<0.41	<0.0090	<0.0068	<2.6	10
Freshwater	Seaburn sewer outfall	4	8.6	<0.31	<0.085	<0.30	<0.31	<0.0082	<0.0040	<0.022	0.62
Freshwater	River Calder (downstream)	4	<4.0	<0.28	<0.036	<0.27	<0.30	<0.012	<0.0058	<0.027	<0.10
Freshwater	River Calder (upstream)	4	<4.0	<0.22	<0.038	<0.21	<0.23	<0.0082	<0.0062	<0.027	<0.10
Freshwater	Wast Water	2	<4.0	<0.17			<0.20			<0.020	<0.10
Freshwater	Ennerdale Water	1	<4.0	<0.10			<0.10			<0.020	<0.10
Freshwater	Devoke Water	1	<4.0	<0.10			<0.11			<0.040	<0.10
Freshwater	Thirlmere	1	<4.0	<0.14			<0.17			<0.020	<0.10

Table 3.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2003

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{14}C	^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs
England													
Silloth	Seaweed	4			<3.6		<6.8	<7.9	3200	<14	<2.1	<8.3	<1.5
Harrington Harbour	Seaweed	2			2.2		<1.9	<1.9	11000	<5.2	<0.75	<3.8	<0.59
St Bees	*Fucus vesiculosus*[a]	4[F]	71	<0.05	5.4	1.7	<0.17	<0.21	10000	3.9	0.48	3.0	<0.06
St Bees	*Porphyra*	4[F]	95	<0.07	0.79	0.19	<0.18	<0.18	13	19	<0.13	3.1	<0.07
St Bees	*Rhodymenia spp.*	1[F]		<0.08	3.6		0.35	1.6		20	0.71	3.4	0.08
St Bees	Seaweed	2			11		<3.2	<3.4	7100	<11	<1.7	<6.5	<0.82
Braystones South	*Porphyra*	4[F]		<0.07	1.4		<0.19	<0.19		34	<0.13	2.2	<0.07
Sellafield	*Fucus vesiculosus*	4[F]		<0.12	12	3.1	<0.34	<0.38	27000	10	1.6	6.1	<0.13
Sellafield	Seaweed	2			17		<3.0	<3.0	34000	<9.6	<2.7	<7.6	<0.86
Seascale	*Porphyra*[b]	52[F]		<0.29	1.6		<0.51	<0.31		58	<0.54	<4.8	<0.32
Ravenglass	Seaweed	2			16		<4.0	<4.2	9300	<21	<1.6	<11	<1.2
Half Moon Bay	*Fucus vesiculosus*	4[F]		<0.10	0.58		<0.22	<0.20	5100	<0.90	<0.15	1.1	<0.11
Half Moon Bay	Seaweed	2			<1.6		<2.8	<2.2	3400	<8.5	<1.1	<6.3	<0.9
Marshside Sands	Samphire	1[F]		<0.02	<0.02		<0.07	<0.09		<0.17	<0.03	<0.05	<0.02
Rabbit Cat How	Samphire	1[F]		<0.04	0.18		<0.12	<0.12	1.5	<0.41	<0.07	<0.10	<0.04
Cockerham Marsh	Samphire	1[F]		<0.07	<0.07		<0.27	<0.34		<0.77	<0.12	<0.17	<0.07
Isle of Man	*Fucus vesiculosus*	4		<0.05	<0.12		<0.12	<0.11	1100	<0.42	<0.08	<0.16	<0.05
Wales													
Cemaes Bay	*Fucus vesiculosus*	2[F]		<0.10	<0.11		<0.23	<0.22	350	<0.85	<0.19	<0.21	<0.11
Porthmadog	*Fucus vesiculosus*	1[F]	12	<0.08	<0.07		<0.25	<0.30	34	<0.66	<0.14	<0.17	<0.08
Porthmadog	Seaweed	2			<0.79		<3.2	<3.2	32	<6.0	<1.0	<4.2	<0.79
Fishguard	*Fucus vesiculosus*	1[F]	13	<0.05	<0.06		<0.12	<0.10	27	<0.45	<0.10	<0.11	<0.06
Fishguard	Seaweed	2			<1.2		<2.2	<1.7	14	<7.9	<1.2	<6.4	<1.1
Lavernock Point	*Fucus serratus*[c]	2[F]		<0.05	<0.05		<0.12	<0.11	1.0	<0.40	<0.08	<0.11	<0.05
South Wales, manufacturer A	Laverbread	4[F]		<0.07	<0.07		<0.19	<0.20		<0.69	<0.12	<0.14	<0.07
South Wales, manufacturer C	Laverbread	4[F]		<0.10	<0.10		<0.33	<0.44		<1.0	<0.18	<0.21	<0.10
South Wales, manufacturer D	Laverbread	4[F]		<0.07	<0.07		<0.20	<0.23		<0.66	<0.12	<0.14	<0.07
South Wales, manufacturer E	Laverbread	1[F]		<0.07	<0.08		<0.19	<0.19		<0.70	<0.12	<0.15	<0.07
Northern Ireland													
Ardglass	*Ascophyllum nodosum*	1		<0.17	<0.19		<0.40	<0.32		<1.8	<0.29	<0.45	<0.19
Ardglass	*Fucus vesiculosus*	3		<0.16	<0.16		<0.51	<0.64	580	<1.5	<0.28	<0.34	<0.16
Portrush	*Fucus spp.*	4		<0.05	<0.08		<0.19	<0.26		<0.46	<0.11	<0.12	<0.05
Strangford Lough	*Rhodymenia spp.*	4		<0.10	<0.11		<0.26	<0.26	35	<0.98	<0.18	<0.20	<0.10
Carlingford Lough	*Ascophyllum nodosum*	1		<0.05	<0.05		<0.11	<0.09		<0.41	<0.08	<0.11	<0.05
Carlingford Lough	*Fucus spp.*	3		<0.12	<0.12		<0.44	<0.61	380	<1.1	<0.20	<0.23	<0.12
Isles of Scilly	*Fucus vesiculosus*	1[F]	14	<0.10	<0.10		<0.33	<0.38	0.77	<0.89	<0.18	<0.23	<0.11
Scotland													
Lewis	*Fucus vesiculosus*	1		<0.10	<0.10		<0.12	<0.10	190	<0.49	<0.10	<0.14	<0.10
Islay	*Fucus vesiculosus*	1		<0.10	<0.10		<0.10	<0.10		<0.31	<0.10	0.20	<0.10
Campbeltown	*Fucus vesiculosus*	1		<0.10	<0.10		<0.12	<0.10		<0.39	<0.10	<0.11	<0.10
Port William	*Fucus vesiculosus*	8[F]		<0.10	<0.29		<0.18	<0.16	1700	<0.60	<0.13	<0.33	<0.10
Garlieston	*Fucus vesiculosus*	8[F]		<0.10	0.99		<0.20	<0.18	3000	<0.81	<0.14	<0.81	<0.10
Auchencairn	*Fucus vesiculosus*	8[F]		<0.10	1.1		<0.19	<0.19	3400	<0.71	<0.14	1.1	<0.11
Knock Bay	*Porphyra*	8[F]		<0.07	<0.07		<0.11	<0.12	18	<0.32	<0.09	<0.09	<0.07
Cape Wrath	*Ascophyllum nodosum*	1[F]	22	<0.06	<0.07		<0.12	<0.09	290	<0.56	<0.12	<0.13	<0.07
Wick	*Ascophyllum nodosum*	1[F]	29	<0.06	<0.06		<0.16	<0.16		<0.53	<0.11	<0.12	<0.07

Table 3.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
England													
Silloth	Seaweed	4	17	<13						<15			
Harrington Harbour	Seaweed	2	4.3	<2.3						<3.1			
St Bees	*Fucus vesiculosus*[a]	4[F]	4.5	<0.27	<0.16	<0.13	2.3	9.4		4.6	*	0.012	
St Bees	*Porphyra*	4[F]	1.9	<0.36	<0.22	<0.16	0.64	3.3	32	7.0	*	0.0095	170
St Bees	*Rhodymenia spp.*	1[F]	7.7	2.2	0.35	0.25	2.3	9.6		16	0.051	0.027	
St Bees	Seaweed	2	12	<3.5						<44			
Braystones South	*Porphyra*	4[F]	1.6	<0.39	<0.21	<0.18	0.66	3.3	32	5.8	*	0.013	
Sellafield	*Fucus vesiculosus*	4[F]	8.1	<0.73	<0.33	<0.41	2.9	11		4.8	0.0057	0.012	20000
Sellafield	Seaweed	2	<8.1	<3.2						<8.3			
Seascale	*Porphyra*[b]	52[F]	1.8	<1.6	<0.91	<0.73				6.5			
Ravenglass	Seaweed	2	65	<7.9						<300			
Half Moon Bay	*Fucus vesiculosus*	4[F]	5.0	<0.45	<0.29	<0.24				0.78			4100
Half Moon Bay	Seaweed	2	9.3	<6.4						<5.5			
Marshside Sands	Samphire	1[F]	0.46	<0.12	<0.05	<0.05				<0.05			
Rabbit Cat How	Samphire	1[F]	0.68	<0.21	<0.10	<0.09				1.1			
Cockerham Marsh	Samphire	1[F]	0.98	<0.39	<0.20	<0.16				0.54			24
Isle of Man	*Fucus vesiculosus*	4	0.58	<0.27	<0.16	<0.14				<0.20			800
Wales													
Cemaes Bay	*Fucus vesiculosus*	2[F]	0.83	<0.43	<0.35	<0.23				<0.28			510
Porthmadog	*Fucus vesiculosus*	1[F]	0.53	<0.44	<0.23	<0.21				<0.21			
Porthmadog	Seaweed	2	<2.2	<2.7						<0.81			
Fishguard	*Fucus vesiculosus*	1[F]	0.10	<0.20	<0.21	<0.10				<0.06			200
Fishguard	Seaweed	2	<1.4	<3.2						<1.4			
Lavernock Point	*Fucus serratus*[c]	2[F]	0.41	<0.27	<0.16	<0.14				<0.14			230
South Wales, manufacturer A	Laverbread	4[F]	<0.06	<0.24	<0.20	<0.10				<0.05			
South Wales, manufacturer C	Laverbread	4[F]	0.29	<0.38	<0.31	<0.17				<0.29			
South Wales, manufacturer D	Laverbread	4[F]	<0.10	<0.24	<0.21	<0.10				<0.06			66
South Wales, manufacturer E	Laverbread	1[F]	0.17	<0.23	<0.24	<0.10				0.12			
Northern Ireland													
Ardglass	*Ascophyllum nodosum*	1	0.51	<0.90	<0.52	<0.42				<0.43			
Ardglass	*Fucus vesiculosus*	3	0.99	<0.62	<0.49	<0.28				<0.34			
Portrush	*Fucus spp.*	4	0.16	<0.26	<0.18	<0.12				<0.11			
Strangford Lough	*Rhodymenia spp.*	4	0.83	<0.34	<0.34	<0.15	0.067	0.36		0.49	*	0.0012	
Carlingford Lough	*Ascophyllum nodosum*	1	0.31	<0.22	<0.16	<0.10				<0.07			
Carlingford Lough	*Fucus spp.*	3	0.67	<0.43	<0.33	<0.19				<0.19			
Isles of Scilly	*Fucus vesiculosus*	1[F]	<0.10	<0.56	<0.36	<0.30				<0.45			200
Scotland													
Lewis	*Fucus vesiculosus*	1	<0.10	<0.35	<0.10	<0.18				<0.15			
Islay	*Fucus vesiculosus*	1	<0.10	<0.22	<0.10	<0.11				<0.10			
Campbeltown	*Fucus vesiculosus*	1	0.73	<0.26	<0.10	<0.13				<0.12			
Port William	*Fucus vesiculosus*	8[F]	1.4	<0.36	<0.21	<0.20				<0.69			
Garlieston	*Fucus vesiculosus*	8[F]	4.4	<0.41	<0.23	<0.22				5.9			
Auchencairn	*Fucus vesiculosus*	8[F]	3.9	<0.37	<0.22	<0.20				<2.0			
Knock Bay	*Porphyra*	8[F]	0.37	<0.16	<0.11	<0.09				<0.37			
Cape Wrath	*Ascophyllum nodosum*	1[F]	0.32	<0.23	<0.26	<0.12				<0.08			410
Wick	*Ascophyllum nodosum*	1[F]	0.06	<0.23	<0.22	<0.11				<0.07			310

** Not detected by the method used*
[a] *The concentration of ^{129}I was 8.0 Bq kg^{-1}*
[b] *Counted wet*
[c] *The concentration of ^{131}I was <1.7 Bq kg^{-1}*
[F] *Measurements are made on behalf of the environment agencies unless labelled "F". In that case the Food Standards Agency has also participated in the programme.*

Table 3.13. Concentrations of radionuclides in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2003

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am
Newton Arlosh	Grass	1				2.4							
Newton Arlosh	Washed grass	1				1.4							
Newton Arlosh	Soil	1				11							
Sellafield 14[b]	Beetroot	1	<0.08	<0.17	<0.15	52	<0.72	<0.17	<0.08	<0.07	<0.35	<0.18	<0.27
Sellafield 14[b]	Onions	1	<0.03	<0.07	<0.07	6.8	<0.29	<0.06	<0.03	0.06	<0.11	<0.05	<0.03
Sellafield 14[b]	Potatoes	1	<0.04	<0.10	<0.11	14	<0.31	<0.08	<0.03	0.08	<0.16	<0.07	<0.04
Sellafield 14[b]	Runner Beans	1	<0.05	<0.13	<0.11	43	<0.52	<0.11	<0.05	0.04	<0.19	<0.08	<0.04
Sellafield 14[b]	Soil	1	7.4	<0.91	<0.84	2800	<3.7	1.2	<0.44	49	<2.3	<1.2	17
Sellafield 1674[b]	Beetroot	1	<0.09	<0.32	<0.44	100	<0.82	<0.17	<0.09	<0.07	<0.28	<0.11	<0.06
Sellafield 1674[b]	Onions	1	<0.07	<0.20	<0.22	3.3	<0.65	<0.14	<0.06	<0.06	<0.25	<0.10	<0.05
Sellafield 1674[b]	Potatoes	1	<0.04	<0.10	<0.10	26	<0.30	<0.07	<0.04	0.15	<0.15	<0.07	<0.10
Sellafield 1674[b]	Spinach	1	<0.03	<0.09	<0.10	270	<0.28	<0.06	<0.03	0.04	<0.11	<0.04	<0.03
Sellafield 1674[b]	Soil	1	1.1	<0.44	<0.37	790	<1.7	<0.54	<0.24	57	<1.1	1.6	4.4
Sellafield 1676[b]	Cabbage	1	<0.04	<0.10	<0.08	97	<0.41	<0.10	<0.05	0.10	<0.21	<0.11	<0.15
Sellafield 1676[b]	Cauliflower	1	<0.04	<0.10	<0.10	43	<0.35	<0.08	<0.04	0.10	<0.14	<0.06	<0.03
Sellafield 1676[b]	Potatoes	1	<0.03	<0.07	<0.06	8.7	<0.25	<0.06	<0.03	0.22	<0.12	<0.05	<0.03
Sellafield 1676[b]	Soil	1	4.4	<0.61	<0.56	1300	2.6	<0.73	<0.27	66	<1.5	0.96	32
Hutton Marsh	Grass	1				0.84							
Hutton Marsh	Washed grass	1				0.54							
Hutton Marsh	Soil	1				29							

[a] *except for soil where dry concentrations apply*
[b] *Consumer numbers*

Table 3.14. Concentrations of radionuclides in terrestrial food and the environment near Ravenglass, 2003

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}										
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[d]		4	<3.9	14	<0.46	<0.28	0.050	<0.49	<0.41	<0.0066	<1.9	<0.56	<0.013
Milk[d]	max		<4.0	16	<0.60	<0.33	0.059	<0.60	<0.48	<0.0090	<2.1	<0.65	<0.016
Apples		1	9.0	20	<0.30	<0.30	0.10	<0.40	<0.30	<0.037	<1.7	<0.40	<0.020
Barley		1	4.0	100	3.4	<0.40	0.43	<0.40	<0.30	<0.038	<0.90	<0.70	<0.030
Blackberries		1	5.0	23	<0.30	<0.40	0.54	<0.40	<0.30	<0.042	<2.5	<0.70	<0.024
Bovine kidney		1	<3.0	21	0.90	<0.30	0.25	<0.60	<0.40	<0.039	<2.9	<0.70	<0.027
Bovine liver		1	<3.0	31	<0.70	<0.40	<0.018	<0.50	<0.30	<0.041	<2.3	<0.50	<0.033
Bovine muscle		1	<2.0	38	1.3	<0.20	<0.028	<0.40	<0.30	<0.038	<2.2	<0.70	<0.024
Cabbage		1	2.0	11	2.7	<0.30	0.19	<0.30	<0.20	<0.042	<0.80	<0.40	<0.023
Carrots		1	<2.0	4.0	3.9	<0.30	0.16	<0.60	<1.0	<0.032	<2.6	<0.80	<0.021
Honey		1	<2.0	98	<0.30	<0.10	0.044	<0.30	<0.20	<0.042	<1.5	<0.50	<0.011
Lettuce		1								0.12			
Ovine liver		1	<3.0	51	2.9	<0.40	0.32	<0.60	<0.40	<0.036	<2.7	<0.70	<0.038
Ovine muscle		2	<2.0	58	1.9	<0.25	0.047	<0.30	<0.30	<0.037	<1.7	<0.50	<0.019
Ovine muscle	max			66	2.4	<0.30	0.062	<0.40		0.045	<1.9		<0.020
Ovine offal		1	<3.0	54	3.1	<0.30	0.26	<0.50	<0.30	0.052	<2.4	<0.80	<0.022
Potatoes		1	2.0	15	1.1	<0.30	0.17	<0.40	<0.30	<0.037	<2.4	<0.70	<0.022
Runner beans		1	3.0	24	1.5	<0.50	0.14	<0.60	<0.20	<0.039	<2.7	<0.70	<0.027
Turnips		1								<0.020			
Grass		2								<0.21			
Grass	max									0.38			

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}						
			Total Cs	^{144}Ce	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[d]		4	0.15	<1.1		<0.00024	<0.00017	<0.046	<0.00021
Milk[d]	max		0.21			<0.00035	<0.00018	<0.054	<0.00023
Apples		1	0.11	<0.90		<0.00030	0.00040	<0.059	0.0011
Barley		1	0.22	<1.1		<0.00020	0.0012	<0.066	0.0022
Blackberries		1	0.13	<0.90		<0.00040	0.00090	<0.048	0.0022
Bovine kidney		1	0.64	<1.3		0.00020	<0.00040	0.25	0.0023
Bovine liver		1	0.48	<1.1		<0.00040	0.00070	<0.090	0.00060
Bovine muscle		1	0.48	<1.1		0.00020	<0.00030	<0.081	0.00020
Cabbage		1	0.053	<0.70	<0.026	<0.00010	<0.00030	<0.082	0.00030
Carrots		1	0.22	<1.9		<0.00020	<0.00030	<0.073	0.00030
Honey		1	0.48	<1.4		0.00050	0.00080	<0.11	0.0021
Lettuce[e]		1			<0.027				
Ovine liver		1	1.6	<1.1		<0.00040	0.00050	<0.094	0.0010
Ovine muscle		2	1.8	<0.95		0.00035	<0.00025	<0.062	0.00020
Ovine muscle	max		2.2	<1.0		<0.00040	<0.00030	0.069	
Ovine offal		1	1.4	<2.0		<0.00040	0.00040	<0.083	0.00060
Potatoes		1	0.15	<1.2		<0.00020	<0.00020	0.17	0.00050
Runner beans		1	0.10	<1.2		<0.00050	<0.00020	<0.074	0.00070
Turnips		1			<0.026				
Soil		2			52				
Soil[f]	max				57				

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*

[b] *Except for milk where units are Bq l^{-1} and for soil where dry concentrations apply*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[d] *The mean concentration of ^{137}Cs was <0.29 Bq l^{-1} and the maximum was <0.38 Bq l^{-1}*

[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.011, 0.0010 and 0.012 Bq kg^{-1} respectively*

[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 13, 0.51 and 12 Bq kg^{-1} respectively*

Table 3.15. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2003

Material	Selection[a]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[c]		16	<4.2	<4.8	19	<0.35	<0.29	0.079	<0.0060	<1.9	<0.54	<0.014
Milk[c]	max		<7.5	10	23	<0.43	<0.31	0.21		<2.2	<0.60	<0.020
Apples		2	<17	14	15	<0.95	<0.30	0.13	<0.034	<1.5	<0.60	<0.022
Apples	max		<26	22	17	1.6	<0.40	0.22		<1.7	<0.70	<0.027
Barley		2		6.0	110	<0.70	<0.25	2.1		<2.4	<0.60	<0.045
Barley	max			8.0	120		<0.30	2.6		<2.5	<0.70	<0.046
Blackberries		2	<9.5	7.5	23	<0.30	<0.25	0.50		<2.1	<0.55	<0.025
Blackberries	max		<10	8.0	28		<0.30	0.75		<2.3	<0.60	<0.029
Bovine kidney		1	14	17	19	<0.70	<0.10	0.29	<0.042	<0.90	<0.40	
Bovine liver		1	9.0	13	39	<0.70	<0.20	0.14	<0.038	<1.6	<0.50	<0.021
Bovine muscle		1	<7.0	7.0	37	<0.70	<0.30	<0.026	<0.040	<1.2	<0.50	<0.025
Broccoli		1	<5.0	3.0	<3.0	0.90	<0.40	0.17		<1.8	<0.60	<0.021
Cabbage		1	4.0	9.0	<3.0	1.2	<0.20	0.43		<1.6	<0.60	<0.011
Carrots		1	<8.0	3.0	14	<0.40	<0.20	0.38	<0.029	<1.5	<0.50	<0.020
Cauliflower		1	<4.0	4.0	<3.0	0.70	<0.30	0.21		<2.2	<0.60	<0.021
Chicken		1	<5.0	<5.0	16	<0.60	<0.30	<0.025		<2.1	<0.90	<0.029
Eggs		1	3.0	6.0	7.0	<0.80	<0.10	<0.026	<0.030	<2.2	<0.80	<0.028
Elderberries		1	5.0	12	20	<0.30	<0.40	0.28		<1.7	<0.70	<0.033
Honey		2		<2.5	100	<0.40	<0.15	0.048		<1.5	<0.60	<0.015
Honey	max			<3.0	120		<0.20	0.061		<1.7	<0.70	0.020
Onions		1	<13	8.0	9.0	2.0	<0.30	0.13		<2.1	<0.70	<0.030
Ovine liver		1	<4.0	<3.0	43	5.9	<0.30	0.17	<0.037	<2.2	<0.70	<0.032
Ovine muscle		2	<11	7.5	44	<1.1	<0.30	0.062	<0.036	<1.6	<0.60	<0.021
Ovine muscle	max		<17	11	49	1.5		0.071	<0.038	<1.8		<0.024
Ovine offal		1	4.0	21	32	<0.70	<0.20	0.61	<0.039	<1.3	<0.50	
Potatoes		1	<7.0	5.0	11	0.70	<0.30	<0.016		<2.2	<0.60	<0.022
Runner beans		1	<12	6.0	<3.0	2.1	<0.30	0.23		<2.7	<0.50	<0.022
Sprouts		1	<3.0	<3.0	<3.0	0.60	<0.30	0.12		<2.3	<0.70	<0.032
Swede		1	1.0	7.0	5.0	1.0	<0.30	0.38		<1.7	<0.50	<0.025
Turnips		1	<10	5.0	5.0	<0.40	<0.20	0.18		<2.2	<0.70	<0.019
Wood pigeons		2	<5.5	<7.0	39	<1.3	<0.30	<0.029		<2.2	<0.70	<0.026
Wood pigeons	max		6.0	9.0	43	1.7		0.032				
Grass		5					<0.23		<0.040	<1.5	1.0	
Grass	max						<0.30		<0.041	<1.7	1.5	
Soil		3					<0.90			<3.3	<1.2	
Soil	max						1.6			<4.2	<1.6	

Table 3.15. continued

Material	Selection[a]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			^{134}Cs	^{137}Cs	Total Cs	^{154}Eu	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[c]		16	<0.27	<0.38	0.24	<0.31		<0.00017	<0.00017	<0.055	<0.00018
Milk[c]	max		<0.49	<1.2	0.54	<0.34		<0.00020	<0.00018	<0.066	<0.00020
Apples		2			0.33	<0.30		<0.00040	0.00080	<0.12	0.0011
Apples	max				0.50	<0.40		<0.00050	0.0011	0.18	0.0012
Barley		2			0.89	<0.30		0.0034	0.086	<0.20	0.025
Barley	max				0.98			0.0061	0.16	0.30	0.043
Blackberries		2			0.17	<0.25		0.0025	0.014	<0.15	0.016
Blackberries	max				0.18	<0.30		0.0044	0.026	0.26	0.028
Bovine kidney		1			0.12	<0.20		<0.00090	<0.00040	<0.19	0.00060
Bovine liver		1			0.71	<0.30		<0.0019	0.0042	<0.36	0.00050
Bovine muscle		1			0.87	<0.30		0.00010	<0.00020	<0.089	<0.00030
Broccoli		1			0.13	<0.30		<0.00020	0.00020	<0.080	0.00020
Cabbage		1			0.1	<0.30		<0.00030	<0.00010	<0.048	0.00030
Carrots		1			0.16	<0.20		<0.00020	0.0016	<0.069	0.0012
Cauliflower		1			0.050	<0.40		<0.00030	<0.00020	<0.043	0.00020
Chicken		1			0.91	<0.60		<0.00020	0.00010	<0.040	0.00030
Eggs		1			<0.049	<0.60		<0.00030	0.00010	<0.058	0.00060
Elderberries		1			0.49	<0.40		0.0014	0.0064	<0.086	0.016
Honey		2			0.30	<0.40	<0.023	<0.00020	<0.00030	<0.075	0.00095
Honey	max				0.44	<0.50		0.00020	0.00030	<0.080	0.0012
Onions		1			0.093	<0.30		<0.00050	0.00030	<0.078	<0.00030
Ovine liver		1			3.5	<0.60		<0.00050	0.00070	<0.23	0.00040
Ovine muscle		2			2.8	<0.30		<0.00015	<0.00025	<0.077	<0.00030
Ovine muscle	max				4.6			<0.00020	<0.00030	<0.11	0.00030
Ovine offal		1			0.78	<0.30		<0.00070	0.0028	<0.11	0.0010
Potatoes[e]		1			0.1	<0.30	<0.026	<0.00030	0.00030	<0.077	0.00040
Runner beans		1			0.12	<0.30		<0.00040	0.00070	<0.094	0.0013
Sprouts		1			0.13	<0.40		0.00090	0.0034	<0.062	0.011
Swede		1			0.09	<0.30		<0.00020	0.00040	<0.059	0.00050
Turnips		1			1.3	<0.30		0.00030	0.00070	<0.080	0.00090
Wood pigeons		2			0.97	<0.50		0.00010	0.00055	<0.062	<0.00070
Wood pigeons	max				1.0				0.00070		<0.0012
Grass		5	<0.23	5.1							
Grass	max		0.30	8.8							
Soil		3	<0.40	75		<0.50	61				5.9
Soil[f]	max			89		<0.60	63				7.7

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*
[b] *Except for milk where units are Bq l^{-1} and soil where dry concentrations apply*
[c] *The mean concentration of ^{131}I was <0.013 Bq l^{-1} and the maximum was <0.015 Bq l^{-1}*
[d] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0096, 0.0013 and 0.012 Bq kg^{-1} respectively*
[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 11, 0.54 and 10 Bq kg^{-1} respectively*

Table 3.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2003

Material	Location	No. of sampling observ-ations	Radioactivity concentration (dry), Bq kg^{-1}				
			^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{241}Am
Gullypot sediment	Seascale SS 204	1	<0.61	10	<0.53	170	9.7
Gullypot sediment	Seascale SS 233	1	<0.90	<2.0	<0.81	340	23
Gullypot sediment	Seascale SS 209	1	<0.63	<1.0	<0.55	17	<3.2
Gullypot sediment	Seascale SS 232	1	<0.63	<1.0	<0.57	48	12.0
Gullypot sediment	Whitehaven SS 201	1	<0.80	<3.0	<0.64	4.3	1.8

Table 3.17(a). Concentrations of radionuclides in food and the environment near Springfields, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}Th
Marine samples											
Flounder	Ribble Estuary	1		<0.06		<0.18	4.6				
Salmon	Ribble Estuary	1		<0.11	0.72	<0.25	0.22				
Sea trout	Ribble Estuary	1		<0.07	1.5	<0.20	6.7				
Bass	Ribble Estuary	1		<0.07		<0.17	7.7				
Mullet	Ribble Estuary	1		<0.16		<0.41	2.4				
Shrimps[d]	Ribble Estuary	2	59	<0.07	3.0	<0.15	2.5	0.0059	0.0076	0.0022	
Cockles	Ribble Estuary	2		0.57		<0.28	2.4	0.45	0.44	0.20	20
Mussels	Ribble Estuary	1		0.18		0.38	1.3	0.18	0.31	0.080	36
Samphire	Marshside Sands	1		<0.02		<0.05	0.46				
Grass (washed)	Hutton Marsh	1			0.54						
Grass (unwashed)	Hutton Marsh	1			0.84						
Soil	Hutton Marsh	1			29						
Sediment	River Ribble outfall	4[E]		<2.3			260	28	120	27	15000
Sediment	Savick Brook (tidal limit)	2[E]		<1.7			180	29	410	30	100000
Sediment	Lea Gate	1[E]		<0.34			40	26	95	36	2000
Sediment	Lower Penwortham	3[E]		<2.3			270	36	310	33	21000
Sediment	Penwortham rail bridge	4[E]		<1.2			110	20	82	18	8700
Sediment	Penwortham position 1	3[E]		<1.4			140	32	170	23	14000
Sediment	Penwortham position 2	1[E]		<0.10			33	18	29	16	530
Sediment	Lytham	1[E]		4.9			430	43	150	40	23000
Sediment	Becconsall	4[E]		<2.5			320	34	130	29	<2700
Sediment	Freckleton	1[E]		3.1			440	49	320	39	43000
Sediment	Hutton Marsh	1[E]		<34			400	30	71	26	<7000
Sediment	Longton Marsh	1[E]		3.3			540	46	210	39	1100

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Marine samples												
Flounder	Ribble Estuary	1						<0.17				
Salmon	Ribble Estuary	1						<0.32				
Sea trout	Ribble Estuary	1						<0.19				
Bass	Ribble Estuary	1						<0.08				
Mullet	Ribble Estuary	1						<0.34				
Shrimps[d]	Ribble Estuary	2				0.0015	0.0088	0.015	*	*		
Cockles	Ribble Estuary	2				0.20	1.1	3.4	0.0042	0.0060		
Mussels	Ribble Estuary	1						0.74				
Samphire	Marshside Sands	1						<0.05				
Sediment	River Ribble outfall	4[E]	25	<1.7	23			160			860	10000
Sediment	Savick Brook (tidal limit)	2[E]	38	<2.3	34			130			1100	47000
Sediment	Lea Gate	1[E]	11	<1.9	13			20			510	2000
Sediment	Lower Penwortham	3[E]	37	<2.3	35			190			1200	17000
Sediment	Penwortham rail bridge	4[E]	25	<1.6	24			79			730	12000
Sediment	Penwortham position 1	3[E]	24	<1.8	22			98			790	3100
Sediment	Penwortham position 2	1[E]	12	<0.48	12			14			240	1200
Sediment	Lytham	1[E]	32	1.9	28			240			800	12000
Sediment	Becconsall	4[E]	28	<1.2	30			190			900	3300
Sediment	Freckleton	1[E]	27	1.4	29			240			1400	1600
Sediment	Hutton Marsh	1[E]	25	1.5	25			150			670	1600
Sediment	Longton Marsh	1[E]	29	<1.9	28			240			600	4200

Table 3.17(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}										
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{129}I	^{137}Cs	Total Cs	^{228}Th	^{230}Th	^{232}Th	^{234}Th
Terrestrial samples													
Apples		1	<4.0	15	<0.30	0.057	<0.023		0.032		0.0097	0.0018	
Cabbage		1	<4.0	6.0	<0.40	<0.017	<0.029		<0.030		0.0081	0.0013	
Eggs		1	<5.0	64	<0.40	<0.015	<0.022		0.061		0.0031	0.00070	
Elderberries		1	<2.0	27	<0.20	0.18	<0.045		0.061		0.0063	0.0027	
Potatoes		1	3.0	14	<0.40	0.061	<0.031		0.077		0.0057	0.0018	
Runner beans		1	5.0	15	<0.30	0.076	<0.032		<0.030		0.0085	0.0015	
Swede		2	<4.0	12	<0.20	0.38	<0.019		0.066		0.013	0.0059	
Swede	max												
Sediment	Deepdale Brook	2[E]			<0.45			<1.7					<370
Grass		1			<0.40			3.3					
Freshwater	Ulnes Walton	1[E]	<4.0		<0.10			<0.10		<0.0080	<0.0060	<0.0050	

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{234}U	^{235}U	^{238}U	Total U	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Pu	^{241}Am	Total alpha	Total beta
Terrestrial samples												
Milk		6				<0.0065						
Apples		1				<0.025	<0.00050	0.00020	<0.068	<0.00030		
Cabbage		1					<0.00030	<0.00040	<0.10	0.00030		
Eggs		1					<0.00040	<0.00040	<0.11	<0.00030		
Elderberries		1				0.062	0.00060	0.0018	<0.092	0.0049		
Potatoes		1				<0.026	<0.00020	<0.00020	<0.052	<0.00020		
Runner beans		1				<0.026	<0.00030	<0.00020	<0.070	0.00040		
Swede		2				<0.031	<0.00030	<0.00010	<0.064	<0.00020		
Swede	max					0.035						
Sediment	Deepdale Brook	2[E]	25	<1.3	27					<2.7	<240	620
Grass		1				0.44				1.4		
Grass	Site fence	1[E]	0.62	<0.030	0.55							
Grass	Opposite windmill	1[E]	1.9	0.074	1.4							
Silage		1				0.38						
Soil		1				100						
Soil	Site fence	1[E]	140	5.5	120							
Soil	Opposite windmill	1[E]	160	5.4	150							
Freshwater	Deepdale Brook	4[E]	0.56	<0.021	0.58						<1.4	<1.0
Freshwater	Ulnes Walton	1[E]	0.98	0.037	0.93						1.3	0.98

** Not detected by the method used*

[a] Data are arithmetic means unless stated as 'max'.' Max' data are selected to be maxima. If no 'max' value is given, the mean also is the maximum

[b] Except for milk and freshwater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply

[c] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime

[d] The concentration of ^{237}Np was <0.00035 Bq kg^{-1}

[E] Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency

Table 3.17(b). Monitoring of radiation dose rates near Springfields, 2003

Location	Material or ground type	No. of sampling observations	μGy h⁻¹
Mean gamma dose rates at 1m			
Lytham Yacht Club	Mud	1	0.095
Warton Marsh	Mud	4[F]	0.12
Warton Marsh	Mud[a]	4[F]	0.13
Warton Marsh	Salt marsh	4[F]	0.12
Warton Mud Marsh	Mud	1	0.12
Warton Mud Marsh	Salt marsh	1	0.11
Warton Salt Marsh	Salt marsh	2	0.12
Naze Point	Grass and salt marsh	1	0.11
Naze Point	Sand	1	0.10
Banks Marsh	Mud	4[F]	0.12
Banks Marsh	Mud[a]	4[F]	0.13
Banks Marsh	Salt marsh	4[F]	0.15
Banks Marsh	Salt marsh	2	0.11
Hesketh Bank	Grass and salt marsh	1	0.13
Hesketh Bank	Salt marsh	1	0.10
Freckleton	Salt marsh and mud	1	0.078
Becconsall	Mud	4	0.095
Becconsall (houseboat)	Grass	2	0.086
Longton Marsh	Salt marsh	1	0.14
Hutton Marsh	Salt marsh and mud	1	0.11
River Ribble outfall	Mud	2	0.11
River Ribble outfall	Grass and mud	2	0.098
Savick Brook, tidal limit	Mud	1	0.12
Savick Brook, tidal limit	Grass and mud	1	0.11
Savick Brook, confluence with Ribble	Grass	1	0.087
Savick Brook, confluence with Ribble	Grass and mud	1	0.081
Savick Brook, Lea Gate	Grass and mud	1	0.098
Lower Penwortham Park	Grass	4	0.077
Lower Penwortham Railway Bridge	Mud	4	0.085
River Darwen	Grass	1	0.077
River Darwen	Grass and mud	3	0.075
Riverbank Angler location 1	Grass	2	0.072
Riverbank Angler location 1	Grass and mud	2	0.072
Riverbank Angler location 2	Grass	1	0.073
Ulnes Walton, BNFL area survey	Grass	21	0.087
Mean beta dose rates			
Lytham - Granny's Bay	Mud and sand	1[F]	0.28
Ribble Estuary	Gill net	2[F]	1.3
Ribble Estuary	Shrimp net	2[F]	0.26
Banks Marsh	Mud	4[F]	4.3
Banks Marsh	Salt marsh	4[F]	0.95
Warton Marsh	Mud	4[F]	4.3
Warton Marsh	Salt marsh	4[F]	0.88

[a] *15cm above substrate*

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

4. RESEARCH ESTABLISHMENTS

This section considers the effects of discharges from research establishments that hold nuclear site licences.

The United Kingdom Atomic Energy Authority (UKAEA) operates the majority of such sites, with licensed nuclear sites at Harwell, Winfrith and Windscale in England, and at Dounreay in Scotland. All of the sites have reactors that are at different stages of decommissioning. Discharges of radioactive waste are largely related to decommissioning and decontamination operations and the nuclear related research that is undertaken. Tenants, or contractors, such as AEA Technology carry out some of this work.

Regular monitoring of the environment was undertaken in relation to all UKAEA sites, which included the effects of discharges from neighbouring sites and tenants where appropriate, i.e. the Vulcan Naval Reactor Test Establishment (NRTE) and AEA Technology at Dounreay, and Amersham plc* at Harwell. Windscale is adjacent to the BNFL Sellafield site, therefore its discharges, which are negligible compared with Sellafield, are monitored and considered as part of the Sellafield monitoring programme.

Other research sites considered in this section are the Imperial College Reactor Centre, Imperial Chemical Industries plc, the Scottish Universities' Research Reactor Centre and Culham.

4.1 Culham, Oxfordshire

Culham is home to an experimental fusion reactor, the Joint European Torus. Monitoring of soil and grass around Culham and of sediment and water from the River Thames was undertaken in 2003 and data is shown in Table 4.1. No significant effects due to site operation were detected. The measured concentrations of caesium-137 in the River Thames sediment are not attributable to Culham but are due to discharges from Harwell, nuclear weapons testing fallout from the 1950s and 1960s and the Chernobyl reactor accident in 1986. The dose from using the River Thames directly as drinking water downstream of the discharge point at Culham in 2003 was estimated to be much less than 0.005 mSv (Table 4.2).

4.2 Dounreay, Highland

Radioactive waste discharges from Dounreay are made by UKAEA under authorisations granted by SEPA. The quantities discharged in 2003 were generally similar to those in 2002. Historically some solid waste was authorised for disposal in a shaft 55 metres deep at the Dounreay site but no such disposals have been made since 1977. Radioactive waste discharges from the site also include a minor contribution from the adjoining reactor site (Vulcan NRTE) which is operated by the Ministry of Defence (Procurement Executive) and the activities of AEA Technology at two facilities.

SEPA made changes to the authorisation covering UKAEA Dounreay's discharges of gaseous radioactive waste in 2003. A substantial reduction in the quantity of tritium that the site was allowed to release to the environment came into effect on 18th July 2003. The change also permitted the operation of UKAEA's new facility for collecting and disposing of liquid waste to sea. This facility, known as the Low Level Liquid Effluent Treatment Plant, will replace the old sea discharge tanks that were the subject of a SEPA enforcement notice in January 2002 (Scottish Environment Protection Agency, 2003).

Technical problems that had limited the throughput of the sodium disposal plant, which opened in 2002, were resolved in 2003. The plant is scheduled to start full operation in 2004 and will continue

Amersham plc was bought by General Electrics (GE) on 8th April 2004 and trades under the name GE Healthcare Biosciences, although Amersham plc. remains its registered name.

with the destruction of the remainder of the 1500 tons of sodium, which was used as a coolant in the Prototype Fast Reactor. UKAEA was also given regulatory consent to begin transferring radioactive liquor from its D1208 storage facility to the Dounreay Cementation Plant. The liquors will be mixed with cement to produce a solid waste that can be stored until a disposal option is available. This treatment will result in the removal of one of the major hazards on site.

Monitoring conducted in 2003 included sampling of grass and soil and terrestrial foods including meat, vegetables and cereals. As there are no dairy herds in the Dounreay area no milk samples were collected. Routine marine monitoring included sampling of seafood around the Dounreay outfall in the Pentland Firth and other materials from further afield. Beta and gamma dose rate measurements were also taken. Seafood samples from within the zone covered by a FEPA order are collected under consent granted in 1998 by the Scottish Office. The FEPA order was made in 1997 following the discovery of 34 fragments of irradiated nuclear fuel near Dounreay, by UKAEA, and prohibits the harvesting of seafoods within a 2 km radius of the discharge pipeline. The results of SEPA's monitoring are presented in Tables 4.3(a) and (b).

In June 2003, SEPA informed the Food Standards Agency that it had served an enforcement notice on UKAEA requiring them to take measures to prevent wildlife from entering the area of the site containing the solid low-level radioactive waste disposal pits. Rabbits that had entered the site could potentially be caught off the site and consumed. Reassurance monitoring of rabbits at Dounreay was carried out in the vicinity of Dounreay (Food Standards Agency, 2003b). The results are included in Table 4.3(a).

During 2003, UKAEA continued vehicle-based monitoring of local public beaches for radioactive fragments* in compliance with the requirements of the authorisation granted by SEPA. It should be noted that the agreement for vehicular access to a privately owned, publicly accessible beach ceased on 1st April 2004 and consequently, monitoring at this beach is not at present undertaken.

In 2003, 24 fragments were recovered from Sandside Bay and three from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 8.4 kBq and 280 kBq. Surveys undertaken by divers during 2003 identified 56 fragments on the offshore seabed, all of which were recovered.

The offshore work provided data on repopulation rates of particles to areas of the seabed previously cleared of particles. This work has improved the understanding of particle movements in the marine environment. The current state of knowledge is described in the Dounreay Particles Advisory Group's (DPAG)[#] Second Interim Report, which is available on SEPA's website (Dounreay Particles Advisory Group, 2003). This report also contains details of the locations where particle sampling was conducted in the area.

SEPA has commissioned the NRPB to undertake a re-assessment of potential health effects of particles. This work is scheduled to be complete in summer 2005.

The marine monitoring programme relates to the existence of four potential exposure pathways at Dounreay. Details are given in Appendix 4. The characteristics of the pathways were revised in 2003 with the results from a local habits survey.

The first potential pathway involves the internal exposure of consumers of locally collected fish and shellfish. Crabs, mussels and winkles from the outfall area were sampled. Additionally, seawater and seaweed were sampled as indicator materials. Concentrations of radionuclides in 2003 were generally similar to those for 2002. Technetium-99 in crabs, molluscs and seaweed remained at the expected levels for this distance from Sellafield. The estimated dose from consumption of fish and shellfish by high-rate consumers was less than 0.005 mSv or less than 0.5% of the annual dose limit for members of the public of 1 mSv (Table 4.2).

** 'Fragments' are considered to be fragments of irradiated fuel which are up to a few mm in diameter.*

[#] DPAG was set up in 2000 to provide independent advice to SEPA and UKAEA on issues relating to the Dounreay fragments.

The second potential pathway relates to external exposure over local beaches. Gamma dose rates measured over intertidal areas were similar to those measured in previous years. The radiation dose due to occupancy in such areas was 0.011 mSv, which was approximately 1% of the annual dose limit for members of the public of 1 mSv.

The third potential pathway relates to external exposure from the uptake of radioactivity by particulate material that has accumulated in rocky areas of the foreshore. Monitoring of spume at Oigin's Geo and measurements of gamma dose rates above areas of the foreshore remained similar to those for 2002. The radiation dose to the public from these rocky areas was less than 0.005 mSv, which was less than 0.5% of the annual dose limit for members of the public of 1 mSv.

The fourth potential pathway relates to external exposure from radioactivity adsorbed on fine particulate matter that becomes entrained on fishing gear that is regularly handled. This results in a radiation dose to the skin of the hands and forearms of fishermen, mainly from beta radiation. The critical group is represented by a small number of people who operate a fishery close to Dounreay. Measurements in 2003 indicated that this pathway was of no radiological significance.

The results for terrestrial samples and radioactivity in air are given in Table 4.3(a) and (c) and generally show low levels of radioactivity. Low levels of tritium, strontium-90, iodine-129, caesium isotopes, plutonium isotopes and americium-241 were found in samples. Taking these results together with information on consumption rates, the dose to the critical group of local terrestrial consumers, including a contribution due to weapon test fallout, was estimated to be 0.006 mSv, which was less than 1% of the annual dose limit for members of the public of 1 mSv. This includes a small contribution due to the possible consumption of local rabbits. The decrease from 2002 (0.032 mSv) was largely due to the observed decrease in iodine-129 in potatoes. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

4.3 Harwell, Oxfordshire

Discharges of radioactive wastes from Harwell continued in 2003 under a revised authorisation issued on 31st March 2003 and effective 1st May 2003. Liquid discharges were made under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site, while gaseous discharges were made to the atmosphere. The Environment Agency launched a public consultation in February 2004 to consider an application by one of the tenants on the site, Amersham plc, to vary its authorisations for disposal of radioactive waste. Further details are provided in Section 7.

The monitoring programme sampled milk, other terrestrial foodstuffs, freshwater fish, water and indicator materials together with measurements of gamma dose rates close to the liquid discharge point. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 4.1. Monitoring of the aquatic environment at Newbridge (upstream of the site) is undertaken as a control site to indicate background levels remote from nuclear establishments.

The results of measurements of radioactivity concentrations and dose rates are shown in Tables 4.4(a) and (b).

Concentrations of some nuclides, notably cobalt-60 and caesium-137, were enhanced close to the outfall for liquid discharges at Sutton Courtenay but the levels were small in terms of any radiological effect. The concentration of tritium determined in local pike was well above the LoD and higher than the value found at the control location at Newbridge. However, there are other potential sources of tritium in this area as indicated by earlier results for Newbridge (Food Standards Agency and Scottish Environment Protection Agency, 2001). The concentration of caesium-137 in pike was the same as that for 2002 (2002: 0.53 Bq kg^{-1}, 2001: 1.7 Bq kg^{-1}, 2000: 3.0 Bq kg^{-1}; 1999: 7.4 Bq kg^{-1}). Concentrations of caesium-137 and plutonium-239/240 in Lydebank Brook were similar to those in 2002.

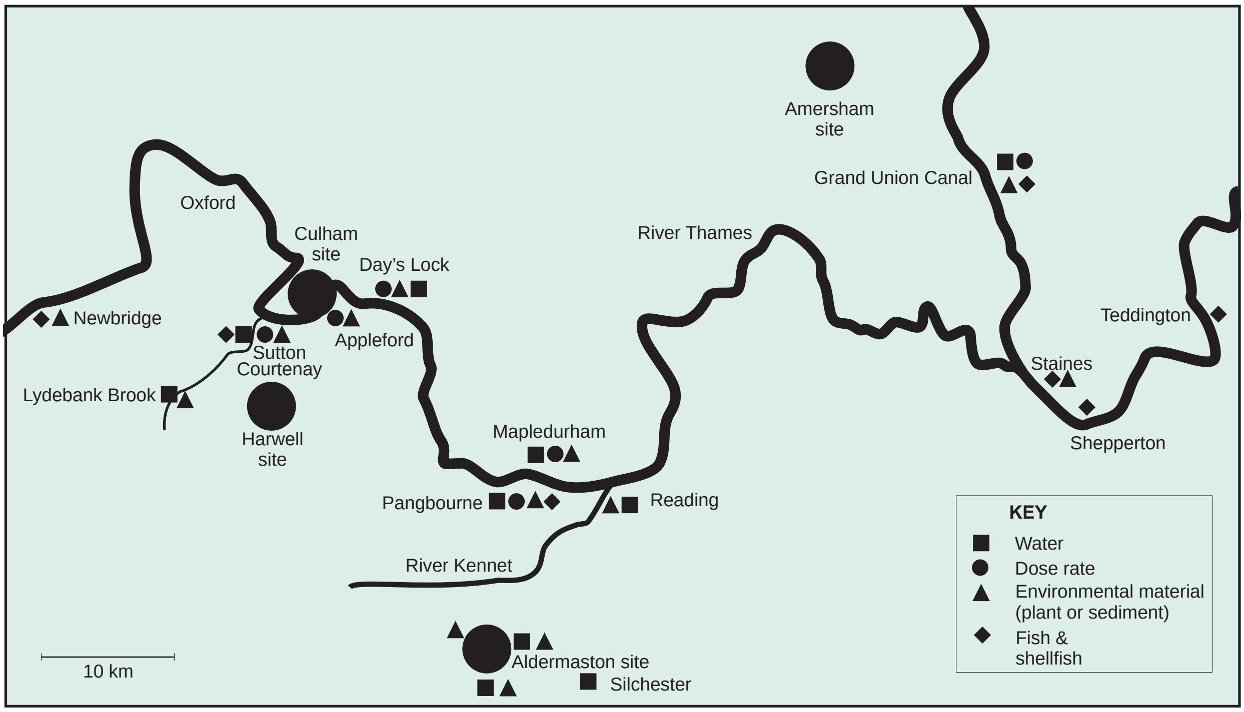

Figure 4.1 Monitoring locations at Thames sites (excluding farms)

Habits surveys have identified anglers as the critical group affected by direct discharges into the river. Their occupancy of the riverbank has been assessed to estimate their external exposures. Consumption of indigenous freshwater fish was not found to occur, but it is considered prudent to include a component in the assessment of the angler's exposure. A consumption rate of 1 kg $year^{-1}$ was selected. On this basis, and excluding a background dose rate of 0.06 μGy h^{-1}, the radiation dose to anglers in 2003 was 0.011 mSv, which was about 1% of the dose limit for members of the public of 1 mSv (Table 4.2). The tritium contribution to this dose was substantially less than 0.005 mSv. Thames river water is used as a source of drinking water. The annual dose from drinking River Thames water downstream of the discharge point was much less than 0.005 mSv.

The results of tritium and gamma spectrometry analyses of terrestrial food samples were all below detection limits. The dose to the critical group of terrestrial food consumers was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

4.4 Winfrith, Dorset

Discharges of radioactive wastes from this site continued in 2003 at the low rates typical of recent years. Following public consultation, the Environment Agency granted a new authorisation to RWE NUKEM Ltd. to dispose of radioactive wastes from the site (Environment Agency, 2003a). RWE NUKEM Ltd. are one of the tenants on the Winfrith site and the new authorisation was granted to allow them to operate a facility to decontaminate equipment used in the oil extraction industry that has become contaminated with naturally occurring radioactive material. This type of work has been carried out at Winfrith for several years. A new authorisation was required because the work was transferred from another company on the site. It came in force on 8th October 2003.

The Environment Agency also consulted on an application by NNC Ltd. to vary its authorisation for radioactive waste disposal from the Winfrith site. The authorisation is being reviewed because the NNC facility is being relocated to a new building on the site (Environment Agency, 2004a).

Liquid wastes are disposed of under authorisation to deep water in Weymouth Bay. Gaseous wastes are disposed of from various stacks on site. The monitoring programme consisted of samples of milk, crops, fruit, seafood, water and environmental materials. A habits survey was undertaken in 2003 and the results have been included in the assessment of exposures given below.

Data are presented in Table 4.5(a) and (b). Results for terrestrial samples gave little indication of an effect due to gaseous discharges. Low levels of tritium were found in surface water to the north of the site, similar to previous years. In all cases the total alpha and beta activities were below the WHO's screening values for drinking water. The critical group for gaseous discharges was terrestrial food consumers who were estimated to receive a dose of less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 4.2). Previous assessments have shown that other pathways are insignificant (Environment Agency, 2002a).

Concentrations of radionuclides in the marine environment largely continued at the low levels found in recent years. The level of technetium-99 in seaweed from Lulworth Cove, 200 Bq kg^{-1} was anomalously high and was higher than samples taken further down the English Channel at Dungeness (see Figure 3.16). It was nevertheless a hundred times lower than current levels found near Sellafield. Gamma dose rates were difficult to distinguish from natural background. The radiation dose to the critical group of fish and shellfish consumers, including a contribution from external exposure, remained low in 2003 at less than 0.006 mSv which was less than 1% of the dose limit for members of the public.

4.5 Minor sites

Three minor sites with very low levels of discharge are monitored using a small sampling programme of environmental materials. The results, given in the following sections, show that there was no detected impact on the environment in 2003 due to operation of these sites.

4.5.1 Imperial College Reactor Centre, Ascot, Berkshire

A public consultation was launched by the Environment Agency in March 2004 to consider an application from the Imperial College of Science, Technology and Medicine principally to reduce the discharge limits in the authorisation for radioactive gaseous and aqueous waste from the Reactor Centre (Environment Agency, 2004b). The reductions are being proposed to minimise the headroom between limits and actual discharges from the site. The Environment Agency expects to issue the revised authorisation in 2004.

The discharges are very low and the environmental monitoring of their effects comprises sampling of grass. Two grass samples were analysed by gamma-ray spectrometry. Both sets of results in 2003 were less than the limits of detection.

4.5.2 Imperial Chemical Industries plc, Billingham, Cleveland

The reactor at this site ceased operation on 28 June 1996. The demolition of the facility and the ancillary buildings was completed in June 2003.

Two grass samples were analysed by gamma-ray spectrometry. Both sets of results in 2003 were less than the limits of detection.

4.5.3 Scottish Universities' Research Reactor Centre, South Lanarkshire

The small research reactor at this site has been decommissioned and the waste disposed of under the authorisations granted by SEPA in 2001 for decommissioning. The site continues to hold a nuclear site licence. Routine laboratory work continues at the site, resulting in the authorised disposal of small quantities of radioactive substances. SEPA has received applications to amend the operational authorisations in line with current work.

Table 4.1. Concentrations of radionuclides in the environment near Culham, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	Total ^{3}H	^{14}C	^{32}P	^{33}P	^{35}S	^{90}Sr	^{137}Cs	^{210}Pb
Rabbit		1[F]		<5.0	24	<20	<40	<0.30	<0.90	<0.10	0.050
Freshwater	River Thames (upstream)	1	<4.0							0.13	
Freshwater	River Thames (downstream)	1	<4.0							<0.11	
Grass	1 km west of site perimeter	1		<25	<25			<10	<1.0	<7.6	
Grass		4[F]		<6.0	60	<0.87	<1.8	<1.4	0.79	<0.33	3.6
Sediment	River Thames (upstream)	1								30	
Sediment	River Thames (downstream)	1								24	
Soil	1 km west of site perimeter	1		<25	<25			<10	<1.0	4.9	
Soil		4[F]			12			<2.5	1.0	5.1	26

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{210}Po	^{226}Ra	^{232}Th	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha	Total beta
Rabbit		1[F]	0.11	0.029	0.0013	<0.00010	<0.00010	0.00010		
Freshwater	River Thames (upstream)	1							<0.063	0.26
Freshwater	River Thames (downstream)	1							0.085	<0.10
Grass	1 km west of site perimeter	1								110
Grass		4[F]	3.4	0.37	0.098	0.00035	0.0013	<0.0017		
Soil	1 km west of site perimeter	1								550
Soil		4[F]	20	23	18	0.031	0.15	0.063		

[a] *Except for freshwater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*

[F] *Measurements are made on behalf of the environment agencies unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 4.2. Individual radiation exposures – research sites, 2003

Site	Exposed population group[a]	Exposure mSv				
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water
Culham	Drinkers of river water	<0.005	-	-	-	<0.005
Dounreay	Seafood consumers	<0.005	<0.005	-	-	-
	Beach occupants	0.011	-	-	0.011	-
	Geo occupants	<0.005	-	-	<0.005	-
	Consumers of locally grown food	0.006	-	0.006	-	-
Harwell	Anglers	0.011	<0.005	-	0.011	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Winfrith	Seafood consumers	0.006	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-

[a] *Adults are the most exposed age group unless stated otherwise*

[b] *Children aged 1y*

Table 4.3(a). Concentrations of radionuclides in food and the environment near Dounreay, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{58}Co	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{134}Cs	^{137}Cs
Marine samples														
Crabs[b]	Pipeline	3		<0.52	<0.11	<0.38	0.16	<1.2	<4.4	1.0	<1.2	<0.75	<0.11	<0.11
Crabs	Pipeline inner zone	1		<0.72	<0.10	<0.37		<1.6	<7.4		<1.1	<0.14	<0.10	<0.10
Crabs	Pipeline outer zone	2		<0.20	<0.10	<0.21		<0.39	<0.68		<0.66	<0.11	<0.10	<0.18
Crabs	Strathy	3		<0.19	<0.10	<0.26		<0.37	<0.57		<0.84	<0.11	<0.10	<0.12
Crabs	Kinlochbervie	4		<0.18	<0.11	<0.25		<0.33	<0.39	5.2	<0.86	<0.11	<0.10	<0.43
Crabs	Melvich Bay	3		<0.16	<0.10	<0.20		<0.30	<0.49	1.2	<0.65	<0.10	<0.10	<0.11
Winkles	Brims Ness	4		<0.14	<0.10	<0.20	<0.10	<0.23	<0.24		<0.68	<0.10	<0.10	<0.14
Winkles	Sandside Bay	4		<0.21	<0.13	<0.34	0.16	<0.40	<0.37	14	<1.2	<0.13	<0.12	<0.22
Mussels	Echnaloch Bay	4		<0.14	<0.10	<0.21		<0.26	<0.29	26	<0.70	<0.10	<0.10	<0.13
Seaweed	Sandside Bay	4		<0.11	<0.10	<0.18		<0.15	<0.12	270	<0.50	<0.10	<0.10	<0.28
Seaweed	Brims Ness	4		<0.10	<0.10	<0.13		<0.11	<0.10		<0.33	<0.10	<0.10	<0.14
Seaweed	Kinlochbervie	4		<0.10	<0.10	<0.17		<0.14	<0.13	280	<0.47	<0.10	<0.10	<0.26
Seaweed	Burwick Pier	4		<0.12	<0.10	<0.18		<0.19	<0.25	81	<0.47	<0.10	<0.10	<0.14
Sediment	Oigins Geo	3		<0.10	<0.14	<0.22		<0.20	<0.18		<0.66	<0.10	<0.10	6.3
Sediment	Sandside Bay	4		<0.10	<0.11	<0.20		<0.15	<0.14		<0.49	<0.10	<0.10	2.5
Sediment	Rennibister	4		<0.18	<0.10	<0.38		<0.33	<0.34		<0.89	<0.15	<0.12	26
Seawater	Sandside Bay	4	<1.1	<0.10	<0.10	<0.10		<0.11	<0.13		<0.26	<0.10	<0.10	<0.10
Spume	Oigins Geo	1		<0.15	<0.10	<0.12		<0.31	<0.75		<0.37	<0.10	<0.10	3.4

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples												
Crabs[b]	Pipeline	3	<0.76	<0.14	<0.26	0.0059	0.022	0.034	<0.0076	<0.0076		
Crabs	Pipeline inner zone	1	<0.70	<0.11	<0.21			<0.11				
Crabs	Pipeline outer zone	2	<0.44	<0.11	<0.18			<0.16				
Crabs	Strathy	3	<0.51	<0.12	<0.22	<0.0013	0.050	0.0041	<0.00041	<0.00041		
Crabs	Kinlochbervie	4	<0.57	<0.12	<0.24	<0.0028	0.0062	0.0048	<0.00042	<0.00042		
Crabs	Melvich Bay	3	<0.41	<0.10	<0.17	<0.0016	0.0088	0.0054	<0.00045	<0.00045		
Winkles	Brims Ness	4	<0.44	<0.11	<0.19	0.026	0.12	0.018	<0.00012	<0.00012		
Winkles	Sandside Bay	4	<0.71	<0.16	<0.30	0.017	0.078	0.071	0.0011	<0.00086		
Mussels	Echnaloch Bay	4	<0.45	<0.11	<0.19	0.026	0.16	0.071	0.0013	0.0030		
Seaweed	Sandside Bay	4	<0.38	<0.13	<0.20			<0.59			8.5	420
Seaweed	Brims Ness	4	<0.24	<0.10	<0.13			<0.14				
Seaweed	Kinlochbervie	4	<0.33	<0.10	<0.16			<0.15				
Seaweed	Burwick Pier	4	<0.33	<0.10	<0.16			<0.14				
Sediment	Oigins Geo	3	<0.60	<0.16	<0.77	1.8	7.0	4.4	<0.033	<0.033		
Sediment	Sandside Bay	4	<0.43	0.53	0.45	2.5	10	11	<0.025	0.11		
Sediment	Rennibister	4	<0.82	<0.18	0.90			<0.38				
Seawater	Sandside Bay	4	<0.16	<0.10	<0.10			<0.10				
Spume	Oigins Geo	1	<0.23	<0.10	<0.10			0.22				

Table 4.3(a). continued

Material	Selection[c]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{90}Sr	^{95}Nb	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu
Terrestrial samples											
Barley		1	<5.0	0.62			<0.20				
Cabbage		1	7.1	0.37	<0.06	<0.21	<0.11	<0.05	0.08	<0.15	
Potatoes		1	<5.0	0.12	<0.05	<0.22	<0.05	<0.05	<0.05	<0.15	
Rabbit		2[F]			<0.60	<4.8		<0.35	<0.85	<2.7	
Rabbit	max				<0.90	<6.8		<0.40	<1.1	<3.2	
Rosehips		1	<5.0	1.6	<0.18	<0.34	<0.15	<0.05	2.5	<0.25	
Turnips		1	<5.0	0.95	<0.14	<0.43	<0.11	<0.05	0.10	<0.26	
Grass		6	<5.0	0.76	<0.21	<0.41	<0.12	<0.05	<0.15	<0.29	
Grass	max			1.6	<0.33	<0.48	<0.19		0.37	<0.33	
Soil		6	<6.2	<1.4	<0.51	<0.54	<0.15	<0.06	17	<0.53	0.81
Soil	max		<7.6	3.6	<1.6	<0.71	<0.18	<0.08	26	<0.74	0.99

Material	Selection[c]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial samples								
Barley		1				<0.00065	<0.00065	<0.050
Cabbage		1				<0.00062	0.0017	<0.050
Potatoes		1				<0.00082	<0.00082	<0.050
Rabbit		2[F]	0.0063	<0.0023	0.0049	<0.00065	0.00025	<0.0028
Rabbit	max		0.010	<0.0027	0.0052	0.0011	0.00040	<0.0029
Rosehips		1	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Turnips		1				<0.00070	0.0014	<0.050
Grass		6	<0.097	<0.040	<0.089	<0.012	<0.013	<0.043
Grass	max		0.15	<0.050	0.14	<0.050	<0.050	<0.050
Soil		6	22	<1.2	21	<0.066	<0.31	<0.44
Soil	max		54	2.7	51	<0.15	0.79	0.94

[a] *Except for water and seawater where units are Bq l^{-1}, and for soil and sediment where dry concentrations apply*
[b] *The concentration of ^{14}C was 48 Bq kg^{-1}*
[c] *Data are arithmetic means unless stated as 'Max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean is also the maximum.*
[F] *Measurements are made on behalf of the Food Standards Agency.*

Table 4.3(b). Monitoring of radiation dose rates near Dounreay, 2003

Location	Material or ground type	No. of sampling observa-tions	μGy h-1
Mean gamma dose rates at 1m over substrate			
Sandside Bay	Sand	1	0.11
Sandside Bay	Winkle bed	4	0.10
Oigin's Geo	Spume/sludge	4	0.17
Melvich	Salt Marsh	1	0.085
Melvich	Sand	1	0.062
Strathy	Sand	1	0.060
Thurso	Riverbank	1	0.10
Achreregan Hill	Soil	1	0.074
Strathy Park	NA	1	0.091
Archvarasdal	NA	1	0.087
Thurso Park	Soil	1	0.093
Borrowston Mains	Soil	1	0.098
East of Dounreay	Soil	1	0.095
Castletown Harbour	NA	1	0.077
Mean beta dose rates			μSv h-1
Sandside Bay	Sediment	4	<1.0
Oigin's Geo	Surface sediment	4	<1.0
Brims Ness	Surface sediment	4	<1.0

NA Not available

Table 4.3(c). Radioactivity in air near Dounreay, 2003

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m-3		
		^{137}Cs	Total alpha	Total beta
Shebster	11	<0.010	<0.0063	0.14
Reay	12	<0.010	<0.0054	0.11
Balmore	12	<0.024	<0.0072	0.14

Table 4.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{60}Co	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total alpha	Total beta
Freshwater samples											
Pike	Outfall (Sutton Courtenay)	1	63	48	<0.04	0.53			<0.05		
Pike	Newbridge	1	<25	<25	<0.03	<0.03	0.000016	0.000028	0.000071		
Pike	Staines	1	<25	<25	<0.05	0.13			<0.13		
Pike	Shepperton	1	<25	<25	<0.04	0.14			<0.04		
Pike	Teddington	1	<25	<25	<0.05	0.14			<0.05		
Flounder	Beckton	1		<25	<0.04	0.18			<0.12		
Nuphar lutea	Newbridge	1		<25	<0.05	<0.05			<0.04		
Nuphar lutea	Staines	1		<25	<0.05	<0.04			<0.03		
Mud	Position 'E' [b]	2			3.7	420			<6.4		
Sediment	Appleford	4[E]			<0.50	15	<0.67	<0.32		140	470
Sediment	Outfall (Sutton Courtenay)	4[E]			<0.81	25	<0.40	0.67		200	410
Sediment	Day's Lock	4[E]			<0.42	11	<0.54	1.1		190	410
Sediment	Lydebank Brook	4[E]			<0.73	9.0	<0.66	0.75		150	360
Freshwater	Day's Lock	4[E]		<4.0		<0.21	<0.19			<0.045	0.31
Freshwater	Lydebank Brook	4[E]		<4.0	<0.19	<0.25				<0.035	0.15
Freshwater	R Thames (above discharge point)	4[E]		<4.0	<0.18	<0.20				<0.068	0.41
Freshwater	R Thames (below discharge point)	4[E]		<4.0	<0.19	<0.22				<0.047	0.26

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			Organic ^{3}H	^{3}H	^{60}Co	^{134}Cs	^{137}Cs
Terrestrial samples							
Milk		4	<3.7	<3.7	<0.26	<0.24	<0.26
Milk	max		<3.8	<3.8	<0.30	<0.28	<0.30
Apples		1	<4.0	<4.0	<0.30	<0.30	<0.30
Blackberries		1	<4.0	<4.0	<0.20	<0.20	<0.20
Cabbage		1	<4.0	<4.0	<0.30	<0.30	<0.30
Carrots		1	<4.0	<4.0	<0.20	<0.20	<0.30
Honey		1		<6.0	<0.20	<0.20	<0.20
Potatoes		1	<4.0	<4.0	<0.30	<0.20	<0.20

[a] *Except for milk where units are Bq l^{-1} and for sediment where dry concentrations apply*

[b] *Near the outfall*

[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected maxima. If no 'max' is given the mean is also the maximum.*

[d] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency.*

Table 4.4(b). Monitoring of radiation dose rates near Harwell, 2003

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m			
Appleford	Mud	1	0.063
Appleford	NA	1	0.067
Sutton Courtenay	Mud and grass	1	0.073
Sutton Courtenay	Soil	1	0.085
Position "E"[a]	Soil	2[F]	0.080
Day's Lock	Mud	1	0.066
Day's Lock	Mud and grass	1	0.061

[a] *Near the outfall*

NA Not available

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 4.5(a). Concentrations of radionuclides in food and the environment near Winfrith, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{14}C	^{60}Co	^{65}Zn	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu
Marine samples									
Cod	Weymouth Bay	2		<0.05	<0.14		0.22		
Plaice	Weymouth Bay	2		<0.05	<0.15		0.08		
Crabs	Chapman's Pool	1		0.26	<0.13		<0.05	0.00013	0.00055
Crabs	Lulworth Banks	1	28	<0.14	<0.31		<0.11	0.00026	0.0012
Pacific Oysters	Poole	1		<0.04	<0.11		<0.04		
Cockles	Poole	1		0.48	<0.08		0.05		
Whelks	Poole	1		0.22	<0.11		<0.04	0.00045	0.0024
Razor shells	Weymouth Bay	1		0.17	<0.17		<0.06		
Fucus serratus	Kimmeridge	2		0.75	<0.26	0.99	<0.09		
Fucus serratus	Bognor Rock	2		0.45	<0.16	0.98	<0.05		
Seaweed	Lulworth Cove	2[E]		<1.6		200	<0.91		
Seawater	Arish Mell	2[E]		<0.21			<0.21		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Total alpha	Total beta
Marine samples							
Cod	Weymouth Bay	2	<0.12				
Plaice	Weymouth Bay	2	<0.14				
Crabs	Chapman's Pool	1	0.0014	*	*		
Crabs	Lulworth Banks	1	0.0029	0.00014	*		
Pacific Oysters	Poole	1	<0.12				
Cockles	Poole	1	<0.09				
Whelks	Poole	1	0.0026	*	0.000043		
Razor shells	Weymouth Bay	1	<0.16				
Fucus serratus	Kimmeridge	2	<0.34				220
Fucus serratus	Bognor Rock	2	<0.17				
Seaweed	Lulworth Cove	2[E]	<1.5				
Seawater	Arish Mell	2[E]	<1.2			<2.9	<8.0

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		4	<3.7	<3.7	19	<0.29	<0.29		
Milk	max		<4.0	<4.0	21	<0.33	<0.30		
Apples		1	<4.0	<4.0	14	<0.30	<0.30		
Cabbage		1	<4.0	<4.0	12	<0.30	<0.30		
Carrots		1	<4.0	<4.0	14	<0.40	<0.30		
Gooseberries		1	<4.0	<4.0	13	<0.20	<0.20		
Honey		1		<6.0	87	<0.10	0.20		
Potatoes		1	<4.0	<4.0	25	<0.20	<0.30		
Grass		2	<4.5	<4.5	9.0	<0.25	0.40		
Grass	max		<5.0	<5.0	11	<0.30			
Sediment	North of site	2[E]				<0.88	11	<100	<100
Sediment	R Frome (upstream)	2[E]				<0.58	<0.86	<100	<100
Sediment	R Frome (downstream)	1[E]				<0.45	3.0	140	140
Sediment	R Win, East of site	2[E]				<0.70	<1.6	<280	<250
Freshwater	North of site	2[E]		18		<0.17	<0.29	0.025	0.10
Freshwater	R Frome (upstream)	2[E]		<4.0		<0.36	<0.26	<0.025	<0.11
Freshwater	R Frome (downstream)	2[E]		<4.0		<0.28	<0.26	<0.025	<0.10
Freshwater	R Win, East of site	2[E]		<5.0		<0.19	<0.28	<0.020	<0.13

* *Not detected by the method used.*

[a] *Except for milk and freshwater where units are Bq l^{-1} and for sediment where dry concentrations apply.*

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime.*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 4.5(b). Monitoring of radiation dose rates near Winfrith, 2003

Location	Material or ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Weymouth Bay	Pebbles	1	0.055
Red Cliffe Point to Black Head	Pebbles	1	0.053
Osmington Mills	Rock	1	0.063
Ringstead Bay	NA	1	0.054
Durdle Door	Pebbles	1	0.053
Lulworth Cove	Pebbles	1	0.061
Kimmeridge Bay	Pebbles	1	0.094
Swanage Bay 1	Sand	1	0.055
Swanage Bay 2	Sand	1	0.061
Swanage Bay 3	Sand	1	0.053
Poole Harbour	Sand	1	0.051

NA Not available

5. NUCLEAR POWER STATIONS

This section considers the effects of discharges from 13 locations where nuclear power stations were operating or undergoing defuelling or decommissioning during 2003. Calder Hall is considered in Section 3 because of its co-location with the reprocessing works at Sellafield. The operating companies were British Energy Generation Ltd., British Energy Generation (UK) Ltd., Magnox Electric (a wholly owned subsidiary of BNFL plc.) and BNFL. The ownership of each power station is given in Appendix 1. Estimates of dose discussed in this section do not include a component from direct radiation from the site.

5.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire

Berkeley Power Station ceased electricity generation in March 1989, but radioactive wastes have been and are still generated by decommissioning operations. In addition, there is a component of the discharge from the operation of the adjoining Berkeley Centre. Berkeley Centre acts as the headquarters for the generating Magnox stations and provides support functions including radiochemical laboratories used for analysis of liquid effluents and environmental samples. The Oldbury Power Station has continued operation and because the effects of both sites are on the same area, Berkeley and Oldbury are considered together for the purposes of environmental monitoring. Liquid radioactive wastes are discharged to the Severn estuary.

A habit survey has established that the two potentially critical pathways for public radiation exposure in the aquatic environment were internal radiation following consumption of locally-caught fish and shellfish, and external exposure from occupancy of muddy intertidal areas. Therefore, samples of seafood were analysed and gamma dose rates are monitored. Measurements of tritium in seafood were made in order to monitor the additional local effects of discharges from a radiopharmaceutical plant in Cardiff (see Section 7). In addition, measurements of external exposure are supported by analyses of intertidal mud. The main focus for terrestrial sampling was on the tritium, carbon-14 and sulphur-35 content of milk, crops and fruit. Local surface water samples were also taken and analysed. Oldbury reported to the Environment Agency that it had exceeded a weekly level for gaseous discharge of carbon-14 in February 2003. The Food Standards Agency organised early collection and analysis of local milk samples to establish whether further action was needed. There were no increases in the levels detected and no further action was required.

Data for 2003 are presented in Tables 5.1(a) and (b). Where comparisons can be drawn, gamma dose rates and concentrations in the aquatic environment were generally similar to those in recent years. Most of the artificial radioactivity detected was due to tritium and radiocaesium. Concentrations of radiocaesium represent the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. The trend in caesium-137 concentrations in sediment is shown in Figure 5.1. Relatively high concentrations of tritium were detected in fish and shellfish and these were mainly due to discharges from Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance. The total dose to the critical group of fish and shellfish consumers was estimated to be 0.007 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 5.2). This includes external radiation and a component due to the tritium originating from Cardiff.

Sulphur-35 was detected at very low levels in some of the terrestrial food samples monitored. Carbon-14 was detected in locally produced foods, at levels slightly above background values. Total alpha and beta concentrations in surface waters were less than the WHO screening levels. An atmospheric dispersion computer model has been used to estimate the concentrations of radionuclides in air due to gaseous releases from the Oldbury site (Appendix 2). The critical group dose from gaseous releases including consumption of foodstuffs was estimated to be less than 0.005 mSv, which was less than 0.5% of the dose limit. The reduction from 0.013 mSv in 2002 was largely due to reduced discharges of argon-41.

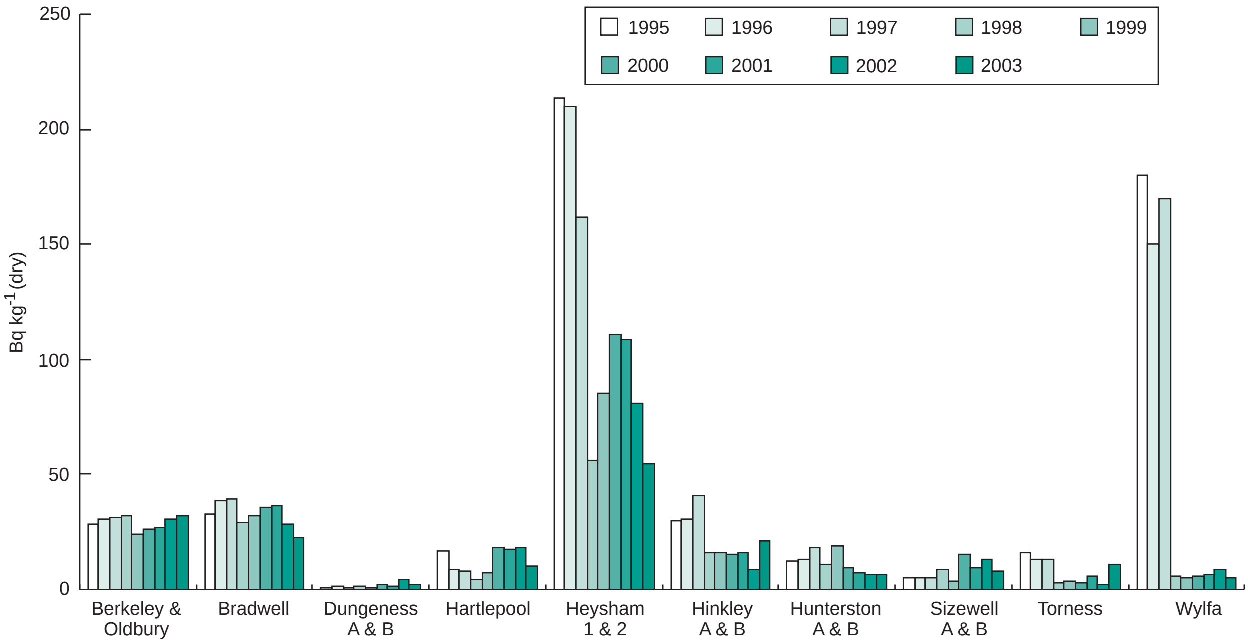

Figure 5.1 Caesium-137 concentration in sediments near nuclear power stations

5.2 Bradwell, Essex

This Magnox power station stopped electricity production in March 2002 after 40 years of operation and is now undergoing defuelling prior to decommissioning**.** It is authorised to discharge gaseous wastes to the local environment and liquid wastes to the estuary of the River Blackwater. Terrestrial sampling is similar to that for other power stations including analyses of milk and crop samples for tritium, carbon-14 and sulphur-35. Samples of water are also taken from a coastal ditch. Aquatic sampling was directed at consumption of locally caught fish and shellfish and external exposure over intertidal sediments. Monitoring included the commercial oyster fishery of importance in the northern part of the estuary. *Fucus vesiculosus* was analysed as an environmental indicator material and leaf beet was collected because it is eaten locally and grows in areas that become tidally inundated.

Measurements for 2003 are summarised in Tables 5.3(a) and (b). Low concentrations of artificial radionuclides were detected in aquatic materials as a result of discharges from the station, discharges from Sellafield and weapons testing. Apportionment of the effects of these sources is difficult because of the low levels detected; concentrations were similar to those for 2002 (Figure 5.1). The technetium-99 detected in seaweeds at Bradwell and Waterside was likely to be due to the long distance transfer of Sellafield derived activity, though there may be a small contribution from discharges from the reprocessing plant at Cap de la Hague. The total beta activity in water from the coastal ditch continued to be enhanced above background levels and was in excess of the WHO screening level of 1 Bq l^{-1}. The ditch is not known to be used as a drinking water source. Gamma dose rates on beaches were difficult to distinguish from natural background. The critical group of seafood consumers received 0.013 mSv, mostly due to the effects of external exposure, which was less than 2% of the dose limit for members of the public of 1 mSv (Table 5.2).

Concentrations of activity were also low in terrestrial samples. There was nevertheless an indication that tritium and carbon-14 levels had been slightly enhanced by the operation of the power station. Low concentrations of sulphur-35 were also detected in some samples. The critical group dose was estimated to be less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv.

5.3 Chapelcross, Dumfries and Galloway

In June of 2004, BNFL formally notified SEPA that it was ceasing electricity generation at Chapelcross and that operations on site would now concentrate on defuelling and decommissioning the power station. There are four Magnox-type reactors at Chapelcross, which were operated by BNFL. Since 1980, the Chapelcross Processing Plant, which produces tritium, also operated on this site. Gaseous wastes from the site are discharged to the local environment and liquid waste is discharged to the Solway Firth under authorisation from SEPA. Habits surveys have been used to investigate aquatic exposure pathways. The most recent survey confirmed the existence of local fishermen who eat large quantities of local seafood and are exposed to external radiation whilst tending stake nets. A second group was identified prior to the survey. They consisted of wildfowlers who were exposed to external radiation whilst on salt marshes. Wildfowling has reduced in the area and is currently only of minor importance. Nevertheless, this situation could change and will be kept under review. Samples of seawater and *Fucus vesiculosus*, as useful environmental indicators, were collected in addition to seafood, sediments and dose rates. Terrestrial monitoring was expanded in 2000 and a greater number of samples are now collected and analysed. Monitoring of air at three locations was added to the programme in 2001.

The results of routine monitoring in 2003 are presented in Tables 5.4(a), (b) and (c). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to the effects of Sellafield discharges and are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides and gamma dose rates in intertidal areas remained at similar levels to those detected in recent years.

The dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.037 mSv in 2003 which was less than 4% of the dose limit for members of the public of 1 mSv (Table 5.2). Measurements of the contact beta dose-rate on fishing nets were below the LoD. A consideration of the discharges from Chapelcross indicates that they contribute a very small fraction of the total dose to the local population; the greater proportion of the dose can be attributed to the emissions from Sellafield.

Since 1992, a number of particles have been found at the end of the discharge outfall. Most of these particles are limescale and originate from deposits within the pipeline. Monitoring of this area continues, which in 2003 resulted in 21 items with radioactivity above background being found and removed. This compares with three items in 2002, one in 2001 and three in 2000. The site has undertaken to build a new filter house, which once complete should eliminate the current problem of limescale escaping from the discharge outfall.

Concentrations of radionuclides in milk and grass were generally similar to those observed in 2002. The more extensive dataset now available on terrestrial foods shows that the effects of discharges from Chapelcross can be seen in the levels of tritium and sulphur-35 in a range of foods. The annual dose to the critical group of terrestrial food consumers, who are also exposed to external radiation from argon-41, was estimated to be 0.020 mSv, which was 2% of the dose limit for members of the public of 1 mSv. The annual dose contribution from argon-41, calculated from an atmospheric transport model (see Appendix 2) was 0.005 mSv compared with 0.032 mSv in 2002. The reduction is largely due to reduced discharges of argon-41 from the site. The remaining 0.015 mSv was from the consumption of terrestrial foods. The doses from consumption of terrestrial foods include contributions due to weapon test and Chernobyl fallout. Measured concentrations of radioactivity in air at locations near to the site were very low (Table 5.4(c)). The annual dose from inhaling air containing caesium-137 at these concentrations was estimated to be much less than 0.005 mSv.

5.4 Dungeness, Kent

There are two separate ‘A’ and ‘B’ nuclear power stations on this site; the ‘A’ station is powered by Magnox reactors and the ‘B’ station by advanced gas-cooled reactors (AGRs). Discharges are made via separate but adjacent outfalls and stacks, and for the purposes of environmental monitoring these are considered together.

Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples. Marine monitoring included gamma and beta dose rate measurements and analysis of seafood and sediments.
On two occasions in 2003 Dungeness operators notified the Environment Agency that weekly advisory reporting limits for gaseous discharge of carbon-14 had been or were likely to be exceeded. In both cases, milk samples from the nearest dairy farms were collected and analysed in advance of the normal programme. No effects related to the releases were detected from the December samples but in April concentrations in milk increased to 30 Bq l^{-1} (the average for the rest of the year for the farm in question was roughly 15 Bq l^{-1}). However, this would have negligible effects on the annual radiation dose and no further action was necessary.

The results of monitoring for 2003 are given in Tables 5.5(a) and (b). Concentrations of radiocaesium in marine materials are attributable to discharges from the stations and to weapon test fallout with a long distance contribution from Sellafield. Apportionment is difficult at these low levels. The small concentrations of transuranics in whelks and mud were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood. Gamma and beta dose rates were difficult to distinguish from the natural background. The critical group was represented by local bait diggers who also eat fish and shellfish. Their radiation dose was low at 0.007 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 5.2).

Activity concentrations in many terrestrial foods were close to the limits of detection. Levels of carbon-14 were generally within the range of activity concentrations observed for background, but some enhancements were observed particularly in peas. Low concentrations of tritium and sulphur-35 were detected in some samples. Concentrations of total alpha and beta activity in freshwater were within WHO screening levels. Relatively high concentrations of argon-41 in air were predicted for this site (Appendix 2). The maximum dose due to gaseous disposals was received by adults. Their dose in 2003 was estimated to be 0.11 mSv, which was 11% of the dose limit for members of the public. Most of this was due to argon-41; the contribution from food pathways was less than 0.005 mSv.

5.5 Hartlepool, Cleveland

This station is powered by twin AGRs. A habits survey has examined the potential pathways for radiation exposure due to liquid effluent disposals and this established that exposures could be represented by consumption of local fish and shellfish and external irradiation whilst digging for bait. Technetium analysis in *Fucus vesiculosus* is used as a specific indication of the far-field effects of disposals to sea from Sellafield. A selection of terrestrial foods including milk is sampled in surveillance of gaseous disposals.

Hartlepool exceeded its Quarterly Notification Limit (QNL) for discharge of sulphur-35 to atmosphere twice in 2003 and once for argon-41 to atmosphere. Milk samples collected from four surrounding farms and analysed for sulphur-35 found no increases above normal levels.

Results of the monitoring programme carried out in 2003 are shown in Tables 5.6(a) and (b). The effects of gaseous disposals from the site were not easily detectable in foodstuffs, though some enhancements of carbon-14 levels in terrestrial samples were apparent. The alpha and beta activities in freshwater were less than the WHO screening levels. The critical group dose in 2003 was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.2).

Although observed in the past, high levels of tritium in seawater were not observed in 2003. Levels of technetium-99 in seaweed *(Fucus vesiculosus)* were at a similar level to the peak observed in 1998 (see also Figure 3.16). They remain nevertheless at less than 1% of the equivalent concentrations near Sellafield. Concentrations of radiocaesium and transuranics were mainly due to disposals from

Sellafield and to weapon test fallout. The enhanced dose rates at Paddy's Hole are believed to be due to waste slag from local steel works, used historically in sea defences, or sediments containing enhanced levels of gamma-ray-emitting natural radionuclides. The critical occupancy group does not spend time at Paddy's Hole. The radiation dose to local fish and shellfish consumers, including external radiation, was low, at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

5.6 Heysham, Lancashire

This establishment comprises two separate nuclear power stations both powered by AGRs. Disposals of radioactive waste from both stations are made under authorisation via adjacent outfalls in Morecambe Bay and stacks but for the purposes of environmental monitoring both stations are considered together. The monitoring programme for the effects of gaseous disposals was similar to that for other power stations. That for liquid disposals was also similar, including sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates, but for completeness the data considered in this section includes all of that for Morecambe Bay. A substantial part of the programme is therefore in place in order to monitor the effects of Sellafield disposals.

The results for 2003 are given in Tables 5.7(a) and (b). In general, similar levels to those for 2002 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Levels of tritium in plaice and mussels were not sufficiently high to demonstrate that any originated as a result of discharges from Heysham. Concentrations of technetium-99 in marine samples remained at the higher levels typical of recent years. They were caused by discharges from Sellafield. Concentrations of caesium-137 in sediments were also largely due to Sellafield (Figure 5.1). The radiation dose in 2003 to the critical group of fishermen, including a component due to external radiation, was 0.075 mSv, which is well within the dose limit for members of the public of 1 mSv (Table 5.2). There was a small increase in the dose compared with 0.066 mSv in 2002.

The effects of gaseous disposals were also difficult to detect in 2003. Small enhancements of concentrations of carbon-14 were apparent in some samples. The critical group dose was estimated to be 0.006 mSv which was less than 1% of the dose limit for members of the public of 1 mSv.

Additional sampling of milk took place in October 2003 in response to an unusual occurrence on site as both reactors were tripped together, although no QNLs were breached. Analysis of tritium and sulphur-35 showed levels in milk below the LoD. For carbon-14, the mean concentration was about 30 Bq l^{-1} to be compared with an expected value of 20 Bq l^{-1}. This level of increase has a very low radiological significance and negligible effects on consumer's dose.

5.7 Hinkley Point, Somerset

At this establishment, there are two separate 'A' and 'B' nuclear power stations; the 'A' station comprises Magnox reactors and the 'B' station AGRs. Magnox Electric announced the closure of Hinkley Point 'A' in May 2000 and the station began defuelling in 2002. Decommissioning began in 2004. Environmental monitoring covers the effects of the two power stations together. Analyses of milk and crops were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were also carried out. Measurements of tritium and carbon-14 are made primarily to establish the local effects of discharges from the Amersham plc plant at Cardiff. A special air sampling exercise was undertaken near Hinkley Point at Burnham-on-Sea as a result of local concerns about resuspension of sediment from the estuary mud flats.

The environmental results for 2003 are presented in Tables 5.8 (a) and (b). Where results can be compared, the concentrations observed in seafood and other materials from the Bristol Channel were generally similar to those in 2002 (see also Figure 5.1). The relatively high level of tritium in seawater in 2002 was probably due to one of the samples being taken in coincidence with a specific discharge from the 'B' station. This was not observed in 2003, and levels of seawater were 18 Bq l^{-1}. Further information of tritium levels in seawater from the Bristol Channel is given in Section 9. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors are Sellafield, weapons test and Chernobyl fallout. Apportionment is generally difficult at the low levels detected. However, the majority of tritium and carbon-14 in seafood was likely to have been due to disposals from Amersham plc, Cardiff. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment, measured using portable instruments, were similar to those for 2002. The critical group of local fishermen was estimated to receive a dose of 0.013 mSv which was less than 2% of the dose limit for members of the public of 1 mSv (Table 5.2). This estimate includes the effects of discharges of tritium and carbon-14 from Cardiff.

Results for 2003 indicate a small enhancement of radioactivity levels due to disposals of gaseous wastes. Activity concentrations of tritium and gamma emitters in terrestrial materials were all below or close to the limits of detection. Concentrations of sulphur-35 showed the effects of the power stations and some of the concentrations of carbon-14 were higher than the default values used to represent background levels (Appendix 6). An unusual dry cloth result detected by the operators in November 2003 triggered supplementary sampling of milk by the Food Standards Agency. The radionuclide of interest was chromium-51. None was detected in the milk samples. No further action was considered necessary. Freshwater contained alpha and beta activities less than WHO screening levels. The estimated critical group dose due to radioactivity in the terrestrial environment was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

The results of the special air monitoring exercise are reported elsewhere (Butcher, 2004). Deployments at two sites in Burnham-on-Sea took place over a six month period. No man-made radionuclides were detected by gamma spectrometry. Concentrations of plutonium isotopes were determined to be below the LoD.

5.8 Hunterston, North Ayrshire

At this location there are two separate nuclear power stations – Hunterston 'A' and Hunterston 'B'. Hunterston 'B' is owned and operated by British Energy while Hunterston 'A' is owned by BNFL. Hunterston 'A' was powered by twin Magnox reactors and Hunterston 'B' is powered by a pair of AGRs. Hunterston 'A' ceased power production at the end of March 1990. Authorised liquid discharges are made to the Firth of Clyde by Hunterston 'B' via the stations' cooling water outfall. Authorised liquid discharges from Hunterston 'A' are also made via the same outfall. Gaseous discharges are made via separate discharge points from the Hunterston 'A' and Hunterston 'B' stations.

Environmental monitoring in the area considers the effects of both sites together. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials. The scope of the terrestrial monitoring programme was enhanced in 2000 and includes the analysis of a comprehensive range of wild and locally produced foods. In addition, air, grass and soil are sampled to provide background information. The most recent habits survey undertaken in 2001 resulted in three critical groups being identified: seafood consumers, terrestrial food consumers and a group of professional shellfish collectors who have a high occupancy time over inter-tidal areas. The results from the monitoring programme are used to quantify the dose to each critical group.

The results of monitoring in 2003 are shown in Tables 5.9(a), (b) and (c). The concentrations of artificial radionuclides in the marine environment are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. The reported concentrations of technetium-99 from Sellafield in *Nephrops* and lobsters decreased substantially in 2003 and were less than half the levels seen in 2002. Small concentrations of activation products such as manganese-54 that are likely to have originated from the site were also detected but were of negligible radiological significance. In 2003, the dose to the critical group from consumption of fish and shellfish was less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.2). Approximately half of the dose to the critical group was from technetium-99 in seafood.

The dose to a separate critical group of shellfish collectors who use local beaches was 0.007 mSv or less than 1% of the dose limit.

The concentrations of radionuclides in air, milk, vegetables and fruit were generally low and, where comparisons can be drawn, similar to concentrations in previous years. The radiation dose to the critical group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout, was estimated to be 0.014 mSv which was less than 2% of the dose limit for members of the public of 1 mSv (Table 5.2). The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

5.9 Sizewell, Suffolk

At this establishment there are two stations. The ‘A’ station has two Magnox reactors whilst the ‘B’ station has a Pressurised Water Reactor. The ‘B’ station began operation in 1995. Authorised discharges of radioactive liquid effluent from both power stations are made via adjacent outfalls to the North Sea. Gaseous wastes are discharged via separate stacks to the local environment. Environmental monitoring for the power stations is considered in a single programme covering the area likely to be affected. The results of monitoring in 2003 are shown in Tables 5.10 (a) and (b).

In the aquatic programme, analysis of seafood, sediment, sand and seawater, and measurements of gamma dose rates in intertidal areas were undertaken. Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield discharges and to weapons testing. Tritium levels in seafood were low. In 2003, the radiation dose to local fish and shellfish consumers was low, at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.2). Measured gamma dose rates were difficult to distinguish from the natural background. The assessment includes a contribution for external exposure based on a calculation using radionuclide concentrations in sediment.

Gamma-ray spectrometry and analysis of tritium, carbon-14 and sulphur-35 in milk, crops and fruit generally showed very low levels of artificial radionuclides near the power stations in 2003. Highest levels were found in blackberries. Some milk was analysed on a weekly basis to investigate if the higher than normal releases that occurred in June 2003 of tritium and in September 2003 of carbon-14 resulted in any unusual levels of activity in the samples. No activity was detected. Concentrations of activity in local freshwater were all low. The estimated dose to the critical group of consumers eating local foods was less than 0.005 mSv. However, making an allowance for radionuclide concentrations in air using the methods and data in Appendix 2, the critical group dose in 2003 was 0.057 mSv or about 6% of the dose limit for members of the public of 1 mSv.

5.10 Torness, East Lothian

This station, which is powered by two AGRs, came into operation at the end of 1987. A review of the monitoring programme at this site was undertaken in 2000, and resulted in increased sampling of milk, vegetables, fruit, seafood, seawater, seaweed and soil. Various plants were monitored as environmental indicator materials and air sampling was introduced in 2001 to investigate the inhalation pathway. Measurements were also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and beta dose rates on fishing gear.

In February 2002, SEPA served an Enforcement Notice on the operator for discharging unsampled liquid radioactive waste to sea. This incident occurred in October 2001. The operator took adequate steps to comply with the notice. In January 2003, the operator pleaded guilty to this offence. The incident was very unlikely to have resulted in any harm to the public or damage to the environment.

In November 2003, SEPA served an Enforcement Notice on the operator for disposing of a small quantity of solid radioactive waste with non-radioactive solid waste to landfill. It should be noted that disposal of radioactive waste to landfills does occur but only in accordance with suitable certificates of authorisation. SEPA regularly authorises the disposal of radioactive waste to landfills from other industries, such as universities and research agencies. The Government in its White Paper Cm 2919 stated that the nuclear industry should not be encouraged to make greater use of this disposal route. Therefore, sites not already authorised to dispose of radioactive waste in this way are not able to use this route. Torness is one such site. The operator has taken adequate steps to prevent a reoccurrence and comply with the conditions of the notice. The radioactive waste was of very low activity and it was unlikely to have caused any harm to the public or the environment.

The results of this monitoring in 2003 are shown in Tables 5.11(a), (b) and (c). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout, although trace levels of activation products were detected which were likely to have originated from the station. The dose to fish and shellfish consumers (the critical group) was 0.005 mSv, which was 0.5% of the dose limit for members of the public of 1 mSv (Table 5.2).

Beta radiation from fishermen’s nets and pots was below the LoD. Gamma dose rates on beaches were generally indistinguishable from natural background though data for St Abbs and Dunbar were higher. The effects of discharges from the power station were seen in low levels of tritium and sulphur-35 in terrestrial foods and environmental indicator materials. The dose to the critical group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout was 0.019 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv. The increase from 0.007 mSv in 2002 was largely due to the inclusion of americium-241 in the assessment due to its detection at low levels in terrestrial samples. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

5.11 Trawsfynydd, Gwynedd

This station is being decommissioned but low level discharges continued during 2003 under authorisations granted by the Environment Agency. Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK terms. Monitoring is carried out on behalf of the Welsh Assembly Government. The aquatic monitoring programme is directed at consumers of freshwater fish caught in the lake and external exposure over the lake shoreline; the important radionuclides are radiocaesium and, to a lesser extent, strontium-90. It is also directed at freshwater and sediment analysis. Habits surveys have established that species of fish regularly consumed are brown trout, rainbow trout and a small amount of perch. Perch and most brown trout are indigenous to the lake but rainbow trout are introduced from a hatchery. Because of the limited period that they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than indigenous fish.

The results of the terrestrial programme, including those for local milk, crops and environmental indicator materials, as well as the aquatics programme, are shown in Tables 5.12 (a) and (b). Concentrations of activity in all terrestrial foods were low. Sulphur-35 was detected in hazelnuts at levels just above the LoD. The source is unknown but it is very unlikely to be Trawsfynydd as there were no discharges of this radionuclide in recent years. The most likely source of radiocaesium in hazelnuts and blackberries is fallout from Chernobyl and weapon tests though it is conceivable that a small contribution may be made by resuspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also carried out in crop and animal samples. Detected activities were low, and generally similar to observations in other areas of England and Wales, where activity was attributable to weapon test fallout. Slightly enhanced activities were detected in carrots, but other than this, there was no evidence of resuspension of activity in sediment from the lakeshore contributing to increased exposure from transuranic radionuclides in 2003.

The critical group for terrestrial foods at Trawsfynydd in 2003 received doses of 0.006 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 5.2). The contribution from the transuranic activity detailed above was less than 1% of the dose.

In the lake itself, there remains clear evidence for the effects of discharges from the power station. However, gamma dose rates found on the shoreline where anglers fish were only slightly enhanced above background and were similar to those in 2002. The time trend of concentrations of caesium-137 in sediments is shown in Figure 5.2.

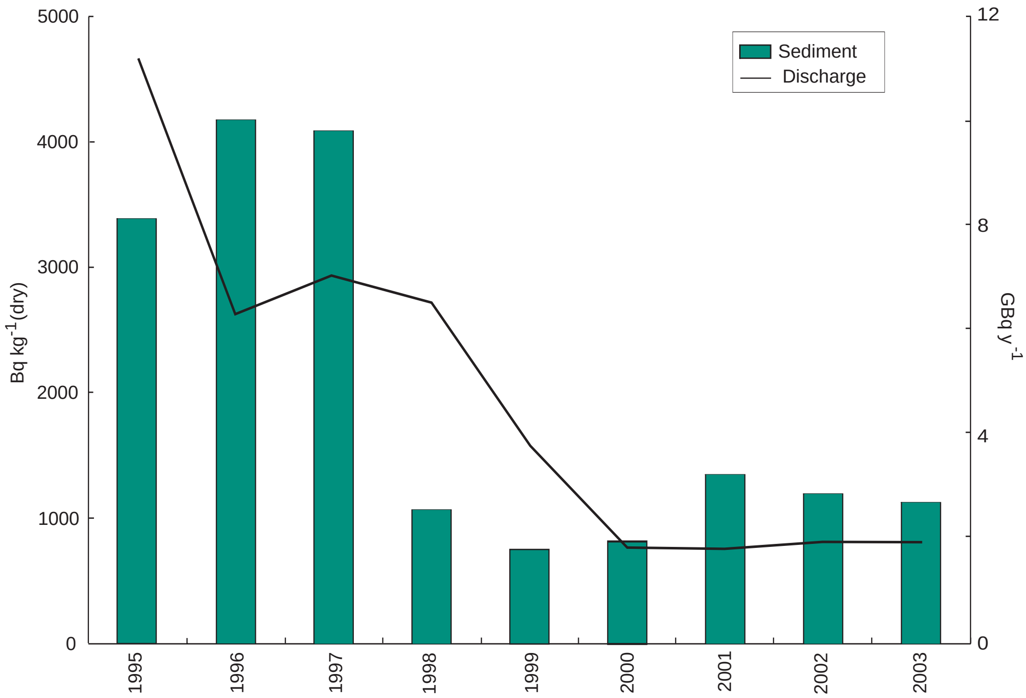

Figure 5.2 Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake

Concentrations of radiocaesium in fish in 2003 were unchanged compared with those in 2002. The activity concentrations in sediments and the residual activity in the fish that result from earlier discharges predominate at this stage. The dose to the critical group of anglers was 0.032 mSv in 2003, which was about 3% of the dose limit for members of the public of 1 mSv.

5.12 Wylfa, Isle of Anglesey

This station generates electricity from two Magnox reactors. Gaseous and liquid wastes from this station were discharged in 2003 under authorisations granted by the Environment Agency. Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is carried out on behalf of the Welsh Assembly Government. Such discharges and effects are very low.

The results of the programme in 2003 are given in Tables 5.13 (a) and (b). The data for artificial radionuclides related to the Irish Sea continue to reflect the distant effects of Sellafield discharges. The concentrations were similar to those for 2002, and continued to show the effects of technetium-99 from Sellafield. The dose to the critical group of high-rate fish and shellfish consumers was low, at 0.012 mSv, which was about 1% of the dose limit for members of the public of 1 mSv (Table 5.2). Gamma dose rates, measured using portable instruments were similar to those found in 2002.

The dose received by high-rate terrestrial food consumers remained low at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public. Due to planned activities on the site in July 2003 the site operators notified the Environment Agency that the weekly advisory levels for tritium would be likely to be exceeded. The Food Standards Agency took extra samples of local milk but found no elevated concentrations of tritium.

Table 5.1(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{99}Tc	^{134}Cs	^{137}Cs	^{238}Pu
Marine samples								
Salmon	Beachley	2	<25			<0.06	0.22	
Bass	River Severn	1	2600			0.37	2.7	
Elvers	River Severn	1	<25			<0.04	0.10	
Shrimps	Guscar	2	1900	44		<0.13	0.72	0.00029
Seaweed	Near pipeline	2^E			9.0	<3.3	<13	
Mud	Hills Flats	2				14	65	
Sediment	Hills Flats	2^E					30	
Mud	1 km south of Oldbury	2				6.1	43	
Sediment	1 km south of Oldbury	2^E					29	
Sediment	2 km south west of Berkeley	2^E					35	
Sediment	Sharpness	2^E					33	
Seawater	Local beach	2^E				<0.07	<0.14	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{239}Pu+^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+^{244}Cm	Total alpha	Total beta
Marine samples								
Salmon	Beachley	2		<0.07				
Bass	River Severn	1		<0.15				
Elvers	River Severn	1		<0.04				
Shrimps	Guscar	2	0.0017	0.0016	0.000018	0.000057		
Seaweed	Near pipeline	2^E		<7.0				
Mud	Hills Flats	2		<1.8				
Sediment	Hills Flats	2^E		<1.6				
Mud	1 km south of Oldbury	2		<2.1				
Sediment	1 km south of Oldbury	2^E		<2.1				
Sediment	2 km south west of Berkeley	2^E		<1.7				
Sediment	Sharpness	2^E		<1.4				
Seawater	Local beach	2^E		<0.70			<2.6	6.8

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		8	<3.7	17	<0.46	<0.27	<0.27		
Milk	max		<3.8	19	<0.63	<0.30	<0.33		
Apples		1	<4.0	18	0.40	<0.20	<0.30		
Blackberries		1	<4.0	20	0.30	<0.30	<0.40		
Cabbage		1	<4.0	6.0	0.50	<0.30	<0.30		
Honey		1	<6.0	73	<0.30	<0.10	<0.10		
Onions		1	4.0	14	0.40	<0.20	<0.30		
Potatoes		1	6.0	13	0.30	<0.30	<0.30		
Runner beans		1	<4.0	10	0.50	<0.20	<0.20		
Wheat		1	4.0	92	1.6	<0.30	<0.30		
Freshwater	Gloucester and Sharpness Canal	2^E	<4.0		<1.8	<0.17	<0.10	<0.045	0.17
Freshwater	Public supply	2^E	<4.0		<1.9	<0.15	<0.25	<0.040	0.21

[a] *Except for milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 5.1(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2003

Location	Ground type	No. of sampling observations	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1 m over intertidal areas			
1km south of Oldbury	Mud	2[F]	0.075
1km south of Oldbury	Mud	1	0.074
1km south of Oldbury	Grass, mud and saltmarsh	1	0.085
2km south west of Berkeley	Mud	1[F]	0.065
2km south west of Berkeley	Mud	1	0.086
2km south west of Berkeley	Mud and rock	1	0.075
Guscar Rocks	Mud and rock	1	0.091
Lydney Rocks	Mud	2	0.080
Sharpness	Mud	1	0.075
Sharpness	NA	1	0.080
Hills Flats	Mud	2[F]	0.072
Hills Flats	Mud	1	0.075
Hills Flats	NA	1	0.073
Aust Rock	Mud	1[F]	0.081

NA Not available

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 5.2. Individual radiation exposures – nuclear power stations, 2003

Site	Exposed population group[a]	Exposure mSv				
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or the shoreline	Gaseous plume related pathways
Berkeley and Oldbury	Seafood consumers	0.007	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.005	-	<0.005	-	<0.005
Bradwell	Seafood consumers	0.013	<0.005	-	0.011	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Chapelcross	Seafood consumers	0.037	0.009	-	0.028	-
	Inhabitants and consumers of locally grown food[b]	0.020	-	0.014	-	0.006
Dungeness	Seafood consumers	0.007	<0.005	-	0.005	-
	Inhabitants and consumers of locally grown food[b]	0.11	-	<0.005	-	0.11
Hartlepool	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Heysham	Seafood consumers	0.075	0.054	-	0.021	-
	Consumers of locally grown food[b]	0.006	-	0.006	-	-
Hinkley Point	Seafood consumers	0.013	<0.005	-	0.009	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Hunterston	Seafood consumers	<0.005	<0.005	-	-	-
	Beach occupants	0.007	-	-	0.007	-
	Consumers of locally grown food[b]	0.014	-	0.014	-	-
Sizewell	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food and inhabitants[b]	0.057	-	<0.005	-	0.056
Torness	Seafood consumers	0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	0.019	-	0.019	-	-
Trawsfynydd	Anglers	0.032	<0.005	-	0.028	-
	Consumers of locally grown food[b]	0.006	-	0.006	-	-
Wylfa	Seafood consumers	0.012	0.007	-	0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*

Table 5.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{99}Tc	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$
Marine samples							
Sole	Bradwell	2		<0.10	0.55		
Bass	Pipeline	1		0.20	2.4		
Mullet	Pipeline	1		0.11	1.3		
Lobsters	West Mersea	1		<0.04	0.34		
Native oysters	Tollesbury N. Channel	1		0.06	0.48	0.00051	0.0021
Pacific oysters	Goldhanger Creek	2		<0.04	0.34		
Winkles	Pipeline	2		<0.15	0.71		
Winkles	Heybridge Basin	2		<0.16	0.75		
Fucus vesiculosus	Waterside	2	6.4	0.25	3.0		
Seaweed	Bradwell	2[E]	19	<0.79	9.3		
Leaf beet	Tollesbury	1		<0.03	<0.02		
Samphire	Tollesbury	1		<0.07	0.32		
Sediment	Pipeline	2[E]			1.5		
Sediment	Maldon	2[E]			73		
Sediment	West Mersea	2[E]			8.1		
Sediment	Waterside	2[E]			30		
Sediment	1.5 km east of pipeline	2[E]			1.9		
Seawater	Bradwell	2[E]		<0.16	<0.15		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{241}Am	$^{243}Cm+^{242}Cm$	^{244}Cm	Total alpha	Total beta
Marine samples							
Sole	Bradwell	2	<0.11				
Bass	Pipeline	1	<0.16				
Mullet	Pipeline	1	<0.13				
Lobsters	West Mersea	1	<0.04				
Native oysters	Tollesbury N. Channel	1	0.0042	0.000031	0.00013		
Pacific oysters	Goldhanger Creek	2	<0.08				
Winkles	Pipeline	2	<0.22				
Winkles	Heybridge Basin	2	<0.32				
Fucus vesiculosus	Waterside	2	<0.22				190
Seaweed	Bradwell	2[E]	<0.89				
Leaf beet	Tollesbury	1	0.02				
Samphire	Tollesbury	1	<0.05				
Sediment	Pipeline	2[E]	<0.65				
Sediment	Maldon	2[E]	<3.1				
Sediment	West Mersea	2[E]	<1.0				
Sediment	Waterside	2[E]	<2.3				
Sediment	1.5 km east of pipeline	2[E]	<0.89				
Seawater	Bradwell	2[E]	<0.63			<3.7	13

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		5	3.5	19	<0.36	<0.27	<0.26		
Milk	max		<3.8	21	<0.43	<0.28	<0.28		
Apples		1	4.0	14	0.40	<0.30	<0.30		
Blackberries		1	6.0	16	<0.30	<0.20	<0.20		
Cabbage		1	<4.0	10	0.80	<0.20	<0.20		
Carrots		1	<4.0	11	<0.30	<0.20	<0.30		
Potatoes		1	20	20	<0.40	<0.30	<0.30		
Rabbit		1	<2.0	25	<0.60	<0.30	<0.40		
Wheat		1	7.0	73	<0.60	<0.20	<0.30		
Lucerne		1	<4.0	15	0.30	<0.30	<0.40		
Freshwater	Public supply	2[E]	<4.0		<1.5	<0.15	<0.17	<0.050	0.26
Freshwater	Coastal ditch 1	1[E]	6.2		2.8	<0.12	<0.11	<0.27	1.5
Freshwater	Coastal ditch 2	1[E]	<4.0		1.2	<0.17	<0.17	<0.28	1.7
Freshwater	Coastal ditch 3	2[E]	19		2.0	<0.13	<0.12	0.29	4.2
Freshwater	Coastal ditch 4	1[E]	15		2.5	<0.18	<0.18	<0.22	3.1

[a] *Except for milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply.*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.*
If no 'max' value is given, the mean is also the maximum.
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 5.3(b). Monitoring of radiation dose rates near Bradwell, 2003

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Bradwell Beach	Sand	1	0.068
Bradwell Beach	Shingle	1	0.076
Beach opposite power station, N side of estuary	Mud	1	0.065
Beach opposite power station, N side of estuary	Mud and shingle	1	0.082
0.5km E of pipeline	Shingle	2	0.057
Waterside	Mud	2	0.059
West Mersea	Mud and shingle	2	0.061
Maldon	Mud	1	0.061
Maldon	Mud and shingle	1	0.056

Table 5.4(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples													
Flounder	Inner Solway	4	<6.9	98	<0.11	<0.30	0.10	<0.45	3.3	<0.98	<0.29	<0.11	13
Lemon sole	Inner Solway	4			<0.12	<0.31		<0.45		<1.0	<0.27	<0.12	1.2
Plaice	Inner Solway	4			<0.11	<0.28		<0.35		<1.0	<0.29	<0.11	1.4
Salmon	Inner Solway	1	22		<0.10	<0.18		<0.24		<0.47	<0.13	<0.10	0.66
Sea trout	Inner Solway	1	9.2		<0.10	<0.22		<0.33		<0.67	<0.18	<0.10	2.9
Shrimps	Inner Solway	4	<12		<0.10	<0.20	0.15	<0.25	2.2	<0.64	<0.22	<0.10	3.7
Cockles	North Solway	7[F,S]	<29	91	1.4	<0.13	0.72	<0.16	32	1.9	0.61	<0.07	5.2
Mussels	North Solway	8[F,S]	<18	79	0.66	<0.10	0.53	<0.12	310	1.6	0.52	<0.07	2.4
Winkles	Southerness	4	<15		4.8	<0.38	0.57	<0.46	460	<13	1.9	<0.15	1.7
Fucus vesiculosus	Pipeline	4			0.97	<0.24		<0.23	1800	<0.67	1.3	<0.14	15
Sediment	Pipeline	4	<5.1		2.4	<0.35		<0.47		4.7	3.7	<0.28	200
Salt marsh	Dornoch Brow	4			2.1	<0.31		<0.39		4.1	2.9	<0.18	140
Seawater	Pipeline	4	10		<0.10	<0.10		<0.10		<0.20	<0.10	<0.10	<0.12
Seawater (high tide)	Pipeline	4	7.5		<0.10	<0.10		<0.13		<0.26	<0.10	<0.10	<0.14
Seawater	Southerness	4	9.7		<0.10	<0.10		<0.12		<0.26	<0.10	<0.10	0.14

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total Alpha	Total beta
Marine samples												
Flounder	Inner Solway	4	<0.13	<0.25	0.0089	0.052		0.088	<0.00064	<0.00064		
Lemon sole	Inner Solway	4	<0.15	<0.27				<0.15				
Plaice	Inner Solway	4	<0.15	<0.28				<0.16				
Salmon	Inner Solway	1	<0.10	<0.14				<0.12				
Sea trout	Inner Solway	1	<0.10	<0.20	0.00016	0.00024		0.0011	<0.00067	<0.00067		
Shrimps	Inner Solway	4	<0.11	<0.18	0.0037	0.015		0.035	<0.00036	<0.00036		
Cockles	North Solway	7[F,S]	<0.13	<0.14	0.67	3.6	32	9.3	<0.00076	0.013		
Mussels	North Solway	8[F,S]	<0.11	<0.12	0.57	3.1	24	5.4	<0.0011	0.0054		
Winkles	Southerness	4	<0.18	<0.33	0.12	0.63		3.5	<0.00061	<0.00061		
Fucus vesiculosus	Pipeline	4	<0.23	<0.33	0.38	2.5		4.3	<0.033	<0.033	11	390
Sediment	Pipeline	4	0.89	1.6	8.0	48		99	<0.33	<0.33		
Salt marsh	Dornoch Brow	4	<0.69	<1.1	8.3	43		79	0.024	0.071		
Seawater	Pipeline	4	<0.10	<0.10				<0.10				
Seawater (high tide)	Pipeline	4	<0.10	<0.10				<0.10				
Seawater	Southerness	4	<0.10	0.10	0.00047	0.0018		<0.0011	<0.00095	<0.00095		

Table 5.4(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial samples								
Milk		12	<26	<16	<1.1	<0.06	<0.10	<1.5
Milk	max		<56	19	<2.3	<0.07	<0.12	<2.6
Apples		2	22	17	<0.50	<0.05	<0.074	<0.24
Apples	max		35	18			<0.10	<0.26
Barley		3	<6.0	99	<1.2	<0.12	0.31	<0.18
Barley	max		6.7	110		0.18	0.43	<0.29
Cabbage		4	<10	<15	<5.0	<0.05	0.19	<0.06
Cabbage	max		21		14		0.23	<0.09
Cauliflower		1	5.2	<15	1.3	<0.05	0.55	<0.09
Comfrey		1	10	<15	1.3	<0.05	1.0	<0.13
Damsons		1	13	24	1.0	<0.05	0.42	<0.16
Duck		1	<5.6	27	4.3	<0.16	<0.10	<0.42
Maize		1	69	31	<0.50	<0.05	<0.10	<0.05
Nettles		1	24	21	14	<0.05		<0.15
Pheasant		1	<9.1	25	4.0	<0.11	<0.10	<0.28
Potatoes		5	<11	20	<1.3	<0.05	<0.11	<0.06
Potatoes	max		31	23	2.6		0.13	<0.07
Rhubarb		1	110	16	<0.50	<0.05	0.18	<0.17
Rosehips		2	6.8	55	1.2	<0.05	1.2	<0.15
Rosehips	max		7.6	58	1.9		2.1	<0.17
Tomatoes		2	5.2	<15	<0.53	<0.05	<0.10	<0.05
Tomatoes	max		5.5		<0.55			<0.06
Turnips		2	27	<15	4.2	<0.05	0.45	<0.11
Turnips	max		46		7.1		0.58	<0.17
Wheat		1	9.9	98	2.4	<0.05	0.39	<0.23
Wood pigeon		1	<5.4	31	6.1	<0.14	<0.10	<0.34
Grass		6	26	<20	3.9	<0.05	0.48	<0.18
Grass	max		90	26	11		0.75	<0.24
Soil		6	<9.5	<17	<1.5	<0.06	1.1	<0.26
Soil	max		23	23	<2.2	<0.07	2.0	<0.56

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am	Total Alpha	Total Beta
Terrestrial samples								
Milk		12	<0.06	<0.06		<0.14		
Milk	max		<0.07	<0.07		<0.42		
Apples		2	<0.05	<0.05		<0.06		
Apples	max					<0.07		
Barley		3	<0.07	<0.07		<0.19		
Barley	max		<0.10	<0.09		<0.30		
Cabbage		4	<0.05	<0.07		<0.06		
Cabbage	max			<0.12		<0.07		
Cauliflower		1	<0.05	<0.05		<0.06		
Comfrey		1	<0.05	<0.05		<0.09		
Damsons		1	<0.05	<0.05		<0.11		
Duck		1	<0.16	0.77		<0.24		
Maize		1	<0.05	<0.05		<0.09		
Nettles		1	<0.05	0.06		<0.08		
Pheasant		1	<0.11	0.66		<0.15		
Potatoes		5	<0.05	<0.10		<0.06		
Potatoes	max			0.20		<0.08		
Rhubarb		1	<0.05	<0.05		<0.11		
Rosehips		2	<0.05	<0.05		<0.13		
Rosehips	max					<0.15		
Tomatoes		2	<0.05	<0.05		<0.07		
Turnips		2	<0.05	<0.12		<0.05		
Turnips	max			0.20		<0.06		
Wheat		1	<0.05	<0.05		<0.15		
Wood pigeon		1	<0.13	1.4		<0.17		
Grass		6	<0.05	<0.08		<0.11	2.6	250
Grass	max			0.13		<0.13	7.6	320
Soil		6	<0.07	11	1.0	<0.22	270	640
Soil	max		<0.09	17	1.3	<0.32	320	820

[a] *Except for seawater and milk where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.*
If no 'max' value is given, the mean is also the maximum.
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[F,S] *Samples collected on behalf of the Food Standards Agency and SEPA*

Table 5.4(b). Monitoring of radiation dose rates near Chapelcross, 2003

Location	Ground type	No. of sampling observa-tions	μGy h⁻¹
Mean gamma dose rates at 1m over intertidal areas			
Southerness	Winkle bed	4	0.079
Glencaple Harbour	Mud and sand	4	0.093
Priestside Bank	Salt marsh	4	0.078
Powfoot Merse	Mud	4	0.081
Pipeline	Sand	4	0.095
Pipeline	Salt marsh	4	0.10
Battlehill	Sand	4	0.086
Dornoch Brow	Mud and sand	4	0.092
Dornoch Brow	Salt marsh	4	0.096
Browhouses	NA	4	0.088
Mean beta dose rates			$\mu Sv\ h^{-1}$
Powfoot	Salt marsh	4	<1.0
Pipeline 500m south	NA	4	<1.0
Pipeline 500m north	NA	4	<1.0
Pipeline	Stake nets	4	<1.0

NA not available

Table 5.4(c). Radioactivity in air near Chapelcross, 2003

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Eastriggs	12	<0.012	<0.0091	0.23
Kirtlebridge	12	<0.019	<0.0077	0.16
Brydekirk	11	<0.011	<0.0075	0.18

Table 5.5(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg-1 Organic ^{3}H	^{3}H	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples								
Plaice	Pipeline	2	<25	<25	<0.04			0.10
Cod	Pipeline	2		<25	<0.04			0.24
Bass	Pipeline	1		<25	<0.05			0.72
Crabs	Hastings	1			<0.05			<0.04
Shrimps[d]	Pipeline	2	<25	<25	<0.08			0.21
Whelks	Pipeline	2			<0.13	0.019		<0.08
Cuttlefish	Hastings	1			<0.02			0.02
Fucus vesiculosus	Copt Point	1					5.2	
Seaweed	Copt Point	2[E]			<1.1		7.4	<0.95
Mud and sand	Rye Harbour	2			<0.79			1.3
Sediment	Rye Harbour 1	1[E]			<1.2			<1.8
Sediment	Rye Harbour 2	2[E]			<1.3			2.9
Sediment	Camber Sands	2[E]			<0.32			<0.26
Sediment	Pilot Sands	1[E]			<0.16			<0.18
Seawater	Pipeline	2		3.1				
Seawater	Dungeness South	2[E]			<0.31			<0.23

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg-1 ^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Marine samples								
Plaice	Pipeline	2			<0.10			
Cod	Pipeline	2			<0.04			
Bass	Pipeline	1			<0.05			
Crabs	Hastings	1			<0.04			
Shrimps[d]	Pipeline	2			<0.19			
Whelks	Pipeline	2	0.00054	0.0025	0.0023	0.00016		
Cuttlefish	Hastings	1			<0.03			
Seaweed	Copt Point	2[E]			<1.5			
Mud and sand	Rye Harbour	2	0.043	0.22	0.21	0.010		
Sediment	Rye Harbour 1	1[E]			<1.2		250	780
Sediment	Rye Harbour 2	2[E]			<0.79		240	710
Sediment	Camber Sands	2[E]			<0.46			
Sediment	Pilot Sands	1[E]			<0.38			
Seawater	Pipeline	2						
Seawater	Dungeness South	2[E]			<0.50		<3.3	15

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg-1 ^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Total alpha	Total beta
Terrestrial Samples									
Milk		2	<3.8	21	<0.41	<0.31	<0.29		
Milk	max			23	<0.45	<0.33	<0.30		
Blackberries		1	6.0	8.0	0.30	<0.20	<0.30		
Honey		1	<6.0	78	<0.30	<0.20	<0.20		
Peas		1	<6.0	81	0.90	<0.30	<0.30		
Potatoes		1	6.0	25	<0.30	<0.30	<0.20		
Sea kale		1	<3.0	6.0	2.2	<0.50	<0.40		
Wheat		1	<6.0	82	<0.60	<0.30	<0.20		
Grass		1				<0.30	0.50		
Freshwater	Long Pits	2[E]	6.2		<1.5	<0.16	<0.16	<0.025	0.11
Freshwater	Well number 1	1[E]	<4.0		<1.0	<0.23	<0.24	<0.030	0.16
Freshwater	Well number 2	1[E]	<4.0		<2.0	<0.11	<0.11	<0.020	0.26
Freshwater	Well number 3	1[E]	<4.0		1.5	<0.17	<0.16	<0.050	0.12
Freshwater	Reservoir	1[E]	<4.0		<2.0	<0.16	<0.16	<0.030	0.15

[a] *Except for milk and water where units are Bq l-1 and for sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[d] *The concentration of ^{14}C was 26 Bq kg-1*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Nuclear power

Table 5.5(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2003

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Littlestone-on-Sea	Shingle	2	0.056
Greatstone-on-Sea	Shingle	1	0.061
Greatstone-on-Sea	Sand	1	0.054
Dungeness East	Shingle	2	0.055
Dungeness South	Shingle	2	0.050
Jury Gap	Shingle	1	0.060
Jury Gap	Sand and shingle	1	0.053
Rye Bay	Sand	2	0.056
Rye Harbour	Mud and sand	2[F]	0.064
Mean beta dose rates			μSv h^{-1}
Rye Harbour	Mud and sand	2[F]	<0.062

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 5.6(a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{137}Cs
Marine samples								
Plaice	Pipeline	2	<25	<26	33	<0.11		0.23
Cod	Pipeline	2				<0.04		0.44
Crabs	Pipeline	2			27	<0.05		<0.09
Winkles	Paddy's Hole	2	<31	38		<0.04		0.38
Fucus vesiculosus	Pilot Station	2				<0.10	24	0.16
Seaweed	Pilot Station	2[E]				<1.2	120	<1.4
Sediment	Seaton Carew	2[E]				<0.26		<0.46
Sediment	Paddy's Hole	2[E]				<1.2		10
Sediment	North Gare	2[E]				<0.42		<0.65
Sediment	Greatham Creek	2[E]				<0.70		11
Sea coal	North Sands	2[E]				<0.53		<2.1
Sea coal	Carr House Sands	2[E]				<1.1		<2.1
Sea coal	Seaton Sands	2[E]				<0.50		<1.2
Seawater	North Gare	2		4.7				
Seawater	North Gare	2[E]				<0.17		<0.17

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Marine samples									
Plaice	Pipeline	2			<0.18				
Cod	Pipeline	2			<0.15				
Crabs	Pipeline	2	0.00034	0.0022	0.0018	*	*		
Winkles	Paddy's Hole	2	0.012	0.079	0.035	0.000056	0.000093		
Fucus vesiculosus	Pilot Station	2			<0.16				250
Seaweed	Pilot Station	2[E]			<4.6				
Sediment	Seaton Carew	2[E]			<0.38				
Sediment	Paddy's Hole	2[E]			<1.7				
Sediment	North Gare	2[E]			<1.5				
Sediment	Greatham Creek	2[E]			<1.2				
Sea coal	North Sands	2[E]			<0.97				
Sea coal	Carr House Sands	2[E]			<1.9				
Sea coal	Seaton Sands	2[E]			<0.79				
Seawater	North Gare	2[E]			<0.91			<4.3	<7.0

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		6	<3.8	15	<0.53	<0.28	<0.27		
Milk	max		<4.8	20	<0.70	<0.30	<0.33		
Apples		1	<2.0	21	0.50	<0.40	<0.30		
Cabbage		1	7.0	<3.0	<0.70	<0.30	<0.30		
Carrots		1	<2.0	6.0	<0.40	<0.50	<0.30		
Elderberries		1	<1.0	26	<0.40	<0.40	<0.40		
Honey		1	<2.0	120	<0.40	<0.10	<0.20		
Potatoes		1	12	20	<0.40	<0.30	<0.40		
Runner beans		1	<2.0	11	<0.40	<0.30	<0.40		
Wheat		1	<3.0	110	<0.70	<0.20	<0.20		
Freshwater	Public supply	2[E]	<4.0		<1.5	<0.13	<0.13	<0.025	<0.10
Freshwater	Borehole, Dalton Piercy	2[E]	<4.0		<1.5	<0.13	<0.13	<0.070	0.15

* *Not detected by the method used*

[a] *Except for milk and water where units are Bq l^{-1} and for sea coal and sediment where dry concentrations apply*

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 5.6(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2003

Location	Ground type	No. of sampling observations	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1 m over intertidal areas			
Hartlepool North Sands	Sand	2	0.055
Seaton Carew	Sand	2	0.063
Greatham Creek Bird Hide	Salt marsh	1	0.077
Greatham Creek Bird Hide	Mud and rock	1	0.074
North Gare	Sand	2	0.055
Paddy's Hole	Winkle bed	2[F]	0.19
Paddy's Hole	Mud and pebbles	1	0.15
Paddy's Hole	Mud, pebbles and rock	1	0.17
Carr House	Sand	2	0.062
Seaton Sands	Sand	2	0.065

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 5.7(a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples													
Flounder	Flookburgh	4			120	<0.09	<0.10			<0.92	<0.27	<0.10	10
Plaice	Morecambe	4	<37	<45		<0.10	<0.11	0.033	2.0	<0.99	<0.26	<0.11	5.1
Bass	Morecambe	2				<0.07	<0.07			<0.75	<0.21	<0.08	14
Whitebait	Sunderland Point	1				<0.08	<0.09	0.13		<0.87	<0.24	<0.10	5.1
Shrimps	Flookburgh	4			120	<0.08	<0.11		12	<0.81	<0.22	<0.09	5.1
Cockles	Middleton Sands	2				<0.05	1.3			1.1	0.56	<0.05	3.3
Cockles[b]	Flookburgh	4			110	<0.06	1.2	0.60	37	2.8	0.59	<0.06	4.6
Winkles	Red Nab Point	4				<0.10	0.99			3.9	1.3	<0.07	5.0
Mussels	Morecambe	4	<38	<62	120	<0.05	0.82		900	4.6	0.92	<0.05	3.7
Fucus vesiculosus	Half Moon Bay	4				<0.10	0.58		5100	<0.90	1.1	<0.11	5.0
Seaweed	Half Moon Bay	2[E]					<1.6		3400	<8.5	<6.3	<0.91	9.3
Mud and sand	Flookburgh	4				<0.47	<0.49			<5.2	<1.9	<0.56	160
Sediment	Flookburgh	4[E]					<1.3			<9.9	<12	<1.1	650
Mud and sand	Half Moon Bay	4				<0.90	6.5			<28	<7.2	<0.97	160
Sediment	Half Moon Bay	2[E]					<1.3						36
Sediment	Pott's Corner	2[E]					<0.99						56
Sediment	Pipeline	2[E]					<1.1						26
Mud and sand	Morecambe Central Pier	4				<0.74	<3.4			<20	7.4	<0.86	160
Sediment	Morecambe Central Pier	2[E]					1.8						100
Sediment	Sunderland Point	4[E]					2.3			<6.1	<5.0	<0.64	100
Sediment	Conder Green	4[E]					<2.2			<6.2	<3.6	<0.58	160
Sediment	Sand Gate Marsh	4[E]					<1.9			<6.0	<4.4	<0.58	180
Turf	Conder Green	4				<0.96	4.0			<11	<3.9	<1.2	320
Turf	Sand Gate Marsh	4				<0.68	<1.7			<7.6	<2.7	<0.87	180
Samphire	Cockerham Marsh	1				<0.07	<0.07			<0.77	<0.17	<0.07	0.98
Seawater	Pipeline	2		28									
Seawater	Heysham Harbour	2[E]					<0.39			<2.8		<0.27	<0.41
Seawater	Half Moon Bay	1										*	0.14

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Total alpha	Total beta
Marine samples											
Flounder	Flookburgh	4	<0.52	0.0016	0.0094		0.017	*	*		
Plaice	Morecambe	4	<0.45				<0.17				
Bass	Morecambe	2	<0.47				<0.15				
Whitebait	Sunderland Point	1	<0.55	0.033	0.21	1.6	0.35	*	0.00092		
Shrimps	Flookburgh	4	<0.39	0.0044	0.024	0.27	0.037	*	0.000053		
Cockles	Middleton Sands	2	<0.26	0.35	1.9		5.3	*	0.0065		
Cockles[b]	Flookburgh	4	<0.28	0.48	2.6	24	6.8	*	0.014		
Winkles	Red Nab Point	4	<0.34	0.42	2.2		4.0	*	0.0053		
Mussels	Morecambe	4	<0.27	0.48	2.6		4.3	*	0.0085		
Fucus vesiculosus	Half Moon Bay	4	<0.45				0.78				4100
Seaweed	Half Moon Bay	2[E]	<6.4				<5.5				
Mud and sand	Flookburgh	4	<4.0				51				
Sediment	Flookburgh	4[E]	<6.4				430			810	1500
Mud and sand	Half Moon Bay	4	<5.9	16	87		150	0.15	0.23		
Sediment	Half Moon Bay	2[E]					<36				
Sediment	Pott's Corner	2[E]					<29				
Sediment	Pipeline	2[E]					<24				
Mud and sand	Morecambe Central Pier	4	<5.0				120				
Sediment	Morecambe Central Pier	2[E]					<77				
Sediment	Sunderland Point	4[E]	<3.7				130			290	890
Sediment	Conder Green	4[E]	<3.4				210			510	900
Sediment	Sand Gate Marsh	4[E]	<2.7				130			390	950
Turf	Conder Green	4	<5.4				200				
Turf	Sand Gate Marsh	4	<4.5				91				
Samphire	Cockerham Marsh	1	<0.39				0.54				24
Seawater	Heysham Harbour	2[E]	<1.0				<0.53			<2.4	15

Table 5.7(a). continued

Material	Location or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{35}S	^{60}Co	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	Total alpha	Total beta
Terrestrial samples												
Milk		6	<3.7	<19	<0.39	<0.33	<2.4	<0.31	<0.35	<1.3		
Milk	max		<5.2	22	<0.46	<0.38	<2.7	<0.36	<0.42	<1.5		
Apples		1	<4.0	11	0.70	<0.30	<1.0	<0.30	<0.30	<1.1		
Barley		1	<2.0	120	<0.70	<0.20	<1.5	<0.20	<0.20	<0.50		
Blackberries		1	<2.0	33	<0.40	<0.20	<2.2	<0.30	<0.30	<1.7		
Cabbage		1	<4.0	4.0	1.2	<0.30	<2.3	<0.30	<0.30	<1.1		
Honey		1	<6.0	87	0.40	<0.20	<1.8	<0.20	0.20	<1.2		
Onions		1	<4.0	13	0.40	<0.30	<1.7	<0.20	<0.20	<0.80		
Potatoes		1	<4.0	28	0.80	<0.30	<2.0	<0.20	<0.30	<1.0		
Sprouts		1	<2.0	<3.0	<0.60	<0.30	<1.9	<0.30	<0.40	<1.4		
Freshwater	Lancaster	2[E]	<4.0		<1.5	<0.51		<0.56	<0.52		<0.020	<0.10

** Not detected by the method used*

[a] Except for milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply

[b] The concentration of ^{210}Po was 15 Bq kg^{-1}

[c] Data are arithmetic means unless stated as ‘max’ in this column. ‘Max’ data are selected to be maxima. If no ‘max’ value is given, the mean is also the maximum.

[d] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime

[E] Measurements are made on behalf of the Food Standards Agency unless labelled “E”. In that case they are made on behalf of the Environment Agency

Table 5.7(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2003

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1 m over intertidal areas			
Greenodd	Salt marsh	2	0.074
Sand Gate Marsh	Salt marsh	4[F]	0.091
Sand Gate Marsh	Salt marsh	2	0.092
Sand Gate Marsh	Grass and salt marsh	1	0.095
Sand Gate Marsh	Grass, mud and sand	1	0.098
Flookburgh	Mud and sand	4[F]	0.082
Flookburgh	Salt marsh	3	0.097
Flookburgh	Grass and salt marsh	1	0.089
High Foulshaw	Salt marsh	4[F]	0.083
High Foulshaw	Salt marsh	3	0.080
High Foulshaw	Grass and salt marsh	1	0.075
Arnside Marsh	Mud and sand	4	0.077
Arnside Marsh	Salt marsh	4[F]	0.093
Arnside Marsh	Salt marsh	4	0.096
Morecambe Central Pier	Mussel bed	4[F]	0.072
Morecambe Central Pier	Mud and sand	4[F]	0.074
Morecambe Central Pier	Mud	1	0.079
Morecambe Central Pier	Mud and pebbles	1	0.084
Half Moon Bay	Mud and sand	4[F]	0.075
Half Moon Bay	Sand	2	0.067
Heysham pipelines	Sand	1	0.076
Heysham pipelines	Sand and algae	1	0.076
Middleton Sands	Mud	1	0.079
Middleton Sands	Sand	1	0.075
Sunderland	Mud	2	0.087
Sunderland	Mud and salt marsh	1	0.091
Sunderland	Mud and grass	1	0.10
Sunderland Point	Mud	1	0.087
Sunderland Point	Mud and sand	2	0.089
Sunderland Point	Sand	1	0.091
Colloway Marsh	Salt marsh	4[F]	0.14
Colloway Marsh	Salt marsh	4	0.10
Lancaster	Grass	4	0.083
Aldcliffe Marsh	Salt marsh	4[F]	0.10
Aldcliffe Marsh	Salt marsh	4	0.11
Conder Green	Mud	1[F]	0.094
Conder Green	Mud and sand	3[F]	0.092
Conder Green	Salt marsh	4[F]	0.11
Conder Green	Salt marsh	1	0.090
Conder Green	Mud and grass	2	0.089
Conder Green	Grass	1	0.093
Cockerham Marsh	Salt marsh	4[F]	0.10
Cockerham Marsh	Salt marsh	2	0.099
Cockerham Marsh	Grass and salt marsh	2	0.10

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 5.8(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2003

Material	Location	No. of sampling observa-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{134}Cs	^{137}Cs
Marine samples									
Cod	Stolford	2	880	880	38	<0.04	<0.04	0.11	1.0
Shrimps	Stolford	2	770	810	33	<0.05	<0.05	<0.06	0.56
Whelks	Stolford	1		2400	61	<0.05	<0.05	<0.06	0.38
Fucus vesiculosus	Pipeline	2				1.2	0.48	0.58	7.6
Seaweed[b]	Pipeline	2[E]					<3.7	<2.4	14
Mud	1.6 km east of pipeline	2				<0.63	<0.62	3.7	45
Sediment	1.6 km east of pipeline	2[E]					<0.78		27
Sediment	Pipeline	2[E]					<0.58		41
Sediment	0.8 km west of pipeline	2[E]					<0.37		8.9
Sediment	Stolford	2[E]					<0.40		7.7
Sediment	Steart Flats	2[E]					<0.35		6.4
Mud and sand	River Parrett	2				<0.75	<0.70	2.2	36
Sediment	River Parrett	2[E]					<0.96		38
Seawater	Pipeline	2		18					
Seawater	Pipeline	2[E]					<0.20	<0.26	<0.59

Material	Location	No. of sampling observa-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Aquatic samples								
Cod	Stolford	2			<0.05			
Shrimps	Stolford	2	0.00017	0.00064	0.00060	0.000017		
Whelks	Stolford	1			<0.15			
Fucus vesiculosus	Pipeline	2			<0.19			270
Seaweed[b]	Pipeline	2[E]			<2.7			
Mud	1.6 km east of pipeline	2			<1.8			
Sediment	1.6 km east of pipeline	2[E]			<1.0			
Sediment	Pipeline	2[E]			<0.79			
Sediment	0.8 km west of pipeline	2[E]			<0.83			
Sediment	Stolford	2[E]			<0.66			
Sediment	Steart Flats	2[E]			<0.68			
Mud and sand	River Parrett	2			<1.7			
Sediment	River Parrett	2[E]			<1.8			
Seawater	Pipeline	2[E]			<0.51		<9.0	9.8

Material	Location or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{60}Co	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples										
Milk		6	<3.3	17	<0.35	<0.25	<0.24	<0.25		
Milk	max		<3.8	20	<0.50	<0.30	<0.28	<0.28		
Apples		2	<3.0	17	0.50	<0.20	<0.20	<0.20		
Apples	max		<4.0	18	0.70					
Blackberries		1	6.0	21	0.90	<0.40	<0.30	<0.40		
Cabbage		1	<4.0	6.0	1.8	<0.10	<0.20	<0.20		
Honey		1	<6.0	78	<0.30	<0.20	<0.20	<0.20		
Potatoes		1	7.0	21	1.7	<0.30	<0.30	<0.30		
Runner beans		1	5.0	15	1.7	<0.40	<0.30	<0.30		
Wheat		1	7.0	91	0.70	<0.20	<0.20	<0.20		
Freshwater	Durleigh Reservoir	2[E]	<4.0		<2.3	<0.25	<0.22	<0.24	<0.045	0.18
Freshwater	Ashford Reservoir	2[E]	<4.0		<2.3	<1.1	<0.97	<0.86	<0.025	<0.10

[a] *Except for milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *The concentration of ^{99}Tc was 12 Bq kg^{-1}*
[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[d] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 5.8(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2003

Location	Ground type	No. of sampling observa-tions	µGy h-1
Mean gamma dose rates at 1m over intertidal areas			
Weston-Super-Mare	Sand	2	0.063
Burnham	Sand	1	0.061
Burnham	NA	1	0.063
River Parrett	Mud and sand	2F	0.071
Steart Flats	Sand	1	0.067
Steart Flats	Mud, pebbles and sand	1	0.070
Stolford	Mud, pebbles and sand	1	0.068
Stolford	NA	1	0.064
Hinkley Point	Mud, pebbles, rock and sand	1	0.067
Hinkley Point	Pebbles and sand	1	0.073
Kilve	Pebbles, rock and sand	1	0.074
Kilve	Pebbles, rock and stones	1	0.068
Watchet Harbour	Pebbles, rock and sand	1	0.087
Watchet Harbour	Pebbles and shingle	1	0.088
Blue Anchor Bay	Pebbles and sand	1	0.070
Blue Anchor Bay	Pebbles, sand and shingle	1	0.069

NA Not available

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 5.9(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{14}C	^{54}Mn	^{59}Fe	^{58}Co	^{60}Co	^{65}Zn	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples														
Hake	Millport	2		<0.10	<0.59	<0.14	<0.10	<0.16		<0.46	<0.10	<0.13	<0.10	1.3
Crabs	Millport	2	42	<0.10	<0.40	<0.11	<0.10	<0.11	2.7	<0.27	<0.10	<0.10	<0.10	0.33
Nephrops	Millport	1		<0.10	<0.93	<0.17	<0.10	<0.19	120	<0.53	<0.10	<0.13	<0.10	0.44
Lobsters	Largs	1		<0.10	<0.24	<0.10	<0.10	<0.11	140	<0.33	<0.10	<0.10	<0.10	<0.10
Squat lobsters	Largs	4		<0.10	<0.39	<0.13	<0.10	<0.17	83	<0.51	<0.11	<0.15	<0.10	0.48
Winkles	Pipeline	2		3.1	<0.69	<0.36	6.3	<0.52		<3.7	0.75	<0.41	<0.20	3.1
Scallops	Largs	3		<0.10	<0.49	<0.12	<0.10	<0.15		<0.42	<0.10	<0.11	<0.10	0.48
Oysters	Fairlie	1		0.12	<0.26	<0.10	<0.10	<0.10		<0.29	0.42	<0.10	<0.10	0.26
Seaweed	N of pipeline	2		4.5	<0.30	<0.10	0.88	<0.17		<0.50	<0.16	<0.13	<0.10	1.2
Seaweed	Pipeline	1		3.7	<0.36	<0.15	1.4	<0.10		<0.45	0.15	<0.11	<0.10	1.3
Ascophyllum nodosum	Pipeline	1		1.2	<0.19	<0.10	0.47	<0.14		<0.40	<0.10	0.19	<0.10	0.49
Seaweed	S of pipeline	2		4.5	<0.39	<0.14	1.4	<0.22		<0.99	<0.27	<0.17	<0.10	1.5
Sediment	Pipeline	2		0.19	<0.16	<0.10	0.19	<0.16		<0.46	<0.10	<0.16	<0.10	14
Sediment	Millport	2		<0.10	<0.19	<0.10	<0.10	<0.16		<0.45	<0.10	<0.15	<0.10	5.3
Sediment	Ardneil Bay	2		<0.10	<0.11	<0.10	<0.10	<0.12		<0.34	<0.10	<0.11	<0.10	2.6
Sediment	Gulls Walk	2		<0.20	<0.14	<0.10	<0.10	<0.16		<0.43	<0.10	<0.14	<0.10	5.2

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$
Marine samples										
Hake	Millport	2	<0.32	<0.10	<0.14			<0.11		
Crabs	Millport	2	<0.21	<0.10	<0.10	0.0023	0.0074	0.0082	<0.00024	0.00051
Nephrops	Millport	1	<0.41	<0.10	<0.16			<0.12		
Lobsters	Largs	1	<0.24	<0.10	<0.11			<0.10		
Squat lobsters	Largs	4	<0.34	<0.11	<0.16	0.0069	0.029	0.024	<0.00027	<0.00040
Winkles	Pipeline	2	<1.5	<0.30	<0.51	0.33	0.64	0.47	0.0064	0.042
Scallops	Largs	3	<0.29	<0.10	<0.13	0.0025	0.011	0.0042	<0.0014	<0.0014
Oysters	Fairlie	1	<0.19	<0.10	<0.10			<0.10		
Seaweed	N of pipeline	2	<0.31	<0.10	<0.15			<0.13		
Seaweed	Pipeline	1	0.52	<0.10	<0.13			0.21		
Ascophyllum nodosum	Pipeline	1	<0.26	<0.10	<0.14			<0.12		
Seaweed	S of pipeline	2	<0.45	<0.15	<0.28			<0.24		
Sediment	Pipeline	2	<0.44	<0.11	<0.16			0.41		
Sediment	Millport	2	<0.43	<0.11	<0.18			0.29		
Sediment	Ardneil Bay	2	<0.31	<0.10	<0.16			<0.12		
Sediment	Gulls Walk	2	<0.40	<0.11	<0.25			0.55		

Table 5.9(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}													
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{106}Ru	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am	Total alpha	Total beta
Terrestrial Samples																
Milk		6	<6.5	<17	<1.8	<0.05	<0.10	<0.37	<0.06	<0.05	<0.11	<0.25		<0.06		
Milk	max		<11	<20	<2.4			<0.38	<0.07		0.31	<0.27		<0.08		
Blackberries		1	<5.0	22	<0.50	<0.05	0.73	<0.41	<0.05	<0.05	0.18	<0.25		<0.08		
Cabbage		1	5.4	19	3.2	<0.05	0.22	<0.26	<0.05	<0.05	<0.05	<0.18		<0.09		
Carrots		3	<5.0	<15	<0.50	<0.05	<0.29	<0.19	<0.05	<0.05	<0.07	<0.12		<0.06		
Carrots	max			16			0.54	<0.38			0.11	<0.24		<0.07		
Nettles		2	<9.2	<15	3.9	<0.05	2.6	<0.36	<0.05	<0.05	<0.45	<0.21		<0.06		
Nettles	max		13		4.1		3.2	<0.46			0.85	<0.26		<0.08		
Onions		3	<5.0	<15	<1.5	<0.05	<0.12	<0.27	<0.05	<0.05	<0.05	<0.18		<0.07		
Onions	max				2.3		0.17	<0.36				<0.22		<0.09		
Potatoes		3	<5.0	24	<0.50	<0.05	<0.20	<0.25	<0.05	<0.05	0.11	<0.16		<0.07		
Potatoes	max			31			0.30	<0.38			0.17	<0.24		<0.09		
Rabbit		2	<7.0	26	7.3	<0.14	<0.10	<1.2	<0.14	<0.13	<0.12	<0.81		<0.18		
Rabbit	max		<7.6		9.2						<0.15			<0.19		
Rowan berries		1	<5.0	34	<0.50	<0.05	0.15	<0.33	<0.05	<0.05	0.13	<0.22		<0.09		
Turnips		2	<5.0	<15	1.5	<0.05	0.30	<0.21	<0.05	<0.05	<0.05	<0.13		<0.06		
Turnips	max				1.9		0.42	<0.25				<0.16		<0.07		
Grass		4	<5.0	21	1.4	<0.05	0.55	<0.41	<0.06	<0.05	<0.17	<0.28		<0.12	3.4	230
Grass	max			27	1.8	<0.06	0.78	<0.56	<0.07		0.30	<0.39		<0.16	5.5	280
Soil		4	<8.8	<17	<2.3	<0.05	0.25	<0.46	<0.07	<0.06	22	<0.42	0.47	<0.18	250	540
Soil	max		15	18	<5.2		0.44	<0.48	<0.08		34	<0.44	0.57	<0.22	330	610

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

Table 5.9(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2003

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Largs Bay	NA	2	0.063
Kilchatten Bay	NA	2	0.054
Millport	NA	2	<0.050
Gulls Walk	Mud	2	<0.061
0.5 km north of pipeline	Sand	2	0.054
0.5 km south of pipeline	Sand and stones	2	0.069
Ardneil Bay	NA	2	<0.053
Ardrossan Bay	NA	2	<0.056

NA Not available

Table 5.9(c). Radioactivity in air near Hunterston, 2003

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Fencebay	12	<0.012	<0.0078	0.19
West Kilbride	12	<0.011	<0.0056	0.14
Crosbie Mains	11	<0.012	<0.0081	0.17

Table 5.10(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Aquatic samples													
Cod	Sizewell	1	<25		<0.06	0.54			<0.06				
Sole	Sizewell	1	<25		0.09	0.61			<0.13				
Crabs	Sizewell	2		24	<0.06	0.35	0.000081	0.00047	0.00098	0.00029	0.000028		
Shrimps	Sizewell	1			<0.04	0.28	0.00026	0.0012	0.00074	*	0.000036		
Pacific Oyster	Blyth estuary	1			<0.03	0.08			<0.04				
Whelks	Dunwich	1			<0.13	0.24			<0.10				
Mussels	River Alde	1	<25		<0.12	<0.11			<0.09				
Sand	Aldeburgh	2			<0.18	0.41			<0.46				
Sediment	Rifle range	2[E]				<0.62			<0.65				
Sediment	Aldeburgh	2[E]				<0.78			<1.0				
Sediment	Southwold	2[E]				8.3			<0.82			300	900
Seawater	Aldeburgh	2	<2.4										
Seawater	Sizewell	2[E]			<0.20	<0.20			<0.77			<3.7	14

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{134}Cs	^{137}Cs	Total Cs
Terrestrial samples									
Milk		6	<3.7	<14	<0.30		<0.28	<0.27	
Milk	max		<3.8	17	<0.33		<0.30	<0.30	
Apples		1	<4.0	14	0.70		<0.20	<0.20	
Blackberries		1	<4.0	23	1.3		<0.30	<0.30	
Cabbage		1	<4.0	<3.0	0.70		<0.30	<0.30	
Carrots		1	<4.0	7.0	<0.30		<0.20	<0.30	
Honey		1	<6.0	40	<0.30		<0.20	<0.20	
Ovine muscle		1	<5.0	45	1.3	<0.036			0.35
Ovine offal		1	11	36	<0.70	0.036			0.26
Porcine muscle		1	<5.0	51	<0.60	<0.021			0.23
Porcine offal		1	<7.0	<10	<0.60	0.040			0.45
Potatoes		1	<4.0	17	<0.30		<0.30	<0.40	
Runner beans		1	<4.0	6.0	0.90		<0.30	<0.30	
Wheat		1	<7.0	96	1.0		<0.30	<0.30	
Freshwater	Nature reserve	2[E]	<4.0		<1.5		<0.16	<0.17	
Freshwater	The Meare	2[E]	<4.0		<1.5		<0.19	<0.23	
Freshwater	Leisure Park	2[E]	<4.0		<1.5		<0.18	<0.17	

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha	Total beta
Terrestrial samples							
Ovine muscle		1	<0.00020	<0.00020	<0.00030		
Ovine offal		1	0.00010	<0.00010	0.00030		
Porcine muscle		1	<0.00010	<0.00020	0.00020		
Porcine offal		1	<0.00020	<0.00010	<0.00040		
Freshwater	Nature reserve	2[E]				<0.045	0.25
Freshwater	The Meare	2[E]				<0.055	0.45
Freshwater	Leisure Park	2[E]				<0.050	0.19

** Not detected by the method used.*

[a] Except for milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply.

[b] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.

[c] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime

[E] Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency

Table 5.10(b). Monitoring of radiation dose rates near Sizewell, 2003

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Sizewell Beach	Shingle	2	0.060
Dunwich	Shingle	2	0.052
Rifle Range	Shingle	2	0.064
Aldeburgh	Sand and stones	2[F]	0.043
Aldeburgh	Shingle	2	0.052
Southwold Harbour	Mud	2	0.065

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 5.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{99}Tc	^{137}Cs
Marine samples								
Fish	Pipeline	1			<0.10	<0.10		0.45
Fish	White Sands	1			<0.10	<0.10		0.54
Seafood	White Sands	1			<0.10	<0.10		0.37
Crabs	Cove	1		33			8.8	
Lobsters	Cove	1			<0.10	<0.10	34	<0.10
Nephrops	Dunbar	3			<0.14	<0.14		<0.26
Winkles	Pipeline	1			<0.10	0.15		0.26
Fucus vesiculosus	Pipeline	2			0.11	<0.11	45	<0.22
Fucus vesiculosus	Thornton Loch	2			<0.53	0.17		0.20
Fucus vesiculosus	White Sands	2			<0.10	<0.10		<0.16
Sediment	Dunbar Inner Harbour	2			<0.10	<0.10		3.3
Sediment	Barns Ness	2			<0.10	<0.10		2.2
Sediment	Thornton Loch	2			<0.10	<0.10		1.0
Sediment	Heckies Hole	2			<0.10	<0.11		6.7
Sediment	Eyemouth	2			<0.10	<0.10		2.2
Salt marsh	Belhaven Bay	2			<0.10	<0.10		2.5
Seawater	Pipeline	2	<2.9		<0.10	<0.10		<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples										
Fish	Pipeline	1	<0.15			<0.10				
Fish	White Sands	1	<0.15			<0.12				
Seafood	White Sands	1	<0.10			<0.10				
Lobsters	Cove	1	<0.26			0.11				
Nephrops	Dunbar	3	<0.33	<0.0011	0.0042	0.0049	<0.00086	<0.00086		
Winkles	Pipeline	1	0.24			0.11			3.1	100
Fucus vesiculosus	Pipeline	2	<0.33			<0.31				
Fucus vesiculosus	Thornton Loch	2	<0.13			<0.14				
Fucus vesiculosus	White Sands	2	<0.13			<0.13				
Sediment	Dunbar Inner Harbour	2	1.0			<0.43				
Sediment	Barns Ness	2	<0.88			<0.41				
Sediment	Thornton Loch	2	<0.27			<0.18				
Sediment	Heckies Hole	2	<0.37			<0.59				
Sediment	Eyemouth	2	0.60			<0.21				
Salt marsh	Belhaven Bay	2	0.56			<0.26				
Seawater	Pipeline	2	<0.10			<0.10				

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	^{155}Eu	^{241}Am	Total alpha	Total beta
Terrestrial samples											
Milk		1	<5.0	<20	<0.96	<0.11	<0.06		<0.09		
Cabbage		1	<5.0	<15	0.89	<0.10	<0.05		<0.07		
Cauliflower		1	<5.0	<15	2.3	<0.10	<0.05		<0.06		
Elderberries		1	<5.0	37	<0.50	0.18	<0.05		<0.10		
Leeks		1	<5.0	<15	0.71	0.23	<0.05		<0.05		
Nettles		1	<5.0	26	9.0	0.45	0.07		<0.11		
Potatoes		1	<5.0	26	<0.50	<0.10	<0.05		<0.09		
Rosebay willow herb		1	<5.0	24	<0.50	0.51	0.06		<0.05		
Rosehips		1	<5.0	60	<0.50	0.36	<0.05		<0.13		
Grass		6	<5.0	<35	<1.4	<0.62	<0.07		<0.14	<6.2	150
Grass	max			54	3.3	1.3	0.12		<0.22	18	380
Soil		6	<5.5	<18	<2.6	1.1	5.6	0.64	<0.22	230	750
Soil	max		<7.6	35	4.5	2.1	12	0.87	0.26	400	2300

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

Table 5.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2003

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1 m over intertidal areas			
Heckies Hole	Sediment	2	0.086
Dunbar Inner Harbour	Sand	2	0.11
Belhaven Bay	Salt marsh	2	0.065
Barns Ness	Mud, sand and stones	2	0.066
Skateraw	Sand	2	0.059
Thornton Loch	Sand	2	0.057
St Abbs Head	Mud	2	0.096
Eyemouth	Mud	2	0.070
Mean beta dose rates on fishing gear			µSv h^{-1}
Cove	Lobster Pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

Table 5.11(c). Radioactivity in air near Torness, 2003

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Innerwick	10	<0.013	<0.0084	0.17
Cockburnspath	12	<0.010	<0.0081	0.20

Table 5.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs
Freshwater samples									
Brown trout	Lake	5		23		<0.15	2.5	<0.18	50
Rainbow trout	Lake	5				<0.09		<0.09	1.5
Perch	Lake	4				<0.14	1.1	<0.23	92
Rudd	Lake	1				<0.27		<0.28	53
Mud	Pipeline	1				39		12	3400
Sediment	Lake shore	2[E]				<1.0	2.0	2.3	1200
Sediment	Bailey Bridge	1[E]				<0.73	<1.0	<0.63	<2.5
Sediment	Fish farm	1[E]				19	25	6.0	1800
Sediment	Footbridge	2[E]				<1.2	<1.0	<1.0	180
Sediment	Cae Adda	2[E]				<0.88	<1.0	<0.95	100
Freshwater	Bailey Bridge	1	1.4						
Freshwater	Cold Lagoon	2						*	0.01
Freshwater	Public supply	2[E]	<4.0		<1.5	<0.32		<0.33	<0.28
Freshwater	Gwylan Stream	2[E]	<4.0		<1.5	<0.26		<0.22	<0.22
Freshwater	Diversion culvert	2[E]	<4.0		<1.5	<0.29		<0.22	<0.31
Freshwater	Hot Lagoon	2[E]	<4.0		<1.5	<0.24		<0.23	<0.32
Freshwater	Afon Prysor	2[E]	<4.0		<1.5	<0.32		<0.27	<0.29
Freshwater	Lake	2[E]	<4.0		<1.5	<0.32		<0.28	<0.31

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{154}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Freshwater samples									
Brown trout	Lake	5	<0.45	0.000080	0.00027	0.00041	0.000015		
Rainbow trout	Lake	5	<0.29			<0.26			
Perch	Lake	4	<0.49	0.000035	0.00011	0.00024	*		
Rudd	Lake	1	<0.81			<0.58			
Mud	Pipeline	1	18			92			
Sediment	Lake shore	2[E]		1.1	2.9	4.1		230	1700
Sediment	Bailey Bridge	1[E]		<0.090	0.24	<0.73			
Sediment	Fish farm	1[E]		22	54	91			
Sediment	Footbridge	2[E]		<1.2	1.6	<1.1			
Sediment	Cae Adda	2[E]		<0.50	0.48	<1.4			
Freshwater	Public supply	2[E]						<0.020	<0.10
Freshwater	Gwylan Stream	2[E]						<0.025	<0.10
Freshwater	Diversion culvert	2[E]						<0.020	<0.10
Freshwater	Hot Lagoon	2[E]						<0.020	<0.10
Freshwater	Afon Prysor	2[E]						<0.025	<0.10
Freshwater	Lake	2[E]						<0.020	<0.10

Table 5.12(a). continued

Material	Selection[b]	No. of sampling observ- ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs
Terrestrial Samples									
Milk		2	<3.5	19		<0.36	0.063		
Milk	max					<0.40	0.067		
Blackberries		1	<4.0	21	<0.30	<0.20		<0.30	0.70
Carrots		1	<2.0	10	<0.30	<0.40		<0.30	<0.40
Chicken		1	<5.0	22	<0.70	<0.30		<0.30	<0.40
Hazlenuts		1	<7.0	67	1.5	<1.4		<1.2	20
Ovine muscle		2	<2.0	31		<0.20	0.033		
Ovine muscle	max		2.0	38		<0.30	0.046		
Ovine offal		2	<3.0	36		<0.25	0.092		
Ovine offal	max			43		<0.30	0.096		
Potatoes		1	<2.0	40	<0.30	<0.30		<0.30	<0.30
Runner beans		1	<4.0	6.0	<0.30	<0.30		<0.20	<0.30

Material	Selection[b]	No. of sampling observ- ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			Total Cs	^{154}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial Samples							
Milk		2	0.25	<0.33			
Milk	max		0.38				
Blackberries		1		<0.30	0.00030	<0.00010	<0.00030
Carrots		1		<0.40	0.00020	0.0020	0.0068
Chicken		1		<0.30	0.00010	<0.00010	<0.00030
Hazlenuts		1		<2.0			
Ovine muscle		2	0.49	<0.25	<0.00010	<0.00015	<0.00030
Ovine muscle	max		0.65	<0.30	0.00010	<0.00020	0.00040
Ovine offal		2	0.35	<0.45	<0.00020	<0.00020	<0.00030
Ovine offal	max		0.39	<0.50	<0.00030	0.00020	0.00040
Potatoes		1		<0.30	<0.00020	0.00040	0.00040
Runner beans		1		<0.30			

* *Not detected by the method used*
[a] *Except for milk and water where units are Bq l^{-1}, and for sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 5.12(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2003

Location	Ground type	No. of sampling observa- tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Rock	2[F]	0.091
Footbridge	Grass	1	0.081
Footbridge	Pebbles and rock	1	0.11
Nant Islyn Bay	Stones	2[F]	0.094
West of footbridge	Stones	2[F]	0.093
Lake shore	Rock and stones	1	0.082
Lake shore	Pebbles and rock	1	0.091
Bailey Bridge	Rock	1	0.072
Bailey Bridge	Pebbles and rock	1	0.090
Fish Farm	Pebbles, rock and stones	1	0.10
Fish Farm	Pebbles and rock	1	0.10
Cae Adda	Grass	1	0.073
Cae Adda	Pebbles and rock	1	0.084

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 5.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{137}Cs
Marine samples								
Plaice	Pipeline	2	<25	<25	30	<0.05		1.9
Crabs	Pipeline	2				<0.06	7.8	0.51
Lobsters	Pipeline	2				<0.06	180	0.30
Winkles	Cemaes Bay	2	<25	<25	24	<0.07		0.35
Fucus vesiculosus	Cemaes Bay	2				<0.11	350	0.83
Seaweed	Cemaes Bay	2[E]				<1.5	560	<1.5
Sediment	Cemaes Bay	2[E]				<0.26		7.0
Sediment	Cemlyn Bay	2[E]				<0.59		<3.0
Seawater	Cemaes Bay	2[E]				<0.21		<0.27
Seawater	Cemlyn Bay	2[E]				<0.31		<0.30

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples									
Plaice	Pipeline	2				<0.10			
Crabs	Pipeline	2	0.0037	0.022		0.089	*		
Lobsters	Pipeline	2				<0.13			230
Winkles	Cemaes Bay	2	0.021	0.12	1.2	0.19	0.00017		
Fucus vesiculosus	Cemaes Bay	2				<0.28			510
Seaweed	Cemaes Bay	2[E]				<2.0			
Sediment	Cemaes Bay	2[E]				<0.35			
Sediment	Cemlyn Bay	2[E]				<0.99			
Seawater	Cemaes Bay	2[E]				<1.2		<1.4	6.6
Seawater	Cemlyn Bay	2[E]				<0.51		<1.7	4.5

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		5	<4.0	21	<0.51	<0.28	<0.25		
Milk	max		<4.4	23	<0.58	<0.33	<0.28		
Apples		1	<2.0	9.0	0.50	<0.20	<0.30		
Barley		1	<3.0	130	4.2	<0.20	<0.30		
Beetroot		1	4.0	10	0.40	<0.30	<0.30		
Blackberries		1	<2.0	25	0.80	<0.40	<0.30		
Broad beans		1	<2.0	41	1.9	<0.30	<0.40		
Honey		1	<3.0	110	<0.30	<0.20	<0.20		
Onions		1	<4.0	15	0.60	<0.50	<0.40		
Potatoes		1	<4.0	17	<0.30	<0.30	<0.20		
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.29	<0.23	<0.020	<0.10

* *Not detected by the method used*

[a] *Except for milk and water where units are Bq l^{-1}*

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 5.13(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2003

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Cemaes Bay	Sand	4[F]	0.054
Cemaes Bay	Sand	1	0.068
Cemaes Bay	Rock and sand	1	0.089
Cemlyn Bay	Pebbles	1	0.066
Cemlyn Bay	Pebbles and rock	1	0.070

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

6. DEFENCE ESTABLISHMENTS

Monitoring by the Environment Agency, Food Standards Agency and SEPA is undertaken routinely near nine defence-related establishments in the UK. Low-level gaseous discharges also occur from Burghfield in Berkshire and the operator carries out environmental monitoring at this site. Monitoring at nuclear submarine berths is also carried out by the MOD (DSTL, 2003).

6.1 Aldermaston, Berkshire

The Atomic Weapons Establishment (AWE) at Aldermaston is authorised to discharge low levels of radioactive waste to the environment. The site is authorised to discharge aqueous radioactive waste to the River Thames at Pangbourne, to the sewage works at Silchester and to Aldermaston Stream. Samples of milk, other terrestrial foodstuffs, freshwater, fish and sediments were collected. The sampling locations are shown in Figure 4.1. Monitoring of the aquatic environment at Newbridge is undertaken to indicate control or background levels upstream of the nearby Harwell site.

The results of measurements of radionuclides concentrations are shown in Tables 6.1(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low and similar to those for 2002. Levels of tritium were all below the LoD. Caesium-137 concentrations were detected in sediment from the Thames and water courses near the site and were similar to those observed in recent years. Currently, routine discharges from AWE do not include significant levels of radiocaesium. The presence of radiocaesium may be as a result of historical discharges or may be from other sources such as Harwell upstream on the Thames. A recent habit survey has established that the critical group affected by discharges into the river can be represented by anglers whose occupancy of the river bank has been assessed to estimate their external exposures. No consumption of freshwater fish has been established but the assessment has conservatively included consumption of fish at a low rate of 1 kg year^{-1}. The overall radiological significance of liquid discharges was very low: the radiation dose to anglers was much less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.2). The total alpha and beta activity concentrations in the freshwater samples were below the WHO screening levels. The drinking water pathway has been shown to be insignificant (Environment Agency, 2002a).

The concentrations of radioactivity in milk, vegetables, fruit and environmental indicator materials were also very low. Results for tritium, caesium-137, uranium and transuranic radionuclides were generally similar to those for 2002. Natural background or weapon test fallout would have made a significant contribution to the levels detected. There were increases in the reported results for caesium-137 and plutonium-239/240 in soils but the sampling locations were different from those in 2002. No conclusions as to trends in levels can therefore be made. Concentrations of uranium in soil were broadly similar to those found elsewhere in the area. Taking into account measured levels of plutonium and other radionuclides in local foodstuffs, the dose to consumers of local food in 2003, including contributions from the natural and fallout sources, was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

6.2 Barrow, Cumbria

The Environment Agency published proposals for revised controls and discharges of radioactive waste from BAE Systems Marine Limited at Barrow in 2003 (Environment Agency, 2003c) and the revised authorisation was issued in April 2004. Discharges from submarine related operations at the site are very low. The Food Standards Agency's monitoring of Barrow is limited to grass sampling. In 2003, no tritium activity was detected (Table 6.3(a)). Any significant effects of discharges from Barrow in the marine environment would be detected in the far-field monitoring of Sellafield (Section 3) and as such the aquatic programme for Barrow has been subsumed into the Sellafield programme. No such effects were found in 2003.

6.3 Derby, Derbyshire

Rolls-Royce Marine Power Operations Ltd. carries out design, development, testing and manufacture of nuclear-powered submarine fuel at its two adjacent sites in Derby. Small discharges of liquid effluent are made via the Magaloughton Sewage Treatment Works to the River Derwent and very low levels of alpha activity are present in releases to atmosphere. Other wastes are disposed of by transfer to other sites, including Drigg. The Environment Agency began a public consultation on proposals for the re-authorisation of disposals from the site in October 2003 (Environment Agency, 2003d).

Results of monitoring at Derby are presented in Table 6.3(a). Routine sampling and analysis of uranium activity in grass and soil samples taken around the site found levels broadly consistent with previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. The total alpha and beta activity levels in river water from the Derwent are less than the WHO screening levels for drinking water. Doses from use of water from the River Derwent as drinking water were much less than 0.005 mSv y^{-1} (Table 6.2).

Table 6.3(a) also includes the results of monitoring of water from Fritchley Brook, downstream of Hilts Quarry. Rolls Royce formerly used the quarry for controlled burial of solid low level radioactive waste. Isotopes of uranium detected in the stream water were at levels similar to those seen elsewhere in Derbyshire (e.g. Meerbrook Sough groundwater in Table 9.14).

6.4 Devonport, Devon

Discharges of liquid radioactive waste are made by Devonport Royal Dockyard Ltd. under authorisation by the Environment Agency and discharged by the MOD under administrative agreement with the Environment Agency into the Tamar Estuary. The Environment Agency is currently assessing the findings of a feasibility study submitted by the company into a range of options, including a pipeline out to sea, in respect of future disposal of liquid radioactive waste from the dockyard (Environment Agency, 2003f).

The routine monitoring programme in 2003 consisted of measurements of gamma dose rate and analysis of fish, shellfish, fruit, vegetables and sediments. The results given in Tables 6.3(a) and (b) were similar to those in 2002 where comparisons can be drawn. Trace quantities of fission and activation products and actinides were detected in the marine environment. The dose to the critical group for the marine environment taking account of consumption of marine foods and occupancy times was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.2). Similarly the dose to high- rate consumers of fruit and vegetables was less than 0.005 mSv. The radiological significance of this site continued to be low.

6.5 Faslane and Coulport, Argyll and Bute

The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport. During 2002, HMNB Clyde entered into a partnership with Babcock Naval Services (BNS), a subsidiary of Babcock Support Services Limited. The partnership has resulted in a high percentage of MOD civil servants transferring from Ministry of Defence to BNS. However, MOD remains in control of the undertaking, through the Director of the Naval Base Clyde, in relation to radioactive waste disposal.

The MOD plans to build a new effluent treatment plant at Faslane. The plant is scheduled for commissioning in 2006 and will replace the existing plant. An application for a new letter of agreement for the disposal of liquid and gaseous wastes from the new plant was submitted to SEPA in 2003.

Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the MOD. The discharges made during 2003 are shown in Appendix 1. The disposal of solid radioactive waste from each site is also made under letters of agreement between SEPA and the MOD. No disposals of solid waste were made from either site during 2003. This was due to the general embargo imposed by BNFL on the MOD(N) waste.

Habit surveys have been used to investigate exposure pathways. The most recent of which, conducted in 2000, identified fish consumption and external radiation from the shore as the major pathways of exposure. The scope of the monitoring programme reflects these pathways and included the analysis of seawater, sediment and fish samples. Results are given in Tables 6.3(a) and (b). These show that caesium-137 concentrations were consistent with the distant effects of discharges from Sellafield and weapons testing and Chernobyl fallout. Additionally, measurements of gamma dose rates made in the surrounding area were difficult to distinguish from natural background. Taking into account occupancy and consumption rate data from the 2000 habit survey, the dose to the critical group from external radiation and the consumption of fish was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.2).

6.6 Holy Loch, Argyll and Bute

A small programme of monitoring at Holy Loch continued in order to determine the effects of past discharges from the US submarine support facilities which closed in March 1992. Low levels of cobalt-60 detected in sediments from the Loch are due to these earlier operations. Measurements of gamma dose rates in intertidal areas were similar to those in 2002 (Table 6.3(b)). There was an increase in the detected activity of cobalt-60 in sediment from the loch but this is most likely to be due to sampling variability. The external radiation dose to the critical group was 0.009 mSv in 2003, which was about 1% of the dose limit for members of the public of 1 mSv (Table 6.2).

6.7 Rosyth, Fife

Following the Government decision to have nuclear submarine refit work carried out at Devonport, submarines are no longer re-equipped, maintained or refuelled at the Rosyth site. Rosyth Royal Dockyard has been contracted by the MOD to decontaminate and decommission the site.

The final nuclear powered submarine refit at Rosyth was completed in March 2003. This gave rise to the discharge of small quantities of liquid radioactive waste into the Forth Estuary. The discharges remained well within the authorised limits. Small gaseous discharges of argon-41 were also made within the limits of the certificate of authorisation. There were no disposals of low level solid waste as the embargo placed by BNFL on MOD(N) remained in force.

The routine SEPA monitoring programme included sampling and analysis of crabs, seaweed and sediment, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 6.3(a) and (b). The radioactivity levels detected were low, and in most part due to the combined effects of Sellafield, weapons testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background. The dose to the critical group of local fishermen in 2003 was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.2).

6.8 Vulcan NRTE, Highland

The Vulcan Nuclear Reactor Test Establishment operated by the Ministry of Defence (Procurement Executive) is located adjacent to the UKAEA Dounreay site and the impact of its discharges is considered along with those from Dounreay in Section 4.

Table 6.1(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples								
Pike	Newbridge	1	<25	<25	<0.03			
Pike	Outfall (Pangbourne)	1	<25	<25	0.17			
Pike	Staines	1	<25	<25	0.13			
Pike	Shepperton	1	<25	<25	0.14			
Pike	Teddington	1	<25	<25	0.14			
Flounder	Beckton	1		<25	0.18			
Signal crayfish	Thatcham	1	<25	<25	<0.14			
Nuphar lutea	Newbridge	1		<25	<0.05			
Nuphar lutea	Staines	1		<25	<0.04			
Clay	Outfall (Pangbourne)	1			1.2			
Sediment	Pangbourne	4[E]			19	7.9	<0.90	9.5
Sediment	Mapledurham	4[E]			20	10	<0.87	10
Sediment	Aldermaston	4[E]			6.0	15	<0.84	15
Sediment	Spring Lane	4[E]			<2.7	12	<0.81	11
Sediment	Stream draining south	4[E]			3.8	8.9	<0.94	10
Sediment	Reading (Kennet)	4[E]			6.7	13	<0.89	13
Gullypot sediment	Falcon Gate	1[E]		<25	5.5	21	<0.63	20
Gullypot sediment	Main Gate	1[E]		<25	<0.80	16	0.84	16
Gullypot sediment	Tadley Entrance	1[E]		<25	<1.6	22	0.85	22
Freshwater	Pangbourne	4[E]		<4.0	<0.18	0.017	<0.0055	<0.0085
Freshwater	Mapledurham	4[E]		<4.0	<0.19	<0.015	<0.0065	<0.012
Freshwater	Aldermaston	4[E]		8.4	<0.29	<0.016	<0.0058	<0.012
Freshwater	Spring Lane	4[E]		<4.0	<0.27	<0.011	<0.0070	<0.0095
Freshwater	Reading (Kennet)	4[E]		<4.0	<0.27	0.0077	<0.0060	<0.0080
Crude liquid effluent	Silchester treatment works	4[E]		<13	<0.74	<0.0070	<0.0062	<0.0070
Liquid effluent	Silchester treatment works	4[E]		<19	<0.24	<0.010	<0.0075	<0.023
Sewage sludge	Silchester treatment works	4[E]		<22	<0.45	0.059	<0.0065	0.061

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	Total alpha	Total beta
Freshwater samples							
Pike	Newbridge	1	0.000016	0.000028	0.000071		
Pike	Outfall (Pangbourne)	1	<0.0000079	0.000023	0.000051		
Pike	Staines	1			<0.13		
Pike	Shepperton	1			<0.04		
Pike	Teddington	1			<0.05		
Flounder	Beckton	1			<0.12		
Signal crayfish	Thatcham	1	<0.000049	0.00021	0.00063		
Nuphar lutea	Newbridge	1			<0.04		
Nuphar lutea	Staines	1			<0.03		
Clay	Outfall (Pangbourne)	1			<1.9		380
Sediment	Pangbourne	4[E]	<0.26	<0.46	<1.2	170	330
Sediment	Mapledurham	4[E]	<0.36	0.81	<1.2	150	330
Sediment	Aldermaston	4[E]	<0.41	2.9	<2.3	270	570
Sediment	Spring Lane	4[E]	<0.52	<1.2	<1.2	200	460
Sediment	Stream draining south	4[E]	<0.31	<0.61	<1.3	280	480
Sediment	Reading (Kennet)	4[E]	<0.40	<0.39	<1.3	210	360
Gullypot sediment	Falcon Gate	1[E]	<0.36	0.30	<2.1	400	510
Gullypot sediment	Main Gate	1[E]	<0.34	<0.25	<0.69	690	740
Gullypot sediment	Tadley Entrance	1[E]	<0.44	0.15	<1.5	370	530
Freshwater	Pangbourne	4[E]	<0.0063	<0.0047	<0.0060	<0.052	0.26
Freshwater	Mapledurham	4[E]	<0.033	<0.0065	<0.0060	<0.046	0.28
Freshwater	Aldermaston	4[E]	<0.0065	<0.0050	<0.0055	<0.027	0.18
Freshwater	Spring Lane	4[E]	<0.0072	<0.0055	<0.0058	<0.028	0.17
Freshwater	Reading (Kennet)	4[E]	<0.0068	<0.0052	<0.0075	<0.031	<0.12
Crude liquid effluent	Silchester treatment works	4[E]	<0.0075	<0.0055	<1.3	<0.055	0.40
Liquid effluent	Silchester treatment works	4[E]	<0.0075	<0.0052	<0.35	<0.060	0.54
Sewage sludge	Silchester treatment works	4[E]	<0.0075	<0.0050	<0.74	12	12

Table 6.1(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{137}Cs	Total U	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk		5	<4.1	<0.28	<0.0065			
Milk	max		<5.8	<0.30				
Blackberries		1	<4.0	<0.30	<0.028			
Carrots		1	<4.0	<0.30	0.079	0.022	0.0018	0.026
Honey		1	<6.0	<0.20	<0.024			
Lettuce		1	<4.0	<0.30				
Potatoes		1	<4.0	<0.20	<0.028			
Raspberries		1	<4.0	<0.20	<0.026			
Runner beans		1	<4.0	<0.30	<0.026			
Rabbit		1	<2.0	<0.30	<0.026	0.0077	<0.0012	0.015
Wheat		1	<6.0	<0.30	<0.026			
Grass	Location 5	1[E]	61	<8.1		0.39	<0.048	0.29
Soil	Location 5	1[E]	<25	200		15	<0.95	16
Soil	Location 8	1[E]	<25	130		14	0.60	15
Soil	Location 9	1[E]	<25	24		18	<0.82	18
Soil		4			60			
Soil	max				70	11	0.48	11

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha	Total beta
Terrestrial samples							
Milk		5	<0.00014	<0.00010	<0.00014		
Milk	max		<0.00020		0.00020		
Blackberries		1	0.00020	0.00010	0.00020		
Carrots		1	<0.00020	0.00040	0.00030		
Honey		1	<0.00040	<0.00020	0.00040		
Lettuce		1	<0.00030	0.00030	0.00030		
Potatoes		1	<0.00020	<0.00020	0.00050		
Raspberries		1	<0.00030	<0.00020	<0.00040		
Runner beans		1	<0.00010	<0.00010	<0.00020		
Rabbit		1	0.00080	<0.00050	0.00020		
Wheat		1	<0.00020	<0.00010	0.00020		
Grass	Location 5	1[E]	<0.34	0.13		<5.0	160
Soil	Location 5	1[E]	<1.0	2.1		190	500
Soil	Location 8	1[E]	<0.53	1.9		170	490
Soil	Location 9	1[E]	0.26	1.2		110	380

[a] *Except for milk, water and liquid effluent where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 6.1(b). Monitoring of radiation dose rates near Aldermaston, 2003

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over riverbank			
Pangbourne	Grass	2	0.064
Pangbourne	Grass and reeds	1	0.065
Pangbourne	Reeds	1	0.063
Mapledurham	Mud and grass	1	0.065
Mapledurham	Mud and stones	1	0.065
Mapledurham	Mud and pebbles	1	0.062
Mapledurham	Grass and stones	1	0.064

Table 6.2. Individual radiation exposures - defence sites, 2003

Site	Exposed population group[a]	Exposure mSv				
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment or water
Aldermaston	Anglers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Derby	Consumers of drinking water	<0.005	-	-	-	<0.005
Devonport	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-
Faslane	Seafood consumers	<0.005	<0.005	-	<0.005	-
Holy Loch	Anglers	0.009	-	-	0.009	-
Rosyth	Boat users	<0.005	-	-	<0.005	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*

Table 6.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2003

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{99}Tc	^{110m}Ag	^{125}Sb	^{137}Cs	^{155}Eu
Barrow												
Grass	Barrow	2[F]		<2.0								
Derby												
Mud	River Derwent, downstream	4				<0.99						
Mud	River Derwent, upstream	1				<0.37						
Water	River Derwent, downstream	4				<0.28						
Water	River Derwent, upstream	1				<0.24						
Water	Hilt's Quarry	1		<4.0		<0.12					<0.11	
Devonport												
Spurdog	Plymouth Sound	1[F]				<0.07	<0.21		<0.15	<0.17	0.18	<0.16
Crabs	Plymouth Sound	2[F]			19	<0.10	<0.23		<0.16	<0.19	<0.08	<0.15
Mussels	River Lynher	1[F]	<25	<25		<0.14	<0.34		<0.25	<0.33	<0.13	<0.23
Fucus vesiculosus	Kinterbury	2[F]				<0.13	<0.28	0.37	<0.19	<0.22	<0.10	<0.21
Mud[c]	Kinterbury	2[F]				<0.62	<1.5		<1.1	<1.6	3.3	<1.9
Sediment	Torpoint (South)	2		<15		<1.4					<2.0	
Sediment	Lopwell	2		<25		<2.4					<9.5	
Seawater	Torpoint (South)	2		<4.0	<4.0	<0.34						
Seawater	Millbrook Lake	2		<13	<4.0	<0.27						
Blackberries		1[F]		8.0		<0.30			<0.20		<0.30	
Courgettes		1[F]		5.0		<0.20			<0.30		<0.30	
Grass	Devonport	3[F]		<5.0		<0.43			<0.30		<0.33	
Grass	max					<0.60					<0.40	
Faslane												
Fish	Carnban boatyard	1				<0.12	<0.32		<0.14	<0.30	1.3	<0.29
Sediment	Carnban boatyard	2				<0.10	<0.13		<0.10	<0.14	5.7	0.90
Seawater	Carnban boatyard	1		2.4								
Holy Loch												
Sediment	Mid Loch	1				<0.10	<0.23		<0.10	<0.18	6.3	<0.28
Rosyth												
Crabs	East of dockyard	2				<0.10	<0.18		<0.10	<0.18	<0.11	<0.17
Fucus vesiculosus	East of dockyard	2				<0.10	<0.16		<0.10	<0.13	0.15	<0.16
Sediment	East of dockyard	2				<0.10	<0.23		<0.10	<0.18	4.1	0.41
Sediment	Port Edgar	2				<0.17	<0.43		<0.22	<0.43	25	<1.0
Sediment	West of dockyard	2				<0.10	<0.18		<0.10	<0.14	1.1	<0.26
Sediment	Blackness Castle	2				<0.10	<0.27		<0.12	<0.20	3.4	0.50
Sediment	Burntisland Bay	2				<0.10	<0.21		<0.10	<0.15	0.74	<0.51
Seawater	East of dockyard	1		<1.0								

Defence

Table 6.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{228}Th	^{230}Th	^{232}Th	Total U	^{234}U	^{235}U	^{238}U	^{241}Am	Total alpha	Total beta
Derby												
Mud	River Derwent, downstream	4					37	<1.3	35		490	640
Mud	River Derwent, upstream	1					15	<1.3	17		220	670
Grass		4[F]				0.41						
Grass	max					0.68	0.059	0.0034	0.044			
Soil		4[F]				120						
Soil	max					180	47	1.6	40			
Water	River Derwent, downstream	4									<0.053	0.29
Water	River Derwent, upstream	1									<0.030	0.12
Water	Hilt's Quarry	1	<0.0090	<0.0050	<0.0050		0.024	<0.0050	0.020		0.037	0.15
Devonport												
Spurdog	Plymouth Sound	1[F]								<0.20		
Crabs	Plymouth Sound	2[F]								<0.08		
Mussels	River Lynher	1[F]								<0.12		
Fucus vesiculosus	Kinterbury	2[F]								<0.23		
Mud[c]	Kinterbury	2[F]								0.15		
Faslane												
Fish	Carnban boatyard	1								<0.14		
Sediment	Carnban boatyard	2								<0.17		
Seawater	Carnban boatyard	1										
Holy Loch												
Sediment	Mid Loch	1								<0.25		
Rosyth												
Crabs	East of dockyard	2								<0.13		
Fucus vesiculosus	East of dockyard	2								<0.15		
Sediment	East of dockyard	2								<0.24		
Sediment	Port Edgar	2								2.4		
Sediment	West of dockyard	2								0.27		
Sediment	Blackness Castle	2								1.1		
Sediment	Burntisland Bay	2								<0.24		

[a] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*

[b] *Except for sediment and soil where dry concentrations apply, and for water where units are Bq l^{-1}*

[c] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.018, 0.40, and 0.0010 Bq kg^{-1} respectively*

[F] *Measurements are made on behalf of the environment agencies unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 6.3(b). Monitoring of radiation dose rates near defence establishments, 2003

Establishment	Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1 m over intertidal areas				
Devonport	Kinterbury	Mud	2[F]	0.077
Devonport	Torpoint South	Shale	1	0.12
Devonport	Torpoint South	Shale, mud and slate	1	0.11
Devonport	Lopwell	Mud	1	0.089
Devonport	Lopwell	Mud, rock and stones	1	0.093
Faslane	Gareloch Head	Mud, sand and stones	2	0.055
Faslane	Gulley Bridge Pier	Sand and stones	2	0.065
Faslane	Rhu	Gravel	2	0.077
Faslane	Rosneath	Sand and gravel	2	0.074
Faslane	Carnban boatyard	Mud and sand	2	0.083
Holy Loch	North Sandbank	Mud and sand	1	0.071
Holy Loch	Kilmun Pier	Sand and stones	1	0.079
Holy Loch	Mid-Loch	Sand	1	0.061
Rosyth	Blackness Castle	Mud and sand	2	<0.053
Rosyth	Burntisland Bay	Sand	2	<0.054
Rosyth	East of Dockyard	Sand	2	<0.057
Rosyth	Port Edgar	Mud	2	<0.060
Rosyth	West of Dockyard	Mud and sand	2	0.055

[F] *Measurements are made on behalf of the environment agencies unless labelled F. In that case they are made on behalf of the Food Standards Agency*

Defence

7. RADIOCHEMICAL PRODUCTION

Amersham plc* manufactures radioactively labelled materials for use in medicine, research and industry. The company's principal establishment is located in Amersham, Buckinghamshire and it also operates from Cardiff and on the Harwell site. The environmental effects of the Harwell facilities are covered by general monitoring of the Harwell site (Section 4). The Environment Agency has considered applications by Amersham plc to change its authorisations at the Amersham and Cardiff sites and, in June 2003, forwarded proposals for significantly more rigorous authorisations for the Cardiff site to the Welsh Assembly Government. New authorisations for both Amersham sites (Cardiff and Buckinghamshire) were introduced in 2004 (Environment Agency, 2004e).

In February 2004, the Environment Agency launched a consultation exercise to consider an application from Amersham plc to vary the authorisation it holds for disposals from the Harwell site (Environment Agency, 2004c). The application reflects the progressive reductions in the company's operations involving radioactivity at the site and the extensive programme to decommission redundant facilities on the site.

7.1 Grove Centre, Amersham, Buckinghamshire

Discharges of liquid radioactive wastes are made under authorisation to sewers serving the Maple Lodge sewage works; releases enter the Grand Union Canal and the River Colne. Discharges of gaseous wastes are also authorised. The routine monitoring programme consists of analysis of fish, milk, crops, water, sediments and environmental materials. The monitoring locations are shown in Figure 4.1. Monitoring at Newbridge, well upstream on the Thames, acts as a control site and gives an indication of background levels in the catchment.

The results are presented in Tables 7.1(a) and (b). The concentration of carbon-14 in fish was typical of the background level and its radiological significance was low. Tritium concentrations in biota in the Thames and the Grand Union Canal were at the LoD. Concentrations in material from Maple Lodge Sewage Works were lower than in 2002. Total alpha and beta activities in water were below the WHO screening levels. The caesium-137 detected in mud from the canal is unlikely to be due to discharges from Amersham. The relatively high concentration of iodine-131 reported (<550 Bq kg^{-1}) is due to a large decay correction being applied to the result at the time a sample was measured. The actual level is likely to be very much lower. Because the site discharges very little of this radionuclide, it is unlikely that the enhanced concentrations of iodine-131 come from the Grove Centre site. Gamma dose rates above the banks of the canal were indistinguishable from background.

The activity concentrations in milk and crops were generally lower than the limits of detection. However, low levels of tritium and sulphur-35 were detected in a few samples.

Habits surveys have identified anglers as the critical group affected by discharges into the canal/river system. Their occupancy of the river bank has been assessed to estimate their external exposures. Even though there was no evidence of local consumption of freshwater fish, it is considered prudent to include a component in the assessment of the anglers' exposure. A consumption rate for fish of 1 kg $year^{-1}$ was therefore assumed. The anglers' dose in 2003 was less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 7.2).

The dose to the critical group of terrestrial food consumers was assessed as being less than 0.005 mSv, which was also less than 0.5% of the dose limit for members of the public.

Radiochemical

* *Amersham plc was bought by General Electrics (GE) on 8th April 2004 and trades under the name of GE Healthcare Biosciences, although Amersham plc remains its registered name.*

7.2 Maynard Centre, Cardiff, South Glamorgan

A second laboratory, situated near Cardiff, produces radiolabelled compounds used in research and diagnostic kits used in medicine for the testing of clinical samples and radio-pharmaceuticals. Liquid wastes are discharged into the Ystradyfodwg and Pontypridd public sewer (YP). This joins the Cardiff East sewer, which after passing through a new waste water treatment works, discharges into the Severn estuary at Orchard Ledges. During periods of high rainfall, effluent from the YP sewer has been known to overflow into the River Taff. In addition, there is run-off from the site into the river. OrthoClinical Diagnostics Ltd. also makes small discharges from the site.

Routine monitoring, carried out on behalf of the Welsh Assembly Government, includes consideration of consumption of locally produced food and external exposure over muddy, intertidal areas (Figure 7.1). Measurements of external exposure are supported by analyses of intertidal sediment. Environmental materials including seawater, freshwater, *Fucus* seaweed, soil and grass provide additional information. Earlier monitoring and research has targeted organic tritium in foodstuffs (Food Standards Agency, 2001a, Swift, 2001, Williams *et al.*, 2001, Leonard *et al.*, 2001 and McCubbin *et al.*, 2001). A full review of monitoring data for tritium bioaccumulation has been undertaken (Rowe *et al*., 2001). A local habits survey was completed in 2003 and the assessment of exposures given below takes the results into account.

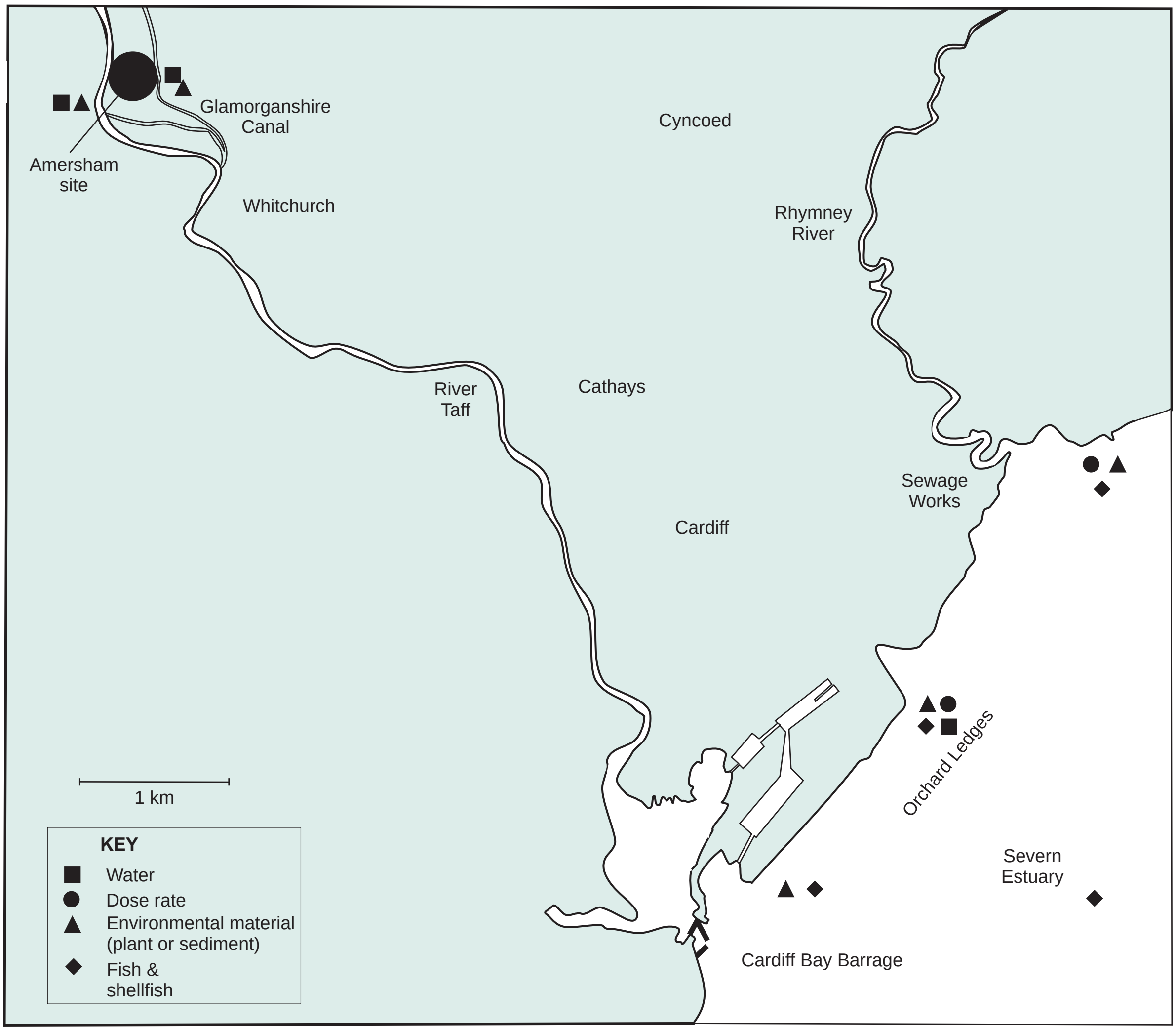

Figure 7.1 Monitoring locations at Cardiff (excluding farms)

The results of routine monitoring in 2003 are presented in Tables 7.3(a) and (b). The main effect of liquid discharges is seen in enhanced tritium and carbon-14 activities in samples above background levels. The results of sample analyses show that up to 90% of the total tritium in marine samples was associated with organic matter. This form of tritium is strongly bound to organic matter and has the potential to transfer through the marine foodchain from small organisms to accumulate in fish. The dose coefficients for this form of tritium differ from those for tritiated water (see Appendix 5) and the estimates of dose for members of the public take this into account. The trends in concentrations of tritium and carbon-14 in seafood and their relationship to discharges are shown in Figures 7.2 and 7.3.

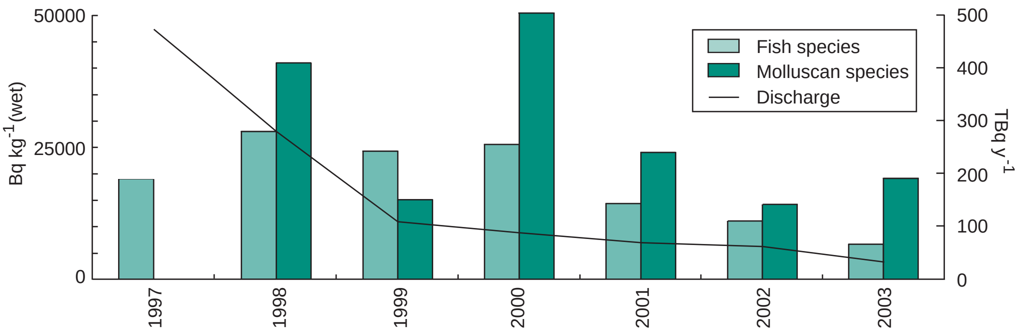

Figure 7.2 Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in Table 7.3 of this report and corresponding tables in previous reports)

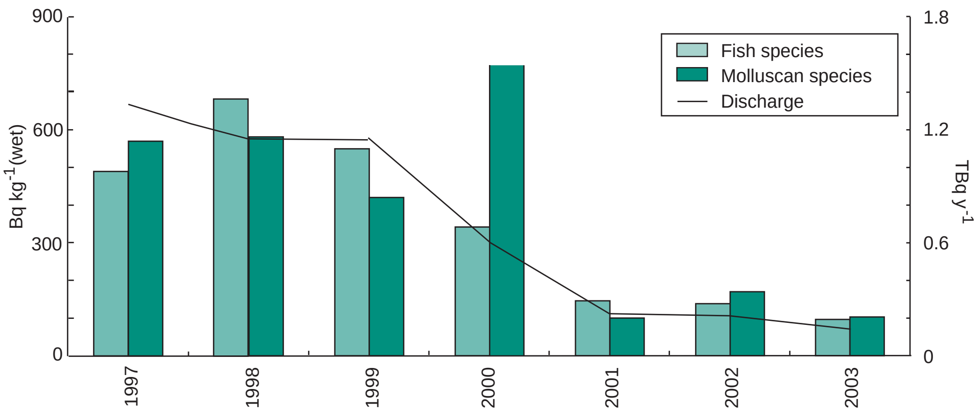

Figure 7.3 Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in Table 7.3 of this report and corresponding tables in previous reports)

In April 2004, the Environment Agency issued a new authorisation for the site requiring the introduction of technology, which should reduce discharges of tritium and carbon-14 in future. Amersham plc have begun work on new treatment plant (project Paragon). At present some tritium effluent, which includes a significant proportion of the organic form, is withheld and stored on site pending the introduction of the plant. Once the new plant is commissioned, both the stored waste and future discharges will be treated where possible. This will significantly reduce the tritium and carbon-14. The current levels of discharge will be maintained until the end of 2005 (the plant commissioning date) but with a greatly reduced organic fraction.

7. Radiochemical production

Tritium continued to be detected in water from the River Taff and the Glamorganshire Canal. Concentrations in run-off from the site into the River Taff increased in 2003 from <25 (2002) to 220 Bq l^{-1}. The reported result for 2003 is an average of analyses on two samples with concentrations of 4 and 440 Bq l^{-1}. Further information on tritium levels in seawater and at other nuclear sites in the Bristol Channel can be found in Sections 5 and 9.

Concentrations of other radionuclides in aquatic samples were low and can largely be explained by other sources such as Chernobyl and weapon test fallout and discharges from other establishments. Gamma and beta dose rates over sediment, as measured using portable instruments, were generally difficult to distinguish from those expected from the natural background. The dose to the critical group of fish and shellfish consumers based on the current ICRP recommended dose coefficient for organic tritium was 0.024 mSv which was less than 3% of the dose limit for members of the public of 1 mSv (Table 7.2). This estimate includes a small contribution due to external radiation. The dose in 2002 was 0.031 mSv and was 0.036 mSv in 2001. For anglers on the banks of the River Taff, the dose from inadvertently ingesting sediment and water was estimated to be much less than 0.005 mSv.

The habits survey in 2003 identified consumers of wildfowl collected near Cardiff. Although samples of wildfowl were not monitored in 2003, an assessment has been undertaken making use of data from an earlier RIFE report when levels in the aquatic environment were much the same as in 2003 (Food Standards Agency and Scottish Environment Protection Agency, 2000). The dose from high-rate consumption of wildfowl based on current consumption data was less than 0.005 mSv.

The main effects of gaseous discharges were also seen in results for tritium and carbon-14. The incidence of detection of enhanced carbon-14 and tritium activities in a wide range of terrestrial samples is relatively high in comparison with other nuclear sites. Sulphur-35 was detected at levels similar to those found in the general diet survey (see Section 9). All these measurements were of low radiological significance.

The maximum estimated dose to local terrestrial food consumers was to the 1-year-old age group. This critical group received 0.016 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv. The largest contribution was from carbon-14 in milk. The estimate includes a small contribution from modelled concentrations of radionuclides in air (Appendix 2).

Table 7.1(a). Concentrations of radionuclides in food and the environment near Amersham, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{32}P	^{35}S	^{57}Co	^{65}Zn
Freshwater samples									
Pike	Newbridge	1	<25	<25				<0.03	<0.10
Pike	Outfall (Grand Union Canal)	1	<25	<25	21			<0.02	<0.12
Pike	Staines	1	<25	<25				<0.03	<0.14
Pike	Shepperton	1	<25	<25				<0.02	<0.10
Pike	Teddington	1	<25	<25				<0.02	<0.14
Flounder	Beckton	1		<25				<0.03	<0.11
Nuphar lutea	Newbridge	1		<25				<0.02	<0.12
Nuphar lutea	Outfall (Grand Union Canal)	1		<25				0.15	0.36
Nuphar lutea	Staines	1		<25				<0.02	<0.11
Mud	Outfall (Grand Union Canal)	1						<0.49	<1.2
Sediment	Outfall (Grand Union Canal)	3[E]			<25			<0.30	<1.4
Freshwater	Maple Cross	4[E]		<4.0	<4.0				
Crude effluent	Maple Lodge Sewage Treatment Works	4[E]	<4.0	<49		<2.9	<1.5	<1.0	<1.1
Digested sludge	Maple Lodge Sewage Treatment Works	4[E]	<4.4	<26		<2.9	<1.9	<0.64	<0.68
Final effluent	Maple Lodge Sewage Treatment Works	4[E]	<4.0	<5.3		<3.6	<1.5	<0.56	<0.71

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{125}I	^{131}I	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Tota alpha	Total beta
Freshwater samples										
Pike	Newbridge	1		*	<0.03	0.000016	0.000028	0.000071		
Pike	Outfall (Grand Union Canal)	1		*	0.28			<0.05		
Pike	Staines	1		*	0.13			<0.13		
Pike	Shepperton	1		*	0.14			<0.04		
Pike	Teddington	1		*	0.14			<0.05		
Flounder	Beckton	1		*	0.18			<0.12		
Nuphar lutea	Newbridge	1		*	<0.05			<0.04		
Nuphar lutea	Outfall (Grand Union Canal)	1		*	<0.05			<0.05		
Nuphar lutea	Staines	1		<0.91	<0.04			<0.03		
Mud	Outfall (Grand Union Canal)	1		*	30			<2.0		380
Sediment	Outfall (Grand Union Canal)	3[E]	<0.97	<550	<1.9				170	260
Freshwater	Maple Cross	4[E]	<0.26	<4.8	<0.37				<0.052	0.42
Crude effluent	Maple Lodge Sewage Treatment Works	4[E]	<0.25		<0.33			<0.58	<1.8	2.9
Digested sludge	Maple Lodge Sewage Treatment Works	4[E]	<0.20		<0.23			<0.32	<2.5	2.7
Final effluent	Maple Lodge Sewage Treatment Works	4[E]	<0.19		<0.23			<0.31	<0.11	1.0

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{35}S	^{75}Se	^{125}I	^{131}I	^{137}Cs
Terrestrial samples								
Milk		2	<3.5	<0.53	<0.34	<0.043	<0.014	<0.25
Milk	max		<4.0	<0.55	<0.35	<0.045	<0.017	
Apples		1	6.0	<0.40	<0.20	<0.041		<0.20
Blackberries		2	7.0	<2.0	<0.30	<0.046		<0.25
Blackberries	max		10	3.6	<0.40	<0.056		<0.30
Onions		1	<4.0	<0.40	<0.30	<0.031		<0.30
Potatoes		1	6.0	0.50	<0.30	<0.052		<0.30
Runner beans		1	<4.0	<0.40	<0.20	<0.035		<0.20
Spinach		1	<4.0	<0.40	<0.40	<0.037		<0.30
Wheat		1	11	0.90	<0.20	<0.030		<0.30

** Not detected by the method used*

[a] *Except for milk, water and effluent where units are Bq l^{-1} and for sediment where dry concentrations apply*

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 7.1(b). Monitoring of radiation dose rates near Amersham, 2003

Location	Ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m			
Grand Union Canal	Grass and mud	1	0.056
Grand Union Canal	Grass and stones	1	0.051
Grand Union Canal	Grass	1	0.055
Grand Union Canal	NA	1	0.054

NA Not available

Table 7.2. Individual radiation exposures – radiochemical sites, 2003

Site	Exposed population group[a]	Exposure mSv					
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment or water	Gaseous plume related pathways
Amersham	Anglers	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-	-
Cardiff	Seafood consumers	0.024	0.022	-	<0.005	-	-
	Recreational users of River Taff	<0.005	-	-	-	<0.005	-
	Wildfowl consumers	<0.005	-	<0.005	-	-	-
	Consumers of locally grown food[b]	0.016	-	0.012	-	-	<0.005

[a] *Adults are the most exposed group unless stated otherwise*
[b] *Children aged 1y*

Table 7.3(a). Concentrations of radionuclides in food and the environment near Cardiff, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{99}Tc	^{125}I	^{131}I	^{134}Cs	^{137}Cs
Marine samples										
Flounder	East of new pipeline	2	14000	15000	180			*	<0.05	0.45
Sole	East of new pipeline	2		17000	190			*	<0.12	0.36
Mullet	East of new pipeline	1		270	38			*	<0.05	0.31
Whiting	East of new pipeline	1		1600	66			*	<0.11	0.43
Lesser spotted dogfish	Off Orchard Ledges	2	1700	2100	50			*	<0.13	0.48
Skates/Rays	Off Orchard Ledges	2	4100	3300	61			*	<0.06	0.65
Mussels	Orchard Ledges	2	19000	19000	100			<0.46	<0.11	0.27
Fucus vesiculosus	Orchard Ledges	2	450	440	11			<4.0	<0.11	0.68
Seaweed	Orchard Ledges	2[E]		87	<26	15	<8.0			
Mud	Orchard Ledges East	2	210	260	17			<4.8	2.0	28
Sediment	East of new pipeline	2[E]		<68	<25		<1.3			<8.3
Sediment	West of new pipeline	2[E]		120	<25		<1.2			25
Seawater	Orchard Ledges East	2		5.9						
Seawater	Orchard Ledges	2[E]	4.8	6.5	<4.0		<0.27			

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{32}P	^{35}S	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples													
Milk		7	<9.0	<15	22	<0.23	<0.39	<0.043		<0.25	<0.26		
Milk	max		<19	36	27		0.53	<0.051		<0.30	<0.30		
Barley		1		<3.0	120		1.1	<0.032		<0.30	<0.40		
Cabbage		1	15	38	3.0		<0.50	<0.042		<0.20	<0.30		
Honey		1		11	110		0.40	<0.014		<0.20	<0.20		
Potatoes		1	10	42	25		0.40	<0.045		<0.20	<0.20		
Rape oil		1		7.0	120		<0.90	<0.036		<0.20	<0.30		
Raspberries		1	18	120	16		<0.30	<0.086		<0.30	<0.30		
Strawberries		1	15	49	17		<0.40	<0.037		<0.20	0.30		
Swede		1	7.0	29	11		<0.30	<0.057		<0.30	<0.30		
Grass		5	130	220	51					<0.33	<0.33		
	max		320	410	59					<0.50	<0.50		
Silage		2	<4.0	<4.0	41								
	max				45								
Soil		3								<0.40	8.8		
	max										11		
Sediment	Canal	1[E]		100	<25			<1.2			13		
Freshwater	Run off into River Taff	2[E]	<200	220	<4.0			<0.19	<0.43		<0.18	<0.030	0.29
Freshwater	Canal	2[E]	21	31	<4.0			<0.19	<15		<0.18	<0.035	<0.07
Freshwater	River Taff	2[E]	<4.0	<13	<4.0			<0.21	<0.60		<0.38	<0.025	0.23

* *Not detected by the method used*

[a] *Except for milk and water where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 7.3(b). Monitoring of radiation dose rates near Cardiff, 2003

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Orchard Ledges East	Mud	2[F]	0.076
East of Pipeline	Mud, pebbles and rock	1	0.073
East of Pipeline	NA	1	0.076
West of Pipeline	NA	2	0.10
Beta dose rates			µSv h^{-1}
Orchard Ledges East	Mud	2[F]	*

* *Not detected by the method used*

NA Not available

[F] *Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

8. INDUSTRIAL AND LANDFILL SITES

This section considers the effects of the main disposal site on land for solid radioactive wastes in the UK, Drigg in Cumbria, as well as other landfill sites receiving small quantities of solid wastes and industrial sites which discharge small amounts of liquid or gaseous radioactive wastes. Solid wastes are also disposed of on site at Dounreay (Section 4).

8.1 Drigg, Cumbria

The main function of the Drigg site is to receive low level solid radioactive wastes from Sellafield and other UK sites and to dispose of them in vaults on land. It is operated by BNFL.

In January 2000, the Environment Agency issued a Variation Notice to the existing authorisation for the disposal of solid waste requiring environmental safety cases to be produced by BNFL. The Company has now submitted a Post-Closure Safety Case and an Operational Environmental Safety Case and the Environment Agency has started a comprehensive assessment of the information submitted (Environment Agency, 2003g). This will inform a review of the current authorisation and future regulations of radioactive waste disposal at Drigg. The review is expected to start in autumn 2004 with public consultation in early 2005.

The current disposal authorisation allows for the discharge of leachate from the trenches through a marine pipeline. The limits for activity to be discharged through the marine pipeline and for concentrations of residual activity in the Drigg Stream are given in Appendix 1. These discharges are small compared with those discharged from the nearby Sellafield site. Marine monitoring of the Drigg site is therefore subsumed within the Sellafield programme that is described in Section 3. The contribution to exposures due to Drigg discharges is negligible compared with that attributable to Sellafield and any effects of Drigg discharges in the marine environment could not, in 2003, be distinguished from those due to Sellafield.

The results of analyses of spot samples of water and sediment taken from the Drigg stream are given in Table 8.1. The concentrations of total alpha and beta activity were significantly below the limits specified in the authorisation. The total beta concentrations were similar to the WHO screening levels for drinking water. Although the stream is not known to be used as a source of drinking water, it is possible that occasional use by, for example, campers could take place. If the stream was used as a drinking water supply for three weeks, the dose would be less than 0.005 mSv. Radionuclide concentrations in sediment from the Drigg stream were similar to those for 2002 (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2003). They reflect the legacy of direct discharges of leachate from the disposal site into the stream (BNFL, 2002). This practice stopped in 1991.

In the past, groundwater from some of the trenches on the Drigg site moved eastwards towards a railway drain along the perimeter of the site. Radioactivity from Drigg was detected in the drain water. BNFL took steps in the early 1990s to reduce ingress of water into the trenches and built a "curtain wall" to reduce lateral migration of leachate into the drain. The results of monitoring in the drain show that levels of radioactivity are now very low and have reduced significantly since the curtain wall was constructed. The concentrations of total alpha and total beta activity were similar to those for 2002 and were approximately the same as WHO screening values. Low concentrations of tritium were detected.

A 1971 generic authorisation allows BNFL to discharge aerial effluents from its sites. This includes adventitious releases from Drigg. These releases are very low level. As such the monitoring programme of terrestrial foodstuffs at Drigg is primarily directed at the potential migration of radionuclides from the waste burial site via ground water.

Results for 2003 are given in Table 8.1. Evidence in support of the proposition that radioactivity in Drigg leachate might be transferring to foods was very limited. In general, concentrations of radionuclides detected were similar to or lower than those found near Sellafield (Section 3). The radiation dose to the critical group, including a component due to Chernobyl and weapon test fallout, was 0.046 mSv which was less than 5% of the dose limit for members of the public of 1 mSv (Table 8.2). In 2003, there was no direct data available for ruthenium-106 in grass, which is used to model the estimated concentration of ruthenium-106 in milk (see Appendix 2). Without this data the 2003 assessment of dose has had to use results for ruthenium-106 at the LoD although the actual concentration is likely to be much lower. Therefore, the increase over 2002 (0.017 mSv) is an overestimate.

8.2 Other landfill sites

Some organisations are authorised by SEPA in Scotland or the Environment Agency in England and Wales to dispose of solid wastes containing low levels of radioactivity to approved landfill sites. Waste with very low levels of radioactivity can also be disposed of in general refuse. Radioactivity in wastes can migrate into leachate and in some cases can enter the groundwater. Monitoring of leachates is carried out by SEPA and the Environment Agency and the results are presented in Tables 8.3 and 8.4. The results, in common with previous years, show very low levels of caesium-137 in leachate and evidence for migration of tritium from some of the discharge sites. The reported tritium concentrations vary from year to year. The variation is thought to be related to changes in rainfall quantity and resulting leachate production and the use of different boreholes for sampling. A possible source of the tritium is thought to be due to disposal of Gaseous Tritium Light Devices (Mobbs *et al.*, 1998). Inadvertent ingestion of leachate (2.5 l y^{-1}) from the site with the highest observed concentration of tritium (Aberdeen) would result in a dose of less than 0.005 mSv or less than 0.5% of the dose limit for members of the public of 1 mSv (Table 8.2).

Levels of uranium isotopes enhanced above natural background levels were found in water samples taken from near the Rhodia Consumer Specialities Ltd. site in Cumbria. This could be due to the historical operations involving the manufacture of phosphoric acid from phosphate ore, which resulted in the discharge of phosphogypsum as liquid slurry containing thorium and uranium. The levels are significantly less than Generalised Derived Limits (GDL) for freshwater (the GDL for each uranium isotope is 20 Bq kg^{-1} (Harvey *et al.*, 2000)). Surface waters from this site are not known to be used as a source of drinking water.

8.3 Rhodia Consumer Specialties Ltd., Whitehaven, Cumbria

Previous surveys (Rollo *et al.*, 1992) have established that an important man-made source of natural radionuclides in the marine environment has been the Rhodia Consumer Specialties Ltd. (formerly Albright and Wilson) chemical plant at Whitehaven in Cumbria which used to manufacture phosphoric acid from imported phosphate ore. Phosphogypsum, containing thorium, uranium and their daughter products, was discharged as a liquid slurry by pipeline to Saltom Bay. Processing of phosphate ore ceased in 1992 and processing of phosphoric acid at the plant ceased at the end of 2001. However, there is an environmental legacy from past operations. Such sources are said to give rise to TNORM (Technologically enhanced Naturally Occurring Radioactive Material). Decommissioning of the plant was undertaken in 2002 and released small quantities of uranium to sea, but discharges were very much lower than in previous years. During 2003, no discharges were reported under the authorisation and demolition of the plant began. Early in 2004, the operator began preparing for revocation of the authorisation.

The results of routine monitoring for natural radioactivity near the site in 2003 are shown in Table 8.5. Analytical effort has focused on lead-210 and polonium-210 that concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other natural radionuclides are slightly enhanced near Whitehaven but quickly reduce to background levels further away. Figure 8.1 shows how concentrations of polonium-210 in winkles have decreased substantially since 1990, and more dramatically since 1992. It also demonstrates the seasonal variations in concentrations that have been previously observed (Rollo *et al.*, 1992). Concentrations of lead-210 and polonium-210 were generally similar to those in 2002. Taking into account the ranges of values observed, it is difficult to distinguish the measured total concentrations from those expected due to natural sources. Estimates of concentrations due to natural sources are given in Appendix 6. However,

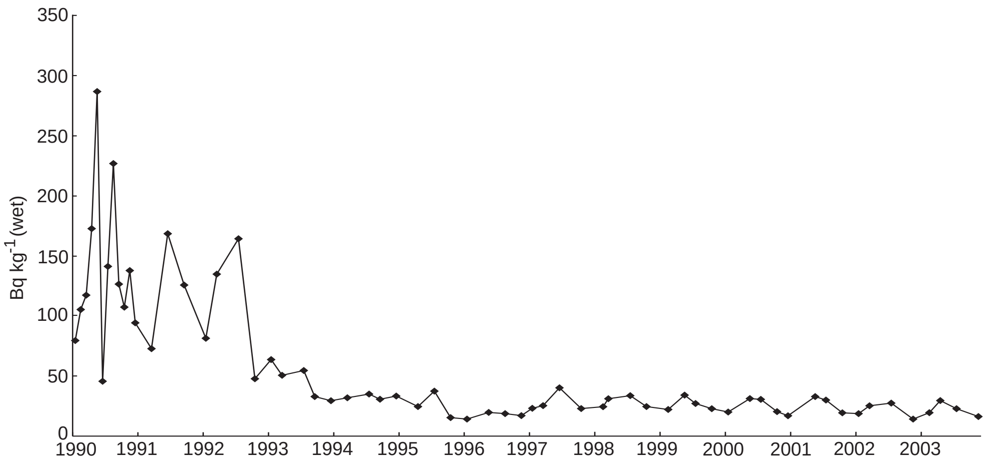

Figure 8.1 Polonium-210 in Parton winkles

there were small enhancements for some radionuclides and marine species and it is these that form the basis of the dose assessment.

The critical radiation exposure pathway is internal irradiation, due to the ingestion of natural radioactivity in local fish and shellfish. A single group of high-rate consumers is considered in this report. Centred on the Sellafield site to the south of Whitehaven it includes activities relating to the immediate area around Whitehaven, including Saltom Bay and Parton. It is identical to the group used to assess the impact of the Sellafield site (Section 3). An additional, smaller group limited to the immediate area around Saltom Bay is no longer assessed separately because the larger group provides adequate protection and a more robust assessment. An estimated contribution due to background levels of natural radionuclides has been subtracted. Consumption rates for the critical group were reviewed and revised in 2003. The assessment is based on averaging the consumption rates over a five year period from 1999-2003. Dose coefficients for polonium-210 were updated in 2003 to reflect new results from research involving the consumption of mussels containing natural levels of polonium-210 (Appendix 5). We have retained the conservative assumption that a high gut transfer factor of 0.8 applies to seafood generally, but have adopted a value of 0.5 for mussels.

The critical group dose from enhanced natural radionuclides (TNORM) was 0.41 mSv in 2003, similar to the estimate for 2002 of 0.42 mSv (Table 8.2). The fish and shellfish consumed also contained artificial radionuclides due to Sellafield discharges. The additional exposure due to artificial radionuclides has been calculated using data from Section 3. In 2003, these exposures added a further 0.21 mSv to the doses above resulting in a total dose to this group of up to 0.62 mSv. The estimated doses in 2003 are therefore below the dose limit for members of the public of 1 mSv.

8.4 Other industrial sites

Levels of radionuclides in gaseous discharges from some other industrial activities also have the potential to raise the radionuclide concentrations in foodstuffs. Examples of such activities are combustion of fossil fuels and waste incineration. Since 1991, a small routine rolling programme to examine the effects of these activities has been carried out. In 2003, five sites were chosen for study. In summary, the sites were:

- Beckenham, Kent (pharmaceutical research)
- Chilton, Oxfordshire (radiological protection)
- Norwich, Norfolk (food research)
- Southampton, Hampshire (hospital)
- Torbay, Devon (hospital)

8. Industrial and landfill sites

The results of the sampling of vegetables, grass, soil, environmental materials and rabbits in 2003 are given in Table 8.6 for all five sites.

In addition, a special sampling exercise was undertaken in July 2003 at Avonmouth where a radiolabelling facility had an unauthorised release of tritium. Samples of local blackberries and grass were taken and analysed for tritium and a range of radionuclides by gamma spectrometry. The results are also given in Table 8.6

There is considerable variability in the concentrations of natural radionuclides in the terrestrial environment. It is therefore difficult to draw firm conclusions about the possible effects of man-made sources on enhancements of natural radionuclides. With this proviso, it was concluded that in 2003 the concentration of natural radionuclides observed at industrial sites were within the ranges expected for natural sources. The concentrations of man-made radionuclides in samples were all low and of negligible radiological significance. Although there was no evidence for consumption of rabbits sampled near the sites, estimated doses included rabbit consumption and were all less than 0.005 mSv (Table 8.2). No enhancement of tritium or gamma emitting radionuclides was detected at Avonmouth.

Table 8.1. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2003

Material	Location or selection[a]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1} ^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk		1	<3.8	19	<0.43	<0.29	0.082	<0.0065	<1.9	<0.50	<0.013
Blackberries		1	9.0	17	<0.30	<0.30	0.63		<2.8	<0.70	<0.029
Eggs		1	6.0	42	<0.80	<0.20	0.042		<2.4	<0.80	<0.033
Mushrooms		1	13	<5.0	<0.40	<0.30	0.22	<0.034	<1.6	<0.50	<0.022
Ovine muscle		1	<2.0	65	1.4	<0.40	0.043	<0.032	<2.3	<0.70	<0.021
Ovine offal		1	4.0	33	1.9	<0.20	0.027	<0.025	<2.0	<0.80	<0.034
Potatoes		1	5.0	26	<0.30	<0.30	0.039	<0.072	<1.8	<0.60	<0.029
Turnips		1	2.0	9.0	<0.30	<0.30	0.36		<1.8	<0.70	<0.019
Grass		2						<0.054			
Grass	max							0.072			
Sediment	Drigg Stream	4[E]				<1.2	<9.5		<5.4	<4.3	
Freshwater	Drigg Stream	4[E]	<17			<0.27	0.18				
Freshwater	Railway Drain	1[E]	22			<0.28	0.69				

Material	Location or selection[a]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1} ^{134}Cs	^{137}Cs	Total Cs	^{210}Po	^{228}Th	^{230}Th	^{232}Th
Milk		1	<0.27	<0.28	0.24				
Blackberries		1			0.14				
Eggs		1			<0.034				
Mushrooms		1			0.36				
Ovine muscle		1			2.0				
Ovine offal		1			1.6				
Potatoes		1			0.29				
Turnips		1			0.25				
Sediment	Drigg Stream	4[E]	<0.67	240		13	22	46	19
Freshwater	Drigg Stream	4[E]	<0.26	<0.30		<0.0088	<0.0070	<0.0058	<0.0050
Freshwater	Railway Drain	1[E]	<0.18	<0.37		<0.0090	<0.0080	<0.0050	<0.0050

Material	Location or selection[a]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1} ^{234}U	^{235}U	^{238}U	Total U	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Pu	^{241}Am	Total alpha	Total beta
Milk		1					<0.00018	<0.00020	<0.051	0.00038		
Blackberries		1					<0.00030	<0.00020	<0.060	0.0010		
Eggs		1				<0.026	<0.00060	0.00020	<0.058	0.00040		
Mushrooms		1					0.0029	0.020	0.092	0.032		
Ovine muscle		1					<0.00050	<0.00030	<0.092	0.00020		
Ovine offal		1					<0.00080	<0.00050	<0.15	0.00090		
Potatoes		1					<0.00040	0.00010	<0.091	<0.00020		
Turnips		1					<0.00040	0.00020	<0.091	0.00030		
Grass		2				<0.050						
Grass	max		0.037	0.0017	0.036	0.073						
Soil		2				34						
Soil	max		6.7	0.26	6.7	38						
Sediment	Drigg Stream	4[E]	24	<1.1	24		5.5	27	260	28	460	1200
Freshwater	Drigg Stream	4[E]	<0.0095	<0.0053	<0.012		<0.014	<0.0068	<1.1	<0.0085	<0.48	1.6
Freshwater	Railway Drain	1[E]	0.022	<0.0050	0.023		<0.010	<0.0050	<0.60	<0.0070	0.078	2.3

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[b] *Except for milk and freshwater where units are Bq l^{-1}, and for sediment and soil where dry concentrations apply*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 8.2. Individual radiation exposures – industrial and landfill sites, 2003

Site	Exposed population group[a]	Exposure mSv					
		Total	Seafood (nuclear industry discharges)	Seafood (other discharges)	Other local food	External radiation from intertidal areas	Intakes of sediment and water
Drigg	Consumers of locally grown food[b]	0.046	-	-	0.046	-	-
	Consumers of water from Drigg stream	<0.005	-	-	-	-	<0.005
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumers	<0.005	-	-	-	-	<0.005
Whitehaven	Seafood consumers[c]	0.62	0.19	0.41	-	0.021	-
Non-nuclear industrial sites	Rabbit consumers	<0.005	-	-	<0.005	-	-

[a] *Adults are the most exposed group unless stated otherwise*
[b] *Children aged 1y*
[c] *Includes the effects of discharges from the adjacent Sellafield site*

Table 8.3. Concentrations of radionuclides in surface water leachate from landfill sites in Scotland, 2003

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip	1	8900	<15	0.15	<0.10
City of Glasgow	Summerston Tip	1	580	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	210	<15	<0.05	<0.05
Dundee City	Riverside	1	<5.0	<15	<0.05	<0.05
Fife	Balbarton	1	92	<15	<0.05	<0.05
Fife	Melville Wood	1	270	<15	<0.05	<0.05
Highland	Longman Tip	1	7.8	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	1600	<15	0.07	<0.05
North Lanarkshire	Kilgarth	1	19	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	330	<15	0.05	<0.05

Table 8.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2003

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1} Organic ^{3}H	^{3}H	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
City of Bristol																			
Crooks Marsh Farm, Avonmouth	Leachate	2		37	<4.0	<13	<0.46	<0.29	<7.7	<0.42								<0.21	4.5
Cambridgeshire																			
Milton landfill, Cambridge	Site borehole	2		61		<34	<0.23			<0.16		<0.0080	<0.0055	<0.0050	<0.010	<0.0055	<0.0080	<0.72	33
Milton landfill, Cambridge	Site drainage	2		<25		<3.5	<0.13			<0.14		<0.013	<0.0070	<0.0065	0.042	<0.0065	0.023	<0.13	0.25
Milton landfill, Cambridge	Ground water borehole	2		<4.0		<3.7	<0.22			<0.26		<0.014	<0.0050	<0.0055	0.029	<0.0055	0.016	<0.095	0.49
Milton landfill, Cambridge	Phase 2 borehole 3.6	2		280		36	<0.23			<0.27		<0.011	<0.0065	<0.0055	<0.0070	<0.0070	<0.0060	<0.90	44
Milton landfill, Cambridge	Phase 2 borehole 3.7	2		49		<11	<0.34			<0.27		<0.0080	<0.0050	<0.0050	0.014	<0.0050	0.011	<0.37	13
Carmarthenshire																			
Cefnbrynbrain	Liquid	1									<3.0								
Cheshire																			
Northwich Tip	Borehole WM5G	2		9.8		<11	<0.44			<0.48		<0.011	<0.0055	<0.0055	<0.0050	<0.0050	<0.0050	<0.43	9.3
Northwich Tip	Borehole WM6G	2		240		<13	<0.39			<0.47		<0.035	<0.0065	<0.030	<0.0050	<0.0055	<0.0055	<1.2	7.8
Northwich Tip	Borehole WM20G	2		<4.0		<5.7	<0.21			<0.28		0.018	<0.0055	<0.0055	<0.0050	<0.0050	<0.0055	<7.2	<8.4
Cleveland																			
Bewley ICI Tip	On-site stream (downstream)	2		450		<11	<0.30			<0.27		<0.0070	<0.0050	<0.0050	0.062	<0.0050	0.061	<1.2	8.0
Bewley ICI Tip	On-site stream (upstream)	2		<6.0		<9.9	<0.11			<0.11		<0.0065	<0.0050	<0.0050	0.022	<0.0050	0.018	<0.80	26
Rhodia Consumer Specialties Ltd, Hut Bank Quarry	Borehole	1		<4.0		<6.8	<0.23			<0.24		<0.015	<0.0050	<0.0070	0.032	0.0050	0.026	0.050	0.48
Rhodia Consumer Specialties Ltd, Ufex	Leachate	2		<4.0		<36	<0.31			<0.52		<0.019	0.0060	<0.018	1.7	<0.068	1.7	2.3	33
Alco Landfill	Borehole	2		<7.5	<4.0	<4.9	<0.22	<0.18	<1.6	<0.20								0.20	0.22
Cumbria																			
BAE Systems Marine Ltd, Walney Island	Waste ponds water	1		<4.0		<5.2	<0.26			<0.36		<0.018	<0.0070	<0.0070	<0.0090	<0.0050	<0.0080	<0.030	0.26
Greater London																			
Murex Ltd	Local water (East stream)	1		<4.0		<5.3	<0.24			<0.27		0.018	<0.0080	0.011	0.030	<0.0050	0.030	<0.20	0.86
Murex Ltd	Local water (West stream)	1		<4.0		<10	<0.23			<0.23		<0.0090	<0.0050	<0.0050	0.036	<0.0050	0.025	<0.13	0.95
Glamorgan																			
Trecatti Landfill , Merthyr Tydfil	Raw Leachate	2	1900	2000	<4.0														
Trecatti Landfill , Merthyr Tydfil	Treated leachate	2	1500	1600	<4.0														

Table 8.4. continued

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}																
			Organic ^{3}H	^{3}H	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
Gwynedd																			
Cilgwyn Quarry	Leachate	2		<190	<4.0	<3.9	<0.15	<0.13	<75	<0.16								<0.070	1.9
Cilgwyn Quarry	2nd pit	2		<120	<4.0	<3.0	<0.15	<0.18	<49	<0.13								<0.050	<1.4
Hertfordshire																			
Braziers Landfill	Borehole W2	2		<6.0		<4.7	<0.16			<0.17		<0.0095	<0.0055	<0.0055	<0.014	<0.0050	<0.013	<0.075	0.36
Braziers Landfill	Borehole W5	2		<4.0		<5.1	<0.20			<0.20		<0.0085	<0.0050	<0.0050	0.018	<0.0055	0.014	<0.060	0.15
Braziers Landfill	Borehole W9	2		<4.0		<1.7	<0.11			<0.11		<0.0060	<0.0070	<0.0050	0.015	<0.0050	<0.0075	<0.055	0.14
Cole Green Landfill	Local water (culvert)	2		<4.0		<4.5	<0.15			<0.16		<0.0075	<0.0050	<0.0050	<0.011	<0.0050	<0.0090	<0.044	0.15
Cole Green Landfill	Static borehole	2		26		<6.4	<0.13			<0.13		<0.0085	<0.0050	<0.0050	0.054	<0.0050	0.041	<0.29	5.4
Lancashire																			
Magnesium Electron, Swinton	Local water	1		<4.0		<5.4	<0.30			<0.33		<0.0070	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.020	0.20
Birkacre Mine Shaft	Pool	1		<4.0		<5.3	<0.25			<0.35		<0.011	0.011	<0.0060	<0.0050	<0.0050	<0.0050	<0.020	2.6
Belthorne Mine Shaft	Local water (brook)	2		<4.0		<7.0	<0.31			<0.27		<0.0085	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.025	0.43
Clifton Marsh	Borehole 6	2		24		<7.7	<0.29			<0.25		<0.019	<0.0075	<0.0095	0.027	<0.0050	0.027	<0.13	2.1
Clifton Marsh	Borehole 19	2		6.4		<8.3	<0.24			<0.23		<0.0065	<0.0050	<0.0050	<0.017	<0.0065	0.018	<0.78	1.9
Clifton Marsh	Borehole 40	2		<4.0		<4.3	<0.21			<0.19		<0.0070	<0.0055	<0.0060	<0.0060	<0.0050	<0.0060	<0.085	1.0
Clifton Marsh	Borehole 59	2		31		<7.4	<0.28			<0.26		<0.011	<0.038	<0.0060	<0.0065	<0.0050	<0.0070	<0.15	2.7
Ulnes Walton	River Lostock (downstream)	1		<4.0		<6.8	<0.48			<0.43		<0.0050	<0.0050	<0.0050	0.052	<0.0050	0.053	0.090	0.37
Ulnes Walton	River Lostock (upstream)	1		<4.0		<5.4	<0.37			<0.56		<0.0080	<0.0050	<0.0050	0.012	<0.0050	<0.0070	<0.024	0.27
Near Whittle Hill Quarry	River Lostock	2		<4.0		<6.9	<0.25			<0.24		<0.0075	<0.0050	<0.0060	0.0075	<0.0050	<0.0065	<0.040	0.18
River Yarrow, Lancashire	Local water	1		<4.0		<3.3	<0.16			<0.17		<0.012	<0.0070	<0.0080	0.0060	<0.0060	<0.0050	<0.020	0.15
Merseyside																			
Sefton Meadows Tip	Local water	1		<4.0	<4.0	<2.0	<0.13	<0.14	<0.18	<0.12								0.11	0.19
Arpley Landfill	Borehole 25 (groundwater)	2		37	<4.0	<5.8	<0.32	<0.40	<350	<0.34								<0.11	0.60
Norfolk																			
Strumpshaw Landfill	Leachate (borehole BH2)	2		<4.0	<4.0	<7.2	<0.31	<0.23	<2.5	<0.48								<0.038	<0.10
Strumpshaw Landfill	Leachate (borehole BH3)	2		<4.0	<4.0	<12	<0.63	<0.25	<7.1	<0.54								<0.057	0.24
Strumpshaw Landfill	Reservoir	1		<4.0	<4.0	<6.8	<0.27	<0.20	<0.24	<0.25								0.049	0.13
Strumpshaw Landfill	Water abstraction	1		<4.0	<4.0	<5.4	<0.22	<0.20	<0.24	<0.40								0.11	0.130
Nottinghamshire																			
School of Agriculture, Nottingham	Local water (stream)	1		<4.0		<5.2	<0.38			<0.28		<0.014	<0.0070	<0.0070	0.061	<0.0050	0.028	0.048	0.54
Oxfordshire																			
Stanford in the Vale	Local water	2		<4.0		<4.3	<0.28			<0.31		<0.0075	<0.0065	<0.0065	<0.011	<0.0065	<0.010	<0.025	0.18
Stanford in the Vale	Borehole 15	2		<4.0		<3.9	<0.25			<0.23		<0.0070	<0.0050	<0.0050	<0.017	<0.0085	<0.014	<0.050	<0.19

Table 8.4. continued

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}																
			Organic ^{3}H	^{3}H	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
South Glamorgan																			
Lamby Way Tip	Borehole 1A	1	25	43	<4.0	<12	<0.22	<0.36	<54	<0.47								<0.80	4.1
South Gloucestershire																			
Berwick Lane landfill	Local water	2		53															
South Yorkshire																			
Beighton Tip, Sheffield	Local water	1		7.1	<4.0	<8.5	<0.43	<0.29	<4.3	<0.41								<0.30	3.5
Beighton Tip, Sheffield	Borehole	1		56	<4.0	<13	<0.27	<0.32	<4.8	<0.23								<0.22	4.1
Sussex																			
Beddingham Quarry	Leachate (site 1)	2		350	<4.0	<12	<0.36	<0.28	<8.9	<0.31								<0.40	10
Beddingham Quarry	Stream (site 2)	2		<4.0	<4.0	<6.8	<0.37	<0.32	<12	<0.34								<0.025	0.19
Beddingham Quarry	Leachate (site 3)	2		280	<4.0	<10	<0.20	<0.21	<4.7	<0.17								<0.73	24
Tyne and Wear																			
High Urpeth Tip	Local water (downstream)	1		<4.0		<2.4	<0.11			<0.12		<0.012	<0.0070	<0.0070	<0.0060	<0.0050	<0.0050	<0.14	1.0
Kibblesworth Colliery	Liquid (sampling point)	1		<4.0		<8.4	<0.17			<0.16		<0.0050	<0.0050	<0.0050	0.029	<0.0090	<0.020	<0.070	0.35
Ryton Tip, Gateshead	Local water	1		<4.0	<4.0	<5.3	<0.23	<0.43	<100	<0.37								<0.20	1.3
West Yorkshire																			
Gelderd Road Tip, Leeds	Borehole	2		<8.5	<4.0	<5.3	<0.21	<0.30	<64	<0.24								<0.14	1.7
Dean House Farm Tip	Borehole	2		13	<4.0	<9.8	<0.47	<0.38	<210	<0.31								<0.22	3.1
Wilson Road Tip	Borehole	2		27	<4.0	29	<0.18	<0.31	<53	<0.27								<1.9	35

Table 8.5. Concentrations of natural radionuclides in fish and shellfish, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{210}Po	^{210}Pb	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Rhodia Consumer Specialities Ltd, Whitehaven										
Winkles	Saltom Bay	4	28	1.7						
Winkles	Parton	4	22	3.8	0.94	1.3	0.64	1.3	0.045	1.2
Winkles	North Harrington	1	20							
Winkles	Nethertown	4	17							
Winkles	Drigg	1			0.45	0.49	0.53			
Winkles	Tarn Bay	1	16							
Mussels	Parton	2	48	2.8						
Mussels	Nethertown	4	54	2.4						
Limpets	St Bees	2	12							
Cockles	Ravenglass	2	27							
Crabs	Parton	5	20	0.085	0.093	0.022	0.010	0.055	0.0022	0.051
Crabs	Sellafield coastal area	4	14	<0.026						
Lobsters	Parton	4	11	0.33	0.029	0.0026	0.0013	0.016	0.00058	0.015
Lobsters	Sellafield coastal area	4	17	<0.024						
Cod	Parton	2	0.85	0.0095	0.023	0.00098	0.00044	0.0069	0.00032	0.0067
Flounder	Whitehaven	1	2.2							
Other samples										
Mussels	Ribble Estuary	1			0.18	0.31	0.080			
Limpets	Kirkcudbright	1	9.6							
Cockles	Southern North Sea	2			0.45	0.23	0.30			
Cockles	Ribble Estuary	1			0.45	0.44	0.20			
Cockles	Flookburgh	2	15							
Whelks	Fleetwood	1	2.7							
Shrimps	Ribble Estuary	2			0.0059	0.0076	0.0022			
Crabs	North Solway coast	1	1.9							
Lobsters	North Solway coast	1	0.87							
Winkles	North Solway coast	1	4.4							

Table 8.6. Concentrations of radionuclides in food and the environment near industrial sites, 2003

Site	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{7}Be	^{14}C	^{32}P	^{33}P	^{35}S	^{40}K	^{82}Br	^{90}Sr	^{99m}Tc	^{125}I	^{131}I
Avonmouth, Gloucestershire	Blackberries	1	<3.0											
	Grass	1	<5.0											
Beckenham, Kent	Grass	4	<3.3	39	49	<0.68	<1.2	<8.7	230	<1.2	0.47	<6.0	<0.023	<0.83
	Soil	4		<2.5	<15			<0.70	280		<1.2			
Chilton, Oxfordshire	Grass	4	<4.5	41	43	<0.70	<1.4	0.78	200	<0.60	0.30	<2.8	<0.020	<0.43
	Soil	4		<2.0	13			<1.1	290		<1.4			
	Rabbit	1	<8.0	<2.0	24	<5.0	<8.0	<0.30	100		<2.0		<0.050	<4.0
Norwich, Norfolk	Grass	4	<4.8	51	29	<0.90	<1.7	0.55	130	<0.45	0.29	<2.7	<0.028	<0.30
	Soil	4		<1.7	7.3			<0.78	220		<0.80			
	Rabbit	1	<8.0	<0.10	25	<9.0	<20	1.0	100		0.30		<0.040	<0.10
Southampton, Hampshire	Grass	4	<2.0	65	37	<0.73	<1.2	1.4	230	<0.73	0.93	<3.7	<0.043	<0.50
	Soil	4		<2.0	<12			<0.90	240		<1.5			
	Rabbit	1	<8.0	<1.0	22	16	<20	<0.30	90		<0.80		<0.060	<1.0
Torbay, Devon	Grass	4	<3.5	35	33	<2.7	<3.4	<0.16	170	<0.68	0.64	<3.5	<0.030	<0.45
	Soil	4		<2.8	13			<1.2	700		2.0			
	Rabbit	1	<9.0	<1.0	27	<2.0	<3.0	<0.30	<100		<0.90		<0.10	<0.40

Site	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{134}Cs	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am
Avonmouth, Gloucestershire	Blackberries	1	<0.40	<0.30							
	Grass	1	<0.30	<0.30							
Beckenham, Kent	Grass	4	<0.23	<0.23	3.7	3.7	0.29	0.036	0.00042	0.00085	0.0011
	Soil	4	<0.38	9.0	40	34	20	12	0.028	0.24	<0.11
Chilton, Oxfordshire	Grass	4	<0.18	<0.15	1.4	3.2	0.15	0.042	0.00022	0.00078	0.00070
	Soil	4	<0.30	4.4	26	25	20	12	0.016	0.19	0.068
	Rabbit	1	<0.20	<0.20	0.18	0.050	0.0030	<0.00090	0.00010	0.00020	0.00020
Norwich, Norfolk	Grass	4	<0.13	<0.15	3.2	2.1	0.25	0.040	0.00030	0.0010	0.00043
	Soil	4	<0.25	5.9	20	16	12	7.0	0.017	0.14	0.060
	Rabbit	1	<0.10	0.11	0.070	0.020	0.0080	0.0045	<0.000060	0.000050	0.00060
Southampton, Hampshire	Grass	4	<0.25	<0.30	4.9	4.0	0.39	0.040	0.00018	0.00088	<0.0015
	Soil	4	<0.38	6.2	31	29	16	9.4	0.027	0.19	0.060
	Rabbit	1	<0.10	<0.10	0.060	0.024	0.0030	0.0010	0.000030	0.00015	0.00040
Torbay, Devon	Grass	4	<0.12	<0.20	3.0	1.3	0.12	0.012	0.00025	0.0014	0.00020
	Soil	4	<0.43	11	37	31	22	18	<0.020	0.32	0.14
	Rabbit	1	<0.10	0.20	0.030	0.022	0.0080	0.00060	<0.00020	0.00020	0.00030

[a] *Except for soil where dry concentrations apply*

9. CHERNOBYL AND REGIONAL MONITORING

9.1 Chernobyl

Radiocaesium is detected in sheep grazing certain upland areas in the UK, which were subjected to heavy rainfall after the Chernobyl accident in 1986. Restrictions are in place on the movement, sale and slaughter of sheep from these areas to prevent meat from entering the food chain above the action level of 1000 Bq kg^{-1} of radiocaesium; a level that was recommended by an EU expert committee in 1986.

In summer 2003, intensive monitoring surveys of parts of the post-Chernobyl restricted areas of Wales and Scotland were carried out. The results of the survey in Scotland identified two farms where controls could be lifted and this decision was implemented in January 2004, leaving 14 farms subject to restrictions. The Welsh survey identified five farms where radiocaesium levels were consistently below the limit and the process of lifting controls from these farms is underway. Once this is implemented, there will be 354 farms in Wales subject to restrictions.

In Cumbria, the mark and release monitoring continued and no sheep above the 1000 Bq kg^{-1} limit were reported. In addition, the radiocaesium monitoring of sheep carcasses at slaughterhouses, which ensures that the monitoring is effective, reported no failures.

There are still 377 farms, or part farms, and approximately 230,000 sheep within the restricted areas of England, Scotland and Wales. This represents a reduction of 96% since 1986 when approximately 8900 farms were under restriction.

In Northern Ireland, concentrations of radiocaesium in sheep are well below 1000 Bq kg^{-1} and no restrictions have been in place since April 2000 (Department of Agriculture and Rural Development, 2000).

Sampling locations for freshwater fish are now limited to Cumbria, an area of relatively high deposition of fallout from Chernobyl. Samples from areas of low deposition in England were also obtained for completeness and comparison. Table 9.1 presents concentrations of caesium-134 and caesium-137 in fish and water. Other artificial radionuclides from the Chernobyl accident are no longer detectable. Concentrations in perch were less than 1000 Bq kg^{-1}, the level attained shortly after the accident, and were generally similar to those in recent years. The long-term trend of radiocaesium in freshwater fish has been reviewed (Smith *et al.*, 2000b) and the effective ecological half-life of radiocaesium during the late 1990s has been shown to be between 6 and 30 years.

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously. A consumption rate of fish of 37 kg $year^{-1}$, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures are likely to be much lower, not only because this consumption rate is cautious (Leonard *et al.*, 1990) but also because, in practice, hatchery-reared or farmed fish have much lower radiocaesium concentration and may contribute most to the diet. In 2003, estimated doses were less than 0.1 mSv.

9.2 Channel Islands

Marine environmental samples provided by the Channel Island States have continued to be analysed. The programme monitors the effects of radioactive discharges from the French reprocessing plant at Cap de la Hague and the power station at Flamanville; it also serves to monitor any effects of historical disposals of radioactive waste in the Hurd deep. Fish and shellfish are monitored in relation to the internal irradiation pathway; sediment is analysed with relevance to external exposures. Sea water and seaweeds are sampled as environmental indicator materials and, in the latter case, because of their use as fertilisers.

The results for 2003 are given in Table 9.2. Nuclides which can be attributed to routine releases from the nuclear industry were detected in some samples (cobalt-60 and technetium-99). However, all concentrations of activity in fish and shellfish were low and similar to those in previous years. Apportionment to different sources, including weapon test fallout, is difficult in view of the low levels detected. No evidence for significant releases of activity from the Hurd Deep site was found.

An assessment of the critical group of high-rate fish and shellfish consumers gives a dose of less than 0.005 mSv in 2003, which is less than 0.5% of the dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine environment of the Channel Islands and the effects of discharges from local sources therefore continued to be of negligible radiological significance.

Results for milk and crop samples are given in Table 9.9 and Table 9.10, respectively, and form parts of the programme considered in Sections 9.6 and 9.7. respectively.

9.3 Isle of Man

The Food Standards Agency carries out an on-going programme of radioactivity monitoring on behalf of the Department of Local Government and the Environment on the Isle of Man for a range of terrestrial foodstuffs. The results complement the Isle of Man Government’s own independent radiation monitoring programme (www.gov.im/dlge/enviro/govlabs) and in conjunction with those additional results provides a comprehensive assessment of environmental radioactivity levels on the Isle of Man. Results of aquatic monitoring are presented in Section 3 because of their significance in relation to Sellafield, but are also included here for completeness (Table 9.3).

Radioactivity monitoring on the Island serves two purposes: first to monitor the continuing effects of radiocaesium deposition resulting from the Chernobyl accident in 1986 and second to respond to public concern over the effects of the nuclear industry. The potential sources of exposure from the UK nuclear industry are: (i) liquid discharges into the Irish Sea and sea-to-land transfer; and (ii) gaseous discharges of tritium, carbon-14 and sulphur-35 and atmospheric transport.

Most radionuclides were present below the limits of detection of the methods used. Carbon-14 was detected in local milk and crops at activity concentrations close to the natural background values observed in the regional network of sampling locations remote from nuclear sites. Levels of strontium-90, radiocaesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of UK dairies and crop sampling locations remote from nuclear sites, at those locations known to have received similar levels of Chernobyl and weapon test fallout. The results demonstrate that there was no significant impact on Manx foodstuffs from operation of mainland nuclear installations in 2003.

The results are similar to those obtained in previous years. The dose to the critical group from consumption of terrestrial foodstuffs monitored in 2003 was 0.013 mSv (0.018 mSv in 2002) or less than 2% of the dose limit for members of the public of 1 mSv.

The effects of liquid discharges from BNFL Sellafield in the Irish Sea are discussed fully in Section 3. The dose to the critical group of Manx fish and shellfish consumers was 0.006 mSv in 2003 (the same as 2002) or less than 1% of the dose limit.

9.4 Northern Ireland

The Environment and Heritage Service in Northern Ireland undertake monitoring of the far field effects of liquid discharges into the Irish Sea from Sellafield (Environment and Heritage Service, 2004). The programme is made up of sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 9.1). The external exposure pathway is studied by monitoring of gamma dose rates over intertidal areas. The results are presented in Tables 9.4(a) and (b).

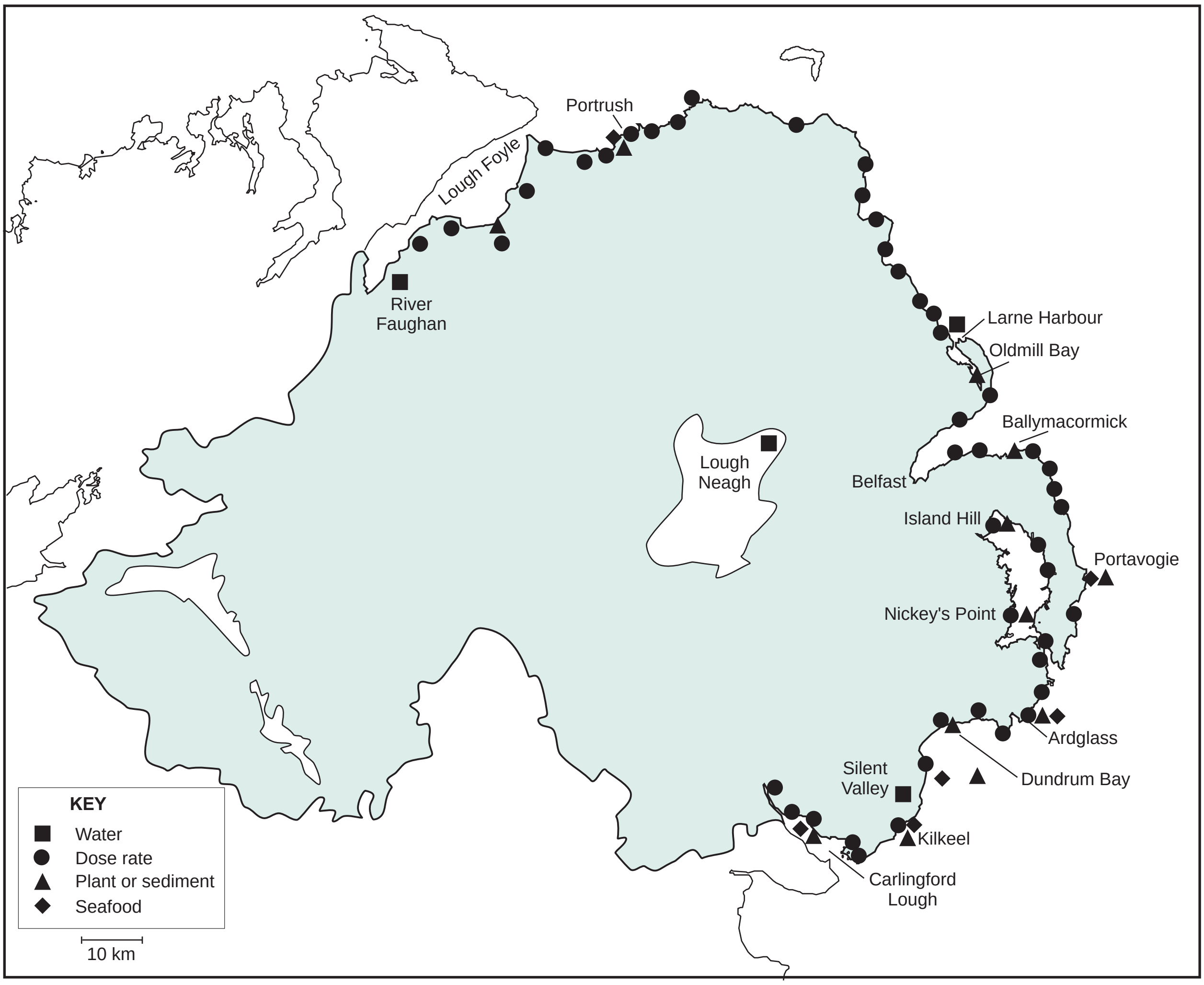

Figure 9.1 Monitoring locations in Northern Ireland

In 2003, the main effects of Sellafield were evident as concentrations of technetium-99, caesium-137 and actinides in marine samples. Observed concentrations and dose rates were less than those found nearer to Sellafield and were similar to those in 2002.

The critical group of high-rate fish and shellfish consumers has been established by a survey of consumption and occupancy habits (Smith *et al.*, 2002). The dose to the critical group on the basis of the observed levels in the marine environment in 2003 was 0.013 mSv, which is less than 2% of the dose limit for members of the public.

9.5 General diet

As part of the Government's general responsibility for food safety, radioactivity in whole diet is determined on a regional basis. Measurements are made on samples of mixed diet from regions throughout the UK. Most samples are derived from the Food Standards Agency's Total Diet Study (TDS). The design of the UK Total Diet Study has been described in detail elsewhere, but basically involves 119 categories of food combined into 20 groups of similar foods for analysis (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al.*, 1983). The relative importance of each food category within a group reflects its importance in the diet and is based on an average of three previous years of consumption data from the National Food Survey (Ministry of Agriculture, Fisheries and Food, 1998). Foods are grouped so that commodities known to be susceptible to contamination (e.g. offals, fish) are kept separate, as are foods which are consumed in large quantities (e.g. bread, potatoes, milk)

(Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al*., 1983). These samples are analysed for a range of food constituents including radioactivity. The system of sampling mixed diet rather than individual foodstuffs from specific locations, provides more accurate assessments of radionuclide intakes because people rarely obtain all their food from a local source (Mondon and Walters, 1990). Radionuclides of both natural and man-made origins were measured in samples in 2003. The results are provided in Tables 9.5 and 9.6.

There was some evidence for the effects of radioactive waste disposal into the environment reaching the general diet in the form of positively detected amounts of tritium and sulphur-35 being determined. However, all of the results for man-made radionuclides were low. Many were close to the limits of detection for the various analytical methods used. There was some variability from region to region, but no more than is usually detected from the programme. Within the normal variability observed, there were no significant trends in concentrations.

Exposures as a result of consuming diet at average rates at the concentrations given in Tables 9.5 and 9.6 have been assessed for adults, infants and 10-year-old children. In all cases the exposures of infants were higher than other age groups. The data are summarised in Table 9.7. The most important man-made radionuclides were strontium-90 derived from weapons test fallout, and sulphur-35. The nationwide mean dose for all man-made radionuclides was low at 0.023 mSv. There is an increase from the value of 0.013 mSv in 2002, mostly because of increased concentrations reported for strontium-90, many of which were below the limits of detection.

The mean dose due to consumption of natural radionuclides was 0.14 mSv, less than the value for 2002 of 0.23 mSv. In addition to potassium-40 the most important radionuclides continued to be lead-210 and polonium-210, and it was an apparent reduction in the concentrations of those radionuclides that resulted in the decrease in dose in 2003. This change can be regarded as being within the uncertainty of the dose estimate caused by the necessarily limited sampling programme. The results demonstrate that radionuclides from natural sources are by far the most important source of exposure in the average diet of consumers and man-made radionuclides only contributed about 13% of the mean dose.

Similar results were found in a survey of radioactivity in canteen meals collected across the UK (Table 9.8).

9.6 Milk

The programme of milk sampling at dairies in the UK continued in 2003. The aim is to collect samples and analyse them monthly for their radionuclide content. The programme, together with that for crops presented in the following section, provides useful information with which to compare data from farms close to nuclear sites and other establishments which may enhance concentrations above background levels. Some of this data is supplied to the EC as part of the requirements under the EURATOM treaty (e.g. Joint Research Centre, 2001).

Where measurements are comparable, detected activity concentrations of all radionuclides in 2003 were similar to those for previous years. These results are summarised in Table 9.9. Tritium and sulphur-35 results were below their respective limits of detection. Mean and maximum values for carbon-14 from all dairies were similar and at expected background levels. The mean concentration of strontium-90 was less than 0.04 Bq l^{-1}. In the past, the levels of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout, however, the levels are now very low and it is less easy to distinguish this trend.

The assessed doses from consumption of dairy milk at average rates were highest to the one-year-old infant age group. For the range of radionuclides analysed, the dose was 0.005 mSv. Previous surveys (e.g. Food Standards Agency and Scottish Environment Protection Agency, 2002) have shown that if a full range of nuclides are analysed and assessed the dose is dominated by naturally occurring lead-210 and polonium-210 and man-made radionuclides contribute less than 10%.

9.7 Crops, bread and meat

The programme of monitoring natural and man-made radionuclides in crops continued in 2003 (Table 9.10). Tritium activity was close to or below the LoD in all samples. The activities of carbon-14 detected in crop samples were close to those expected from consideration of background sources. Within the normal variability observed, the concentrations of other radionuclides in crops were similar to those observed in 2002.

Sampling of bread and meat continued in Scotland in 2003. The results, presented in Table 9.11, show the presence of low levels of man-made and natural radionuclides consistent with naturally occurring sources, and from weapons testing and Chernobyl fallout. The levels observed were similar to those in 2002.

9.8 Air particulate, rain and freshwater

Monitoring of radioactivity in air and rain took place at seven locations as part of a UK wide monitoring programme of background sampling under the EURATOM Treaty. The results are given in Table 9.12. Caesium-137 concentrations were all below or close to the limits of detection. These levels in air, typical of recent years, remain less than 0.01% of those observed in 1986, the year of the Chernobyl reactor accident. Concentrations of beryllium-7, a naturally occurring radionuclide formed by cosmic ray reactions in the upper atmosphere were detected at similar levels at all sampling locations. Peak air concentrations of this radionuclide tend to occur during spring and early summer as a result of seasonal variations in the mixing of stratospheric and tropospheric air (Environment Agency, 2002a). Tritium concentrations in rainwater were similar to those in 2002. Concentrations in air and rainwater are very low and do not currently merit radiological assessment. Monitoring of air in Glasgow gave less than 2.0 mBq m^{-3} of beta activity.

Sampling and analysis of freshwater throughout the UK continued in 2003 (Figure 9.2). Sampling is designed to be representative of the main drinking water sources, namely reservoirs, rivers and groundwater boreholes. Most of the water samples are representative of natural waters before treatment and supply to the public water system. The results in Tables 9.13, 9.14 and 9.15, show that concentrations of tritium are all below the EU indicator parameter for tritium of 100 Bq l^{-1}. Concentrations of total alpha and total beta are also nearly all below the WHO screening values of 0.1 and 1.0 Bq l^{-1} for total alpha and total beta, respectively. As in 2002, total alpha concentrations in groundwater at Meerbrook Sough in Derbyshire exceeded the WHO screening level. The total alpha levels seen in Meerbrook Sough waters is due to high levels of natural uranium arising from local geology (Environment Agency, 2002a).

Results for the River Thames, which receives authorised discharges from Amersham plc, UKAEA Harwell and AWE Aldermaston, are consistent with those from the regulatory monitoring in the vicinity of the site's discharge points.

The highest annual dose from consumption of drinking water in the UK was assessed as 0.23 mSv in 2003 (Table 9.16). The 1-year-old age group received the highest dose. This dose was based on a polonium-210 concentration in water from Cornwall that was at the LoD. The estimated doses were dominated by natural radionuclides. The annual dose from artificial radionuclides in drinking water was less than 0.001 mSv.

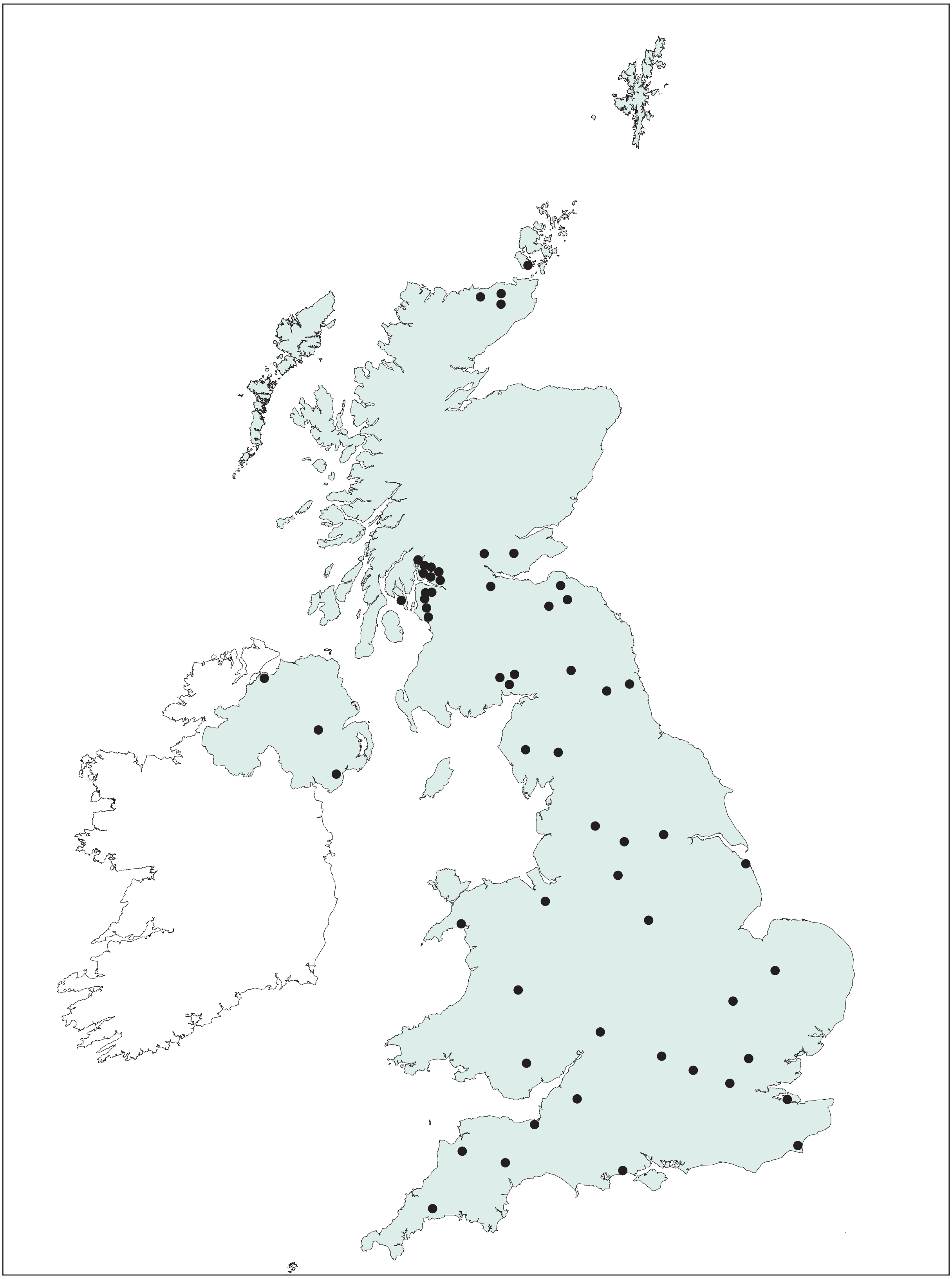

Figure 9.2 Drinking water sampling locations

9.9 Seawater surveys

Seawater surveys support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 2000b) and provide information which can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). In addition, the distribution of radioactivity in seawater around the British Isles is a significant factor in determining the variation in individual exposures at coastal sites, as seafood is a major contribution to food chain doses. Therefore a programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling. Data have been used to examine the long distance transport of activity to the Arctic (Leonard *et al.*, 1998; Kershaw *et al.*, 1999, 2004) and to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). The research vessel programme on radionuclide distribution currently comprises annual surveys of the Bristol Channel and western English Channel and biennial surveys of the Irish Sea and the North Sea. The results of the cruises in 2003 are presented in Figures 9.3 – 9.6. Shoreline sampling around the UK coast is also undertaken and data are given in Table 9.17. Much of the shoreline sampling is directed at establishing whether individual site related effects are detectable. Where relevant, commentary is found in the relevant site section.

The caesium-137 data for the Irish Sea (Figure 9.3) show similar levels to those observed from sampling in recent years, the general distribution being one of falling concentrations as the distance from Sellafield increases. The predominant source term is remobilisation into the water column of previously discharged activity that became associated with seabed sediments and, to a lesser extent, recent discharges from the Sellafield site. The concentrations now observed are only a small percentage of those prevailing in the late 1970s, typically up to 30 Bq l^{-1} (Baxter et al., 1992), when discharges were substantially higher.

Levels in the western English Channel (average concentration 0.002 Bq l^{-1}) were typical of the background due to global fallout (Figure 9.6).

A full assessment of long-term trends in Northern European seas is provided elsewhere (Povinec *et al.*, 2003).

The concentrations of tritium observed in the Irish Sea (Figure 9.4) were generally higher than those observed in the North Sea (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2003) due to the influence of discharges from Sellafield. Compared with the previous survey (Food Standards Agency and Scottish Environment Protection Agency, 2002), the effects of increased tritium discharges from Sellafield are apparent. In the Bristol Channel, the extent of the combined effects of discharges from Hinkley Point, Cardiff and Berkeley/Oldbury is evident (Figure 9.5). Levels in the western English Channel were below the detection limit.

The results of research cruises to study technetium-99 have been published by Leonard *et al.* (1997a and b, 2004) and McCubbin *et al.*, (2002). Discharges of this nuclide from Sellafield substantially increased in 1994, following commissioning of the EARP plant. The discharges peaked in 1995, but have reduced significantly since that time.

Trends in plutonium and americium concentrations in seawater of the Irish Sea have been considered by Leonard *et al.* (1999). A full review of the quality status of the north Atlantic has been published by OSPAR (2000b).

Measurements of beta and potassium-40 activity in water from the Clyde in 2003 gave results of less than 1 and less than 10 Bq kg^{-1} respectively. These concentrations are similar to those for 2002. Caesium-137 was not detected.

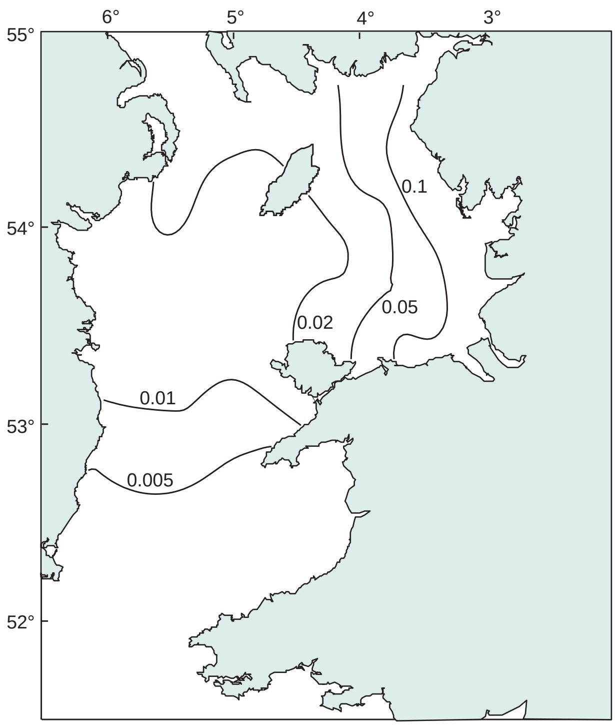

Figure 9.3 ***Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the Irish Sea, August-September 2003***

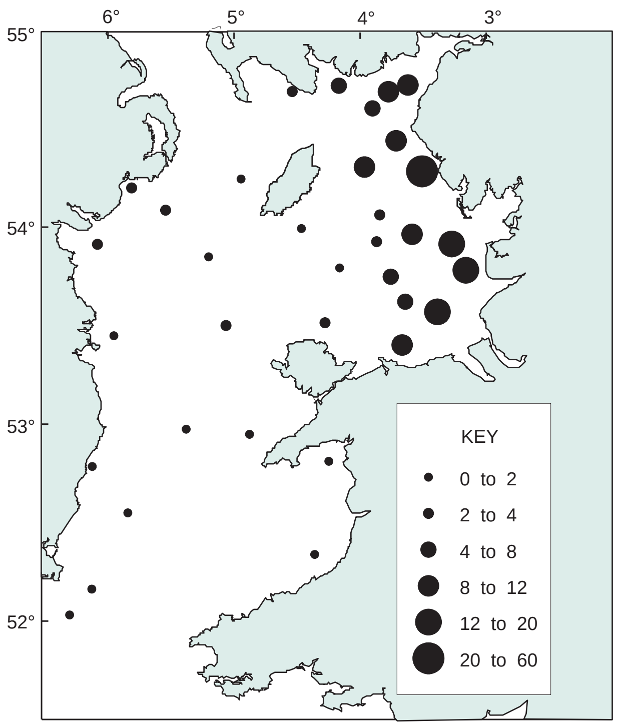

Figure 9.4 ***Concentrations (Bq l^{-1}) of tritium in surface seawater from the Irish Sea, August-September 2003***

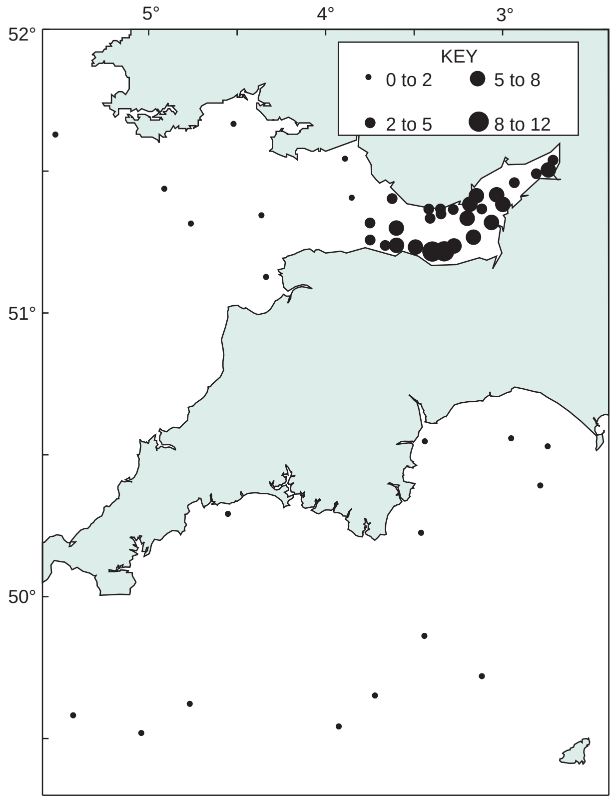

Figure 9.5 ***Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel and western English Channel, September-October 2003***

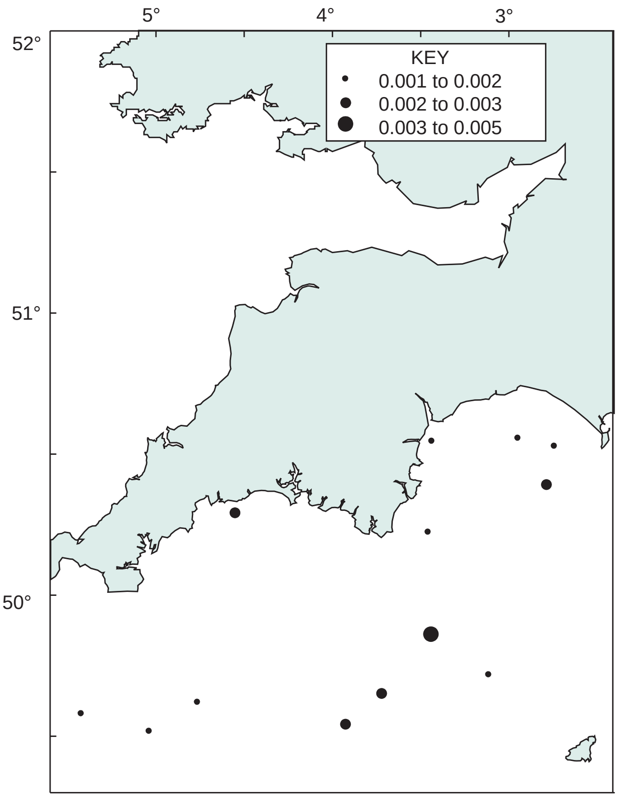

Figure 9.6 ***Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the western English Channel, September-October 2003***

Table 9.1. Concentrations of radiocaesium in the freshwater environment, 2003

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Branthwaite	Rainbow trout	1	<0.06	0.21
Narborough[b]	Rainbow trout	1	<0.05	0.16
Ennerdale Water	Eels	1	<0.30	15
Ennerdale Water	Water	1	*	0.003
Devoke Water	Brown trout	1	0.08	46
Devoke Water	Perch	1	<0.19	180
Devoke Water	Water	1	*	0.01
Gilcrux	Rainbow trout	1	<0.08	0.38
Kielder Water[c]	Brown trout	1	<0.14	1.2
Scotland				
Loch Dee	Brown trout	1	0.28	130
Loch Dee	Water	3	*	0.01

** Not detected by the method used*

[a] *Except for water where units are Bq l^{-1}*

[b] *The concentrations of ^{14}C, ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were 22, 0.0000077, 0.000067 and 0.00013 Bq kg^{-1}(wet) respectively*

[c] *The concentrations of Organic ^{3}H, ^{3}H and ^{14}C were <25, <25 and 13 Bq kg^{-1}(wet) respectively*

Regional/ research

Table 9.2. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs
Mackerel	Guernsey	2				<0.11			<1.0		0.15
Pollack	Jersey	2				<0.03			<0.31		0.18
Bass	Guernsey	1				<0.07			<0.55		0.39
Bass	Jersey	1				<0.05			<0.45		0.45
Edible crabs	Guernsey	1				<0.07			<0.57		<0.06
Edible crabs	Jersey	1				<0.07			<0.54		<0.05
Edible crabs	Alderney	2	<25	<25	26	<0.12		0.11	<0.88		<0.08
Spiny spider crab	Jersey	1				0.16			<0.34		<0.03
Spiny spider crab	Alderney	2				0.51			<1.7		<0.14
Lobsters	Guernsey	1				<0.08			<0.65		<0.06
Lobsters	Jersey	1				<0.16		1.8	<1.7		<0.15
Lobsters	Alderney	1				<0.04			<0.30		<0.03
Oysters	Jersey	1				<0.04			<0.38		<0.04
Limpets	Guernsey	1				<0.05			<0.50		<0.04
Limpets	Jersey										
	La Rozel	1				<0.06			<0.49		<0.05
Toothed winkle	Alderney	1			25	0.33	<0.14		<1.8		<0.16
Scallops	Guernsey	2				<0.06			<0.51		<0.05
Scallops	Jersey	2				<0.06			<0.47		<0.04
Ormers	Guernsey	1				<0.05			<0.52		<0.05
Porphya	Guernsey										
	Fermain Bay	4				<0.11			<1.1		<0.09
Porphya	Jersey										
	Plemont Bay	4				<0.11			<0.75		<0.05
Porphya	Alderney										
	Quenard Point	2				<0.05			1.1		<0.04
Fucus vesiculosus	Jersey										
	La Rozel	4				<0.21	<0.035	5.0	<1.1		<0.11
Fucus vesiculosus	Alderney										
	Quenard Point	2								1.4	
Fucus serratus	Guernsey										
	Fermain Bay	4				<0.15	<0.041	2.7	<0.54		<0.06
Fucus serratus	Alderney										
	Quenard Point	4				0.25	0.039	2.4	<0.44		<0.04
Laminaria digitata	Jersey										
	Verclut	4				<0.05			<0.41		<0.05
Mud and sand	Guernsey										
	St. Sampson's Harbour	1				1.1			<1.6		1.7
Mud	Jersey										
	St Helier	1				6.8			<2.3		3.4
Sand	Alderney										
	Lt. Crabbe Harbour	1				<0.17			<1.7		1.7
Seawater	Guernsey	4									0.003
Seawater	Jersey	1									0.002
Seawater	Alderney										
	East	4		7.3							0.001

Table 9.2. continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Mackerel	Guernsey	2	<0.32	<0.000017	0.000036	0.0001	*	*	96
Pollack	Jersey	2	<0.07			<0.04			110
Bass	Guernsey	1	<0.11	<0.000013	0.000022	0.000046	*	*	110
Bass	Jersey	1	<0.09						110
Edible crabs	Guernsey	1	<0.13	0.00019	0.00064	0.0025	*	0.00027	68
Edible crabs	Jersey	1	<0.13	0.00016	0.00050	0.0026	0.000028	0.00035	69
Edible crabs	Alderney	2	<0.16	0.00070	0.0013	0.0040	0.000070	0.00070	56
Spiny spider crab	Jersey	1	<0.06			<0.04			56
Spiny spider crab	Alderney	2	<0.32	0.0013	0.0034	0.0049	*	0.00068	84
Lobsters	Guernsey	1	<0.16			<0.20			57
Lobsters	Jersey	1	<0.37	0.00041	0.00086	0.0036	0.000044	0.00056	90
Lobsters	Alderney	1	<0.07	0.00041	0.0013	0.0080	0.000045	0.0014	57
Oysters	Jersey	1	<0.08	0.0023	0.0060	0.0048	*	0.00066	78
Limpets	Guernsey	1	<0.14			<0.13			53
Limpets	Jersey								
	La Rozel	1	<0.11	0.0024	0.0065	0.0088	0.000098	0.0012	79
Toothed winkle	Alderney	1	<0.27	0.0098	0.028	0.042	0.00017	0.0061	46
Scallops	Guernsey	2	<0.11	0.0011	0.0033	0.0028	<0.000026	0.00036	120
Scallops	Jersey	2	<0.10	0.0023	0.0057	0.0040	0.000040	0.00042	100
Ormers	Guernsey	1	<0.18			<0.26			74
Porphya	Guernsey								
	Fermain Bay	4	<0.17	0.0010	0.0040	0.0056	*	<0.00057	120
Porphya	Jersey								
	Plemont Bay	4	<0.10			<0.10			96
Porphya	Alderney								
	Quenard Point	2	<0.13			<0.20			88
Fucus vesiculosus	Jersey								
	La Rozel	4	<0.20	0.0061	0.016	0.0059	0.000035	0.00070	170
Fucus serratus	Guernsey								
	Fermain Bay	4	<0.13	0.0049	0.018	0.0059	0.000056	0.00076	210
Fucus serratus	Alderney								
	Quenard Point	4	<0.12	0.0070	0.021	0.0078	0.000073	0.0013	140
Laminaria digitata	Jersey								
	Verclut	4	<0.10			<0.10			190
Mud and sand	Guernsey								
	St. Sampson's Harbour	1	<0.71	0.14	0.47	0.66	*	0.065	430
Mud	Jersey								
	St Helier	1	0.94	0.75	2.0	3.6	*	0.28	550
Sand	Alderney								
	Lt. Crabbe Harbour	1	<0.59			<0.72			340

* *Not detected by the method used*

[a] *Except for seawater where units are Bq l^{-1} and for sediment where dry concentrations apply*

Regional/ research

Table 9.3. Concentrations of radionuclides in food and the environment from the Isle of Man, 2003[c]

Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
		^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Aquatic samples										
Cod	4	<0.09	<0.32	<0.45		<0.81	<0.19	<0.09	2.1	<0.42
Herring	4	<0.09	<0.33	<0.46		<0.85	<0.21	<0.09	0.76	<0.49
Lobsters	4	<0.06	<0.16	<0.15	170	<0.54	<0.14	<0.06	0.36	<0.28
Scallops	4	<0.04	<0.13	<0.17		<0.37	<0.09	<0.04	0.24	<0.21
Fucus vesiculosus	4	<0.12	<0.12	<0.11	1100	<0.42	<0.16	<0.05	0.58	<0.27
Sediment	1[E]	<0.77	<1.8	<1.1		<4.8	<3.9	<0.67	3.0	<2.2

Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
		^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Aquatic samples							
Cod	4	0.00017	0.00078	0.0013	*		
Herring	4	0.000069	0.00037	0.00051	*		
Lobsters	4			<0.10			200
Scallops	4	0.014	0.075	0.025	0.00047		
Fucus vesiculosus	4			<0.20			800
Sediment	1[E]					<100	330

Material or selection[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb
Terrestrial samples									
Milk	2	<3.4	14	<0.36	<0.26	0.026	<0.0050	<1.9	<0.51
Milk	max	<3.8	15	<0.38	<0.28	0.030		<2.0	<0.53
Cabbage	1	<4.0	14	<0.80	<0.20	0.051	<0.033	<1.7	<0.50
Potatoes	1	<4.0	14	<0.40	<0.30	0.049	<0.045	<1.4	<0.50
Strawberries	1	<4.0	21	<0.30	<0.30	0.27	<0.031	<2.0	<0.60

Material or selection[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
		^{129}I	Total Cs	^{238}Pu	^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples							
Milk	2	<0.012	0.067	<0.00020	<0.00010	<0.035	<0.00010
Milk	max		0.069				
Cabbage	1	<0.069	0.10	<0.00020	<0.00020	<0.064	<0.00020
Potatoes	1	<0.026	0.11	0.00010	0.00030	<0.051	<0.00020
Strawberries	1	<0.023	0.036	<0.00020	<0.00030	<0.056	0.00030

* *Not detected by the method used*

[a] *Except for milk where units are Bq l^{-1}*

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean is also the maximum.*

[c] *The gamma dose rate in air at 1m over sand at Douglas[E] was 0.066 µGy h^{-1}*

[d] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 9.4(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2003

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{137}Cs	^{155}Eu
Cod	Kilkeel	4	40	<0.08		<0.18	1.5	<0.16
Cod	Portrush	2		<0.13		<0.31	2.0	<0.29
Haddock	Kilkeel	1		<0.07		<0.17	0.85	<0.20
Haddock	Portavogie	5		<0.11		<0.25	1.2	<0.21
Herring	Ardglass	4		<0.09		<0.20	0.54	<0.17
Saithe	Portrush	2		<0.06		<0.17	2.6	<0.19
Spurdog	Portavogie	4		<0.12		<0.27	1.9	<0.22
Spurdog	Portrush	4		<0.12		<0.29	1.7	<0.25
Whiting	Kilkeel	3		<0.04		<0.11	3.1	<0.10
Whiting	Portavogie	3		<0.05		<0.11	2.1	<0.10
Crabs	Kilkeel	2		<0.08		<0.17	0.26	<0.15
Lobsters	Kilkeel	4		<0.17	210	<0.39	<0.26	<0.37
Lobsters	Portrush	3		<0.11	130	<0.27	0.30	<0.22
Nephrops	Kilkeel	4		<0.10		<0.24	0.74	<0.21
Nephrops	Portavogie	4		<0.10	50	<0.24	0.90	<0.21
Winkles	Ards Peninsula	4		<0.15		<0.33	<0.21	<0.24
Mussels	Carlingford Lough	2		<0.13	30	<0.28	0.35	<0.20
Scallops	Western Irish Sea	2		<0.05		<0.10	0.30	<0.10
Ascophyllum nodosum	Ardglass	1		<0.19		<0.45	0.51	<0.42
Ascophyllum nodosum	Carlingford Lough	1		<0.05		<0.11	0.31	<0.10
Fucus spp.	Carlingford Lough	3		<0.12	380	<0.23	0.67	<0.19
Fucus spp.	Portrush	4		<0.08		<0.12	0.16	<0.12
Fucus vesiculosus	Ardglass	3		<0.16	580	<0.34	0.99	<0.28
Rhodymenia spp.	Strangford Lough	4		<0.11	35	<0.20	0.83	<0.15
Mud	Carlingford Lough	2		<0.62		<2.2	55	<3.3
Mud	Dundrum Bay	2		<0.42		<1.3	5.2	<1.7
Mud	Lough Foyle	1		<0.37		<1.4	4.7	<2.0
Mud	Oldmill Bay	2		<0.50		<1.6	35	<1.9
Mud	Strangford Lough -Nickey's point	2		<0.50		<1.6	33	<2.0
Mud	Ballymacormick	2		<0.42		<1.3	24	<1.7
Mud and sand	Lough Foyle	1		<0.26		<0.82	1.3	<1.2
Sand	Portrush	2		<0.32		<0.77	0.55	<0.98
Seawater	North of Larne	12			0.031		0.02	

Table 9.4(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm + ^{244}Cm$
Cod	Kilkeel	4			<0.13		
Cod	Portrush	2			<0.28		
Haddock	Kilkeel	1			<0.30		
Haddock	Portavogie	5			<0.20		
Herring	Ardglass	4			<0.16		
Saithe	Portrush	2			<0.25		
Spurdog	Portavogie	4			<0.14		
Spurdog	Portrush	4			<0.22		
Whiting	Kilkeel	3			<0.10		
Whiting	Portavogie	3	0.0019	0.00084	0.0014	*	*
Crabs	Kilkeel	2			<0.14		
Lobsters	Kilkeel	4			<0.46		
Lobsters	Portrush	3			<0.20		
Nephrops	Kilkeel	4			<0.22		
Nephrops	Portavogie	4	0.0068	0.039	0.15	*	*
Winkles	Ards Peninsula	4	0.023	0.13	0.13	*	0.00025
Mussels	Carlingford Lough	2			<0.19		
Scallops	Western Irish Sea	2			<0.12		
Ascophyllum nodosum	Ardglass	1			<0.43		
Ascophyllum nodosum	Carlingford Lough	1			<0.07		
Fucus spp.	Carlingford Lough	3			<0.19		
Fucus spp.	Portrush	4			<0.11		
Fucus vesiculosus	Ardglass	3			<0.34		
Rhodymenia spp.	Strangford Lough	4	0.067	0.36	0.49	*	0.0012
Mud	Carlingford Lough	2	2.1	12	9.0	*	0.0070
Mud	Dundrum Bay	2			<2.1		
Mud	Lough Foyle	1	0.15	0.88	1.4	0.0036	0.0011
Mud	Oldmill Bay	2	2.2	12	20	*	0.031
Mud	Strangford Lough -Nickey's point	2	1.6	9.2	9.6	*	0.016
Mud	Ballymacormick	2	1.7	9.2	15	*	0.019
Mud and sand	Lough Foyle	1			<1.3		
Sand	Portrush	2			<0.96		

** Not detected by the method used*

[a] Except for seawater where units are Bq l^{-1} and for sediment where dry concentrations apply

Table 9.4(b). Monitoring of radiation dose rates in Northern Ireland, 2003

Location	Ground type	No. of sampling observa-tions	Mean gamma dose rate in air at 1m, $\mu Gy\ h^{-1}$
Narrow Water	Mud	1	0.092
Rostrevor	Sand	1	0.13
Mill Bay	Mud	1	0.10
Greencastle	Sand	1	0.087
Cranfield Bay	Sand	1	0.085
Annalong	Sand	1	0.12
Newcastle	Sand	1	0.094
Dundrum	Mud	1	0.089
Tyrella	Sand	1	0.084
Rossglass	Sand	1	0.085
Killough	Mud	1	0.089
Ardglass	Mud	1	0.11
Kilclief	Sand	1	0.083
Strangford	Stones	1	0.10
Nickey's Point	Mud	1	0.087
Island Hill	Mud	1	0.086
Ards Maltings	Mud	1	0.084
Greyabbey	Sand	1	0.079
Kircubbin	Sand	1	0.088
Portaferry	Stones	1	0.094
Cloghy	Sand	1	0.070
Ballyhalbert	Sand	1	0.069
Ballywalter	Sand	1	0.070
Millisle	Sand	1	0.074
Groomsport	Sand	1	0.069
Helen's Bay	Sand	1	0.063
Belfast Lough	Sand	1	0.065
Carrickfergus	Sand	1	0.064
Whitehead	Sand	1	0.067
Larne	Sand	1	0.059
Drains Bay	Sand	1	0.055
Ballygally	Sand	1	0.059
Half Way House	Sand	1	0.058
Glenarm	Sand	1	0.055
Carnlough	Sand	1	0.061
Red Bay	Sand	1	0.071
Cushendall	Sand and stones	1	0.069
Cushendun	Sand	1	0.061
Ballycastle	Sand	1	0.061
Giant's Causeway	Sand	1	0.061
Portballintrae	Sand	1	0.061
White Rocks	Sand	1	0.071
Portrush	Sand	1	0.072
Portstewart	Sand	1	0.062
Castlerock	Sand	1	0.070
Benone	Sand	1	0.074
Bellerena	Mud	1	0.066
Carrichue House	Mud	1	0.065
Eglinton	Shingle	1	0.065
Lisahally	Mud	1	0.078

Table 9.5. Concentrations of radionuclides in general diet (TDS survey), 2003[a]

Region	Town	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po
Northern	Blackburn	1	<2.1	40	0.56	80	<2.0	0.02	0.070	0.070
Northern	Billingham	1	<2.2	30	<0.33	70	<0.40	0.03		0.026
Northern	Bridlington	1	<1.8	33	<0.25	60	<0.30	<0.05	0.090	0.047
Central	Milton Keynes	1	<2.2	40	<0.20	70	<2.0	<0.05	<0.040	0.060
Central	Hereford	1	<2.2	40	<0.41	63	<2.0	<0.06	0.030	0.080
Central	Wolverhampton	1	<3.1	44	<0.23	70	<0.60	0.04	0.10	0.050
Southern	Torquay	1	<2.2	40	<0.29	70	<2.0	<0.09	<0.040	0.070
Southern	Littlehampton	1	2.6	34	<0.44	70	<0.90	<0.07	0.050	0.030
Southern	Mitcham	1	<1.8	50	<0.28	61	<0.50	<0.02	0.050	0.016
Wales	Caernarfon	1	<3.0	50	<0.26	70	<1.0	<0.07	0.050	0.030
Northern Ireland	Lurgan	1	<2.2	30	<0.26	60	3.4	0.04	0.060	0.030
Scotland	Edinburgh	1	<20	44	<1.0		<0.050	<0.40	0.088	0.053
Scotland	Dumbarton	1	<20	43	<1.0		<0.050	<0.40	0.062	0.048
Mean			<5.0	40	<0.42	68	<1.2	<0.10	<0.061	0.047

Region	Town	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}					
			^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am
Northern	Blackburn	1	0.035	0.0016	<0.020	0.000078	0.00054	0.00054
Northern	Billingham	1	0.026	0.00090	<0.020	<0.000095	0.000070	<0.00031
Northern	Bridlington	1	0.050	0.0017	0.028	0.000083	0.00011	0.00030
Central	Milton Keynes	1	0.068	0.0032	0.031	<0.000054	0.000051	<0.00030
Central	Hereford	1	0.040	0.0011	<0.020	<0.000068	0.00015	0.00020
Central	Wolverhampton	1	0.025	0.0016	0.051	<0.000043	0.000035	0.0014
Southern	Torquay	1	0.046	0.0033	0.021	<0.000077	0.000086	0.00029
Southern	Littlehampton	1	0.040	0.0014	0.022	<0.000096	0.000097	<0.0011
Southern	Mitcham	1	0.026	0.0017	0.040	0.000092	0.00010	0.00030
Wales	Caernarfon	1	0.040	0.0020	0.17	<0.00012	0.000093	<0.0011
Northern Ireland	Lurgan	1	0.040	0.0014	0.027	<0.000044	0.000090	<0.00064
Scotland	Edinburgh	1	0.047	<0.013	<0.043[b]	<0.0010	<0.0010	<0.051
Scotland	Dumbarton	1	0.053	0.025	<0.039[c]	<0.020	<0.020	<0.00047
Mean			0.041	<0.0045	<0.041	<0.0017	<0.0017	<0.0045

[a] *Results are available for other artificial nuclides detected by gamma spectrometry. All such results are less than the limit of detection.*
[b] *The concentration of ^{234}U, ^{235}U and ^{238}U were <0.030, <0.0050 and 0.0075 Bq kg^{-1} respectively*
[c] *The concentration of ^{234}U, ^{235}U and ^{238}U were 0.024, <0.0020 and 0.013 Bq kg^{-1} respectively*

Table 9.6. Concentrations of radionuclides in regional diet in Scotland, 2003

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}				
		^{3}H	^{35}S	^{40}K	^{90}Sr	^{137}Cs
Dumfries and Galloway (Dumfries)	12	<5.1	<0.65	85	<0.10	<0.06
East Lothian (North Berwick)	12	<5.0	<2.6	87	<0.10	<0.05
Highland (Dingwall)	12	<5.0	<1.4	93	<0.10	<0.08
Renfrewshire (Paisley)	12	<5.0	<0.64	71	<0.10	<0.05

Table 9.7. Estimates of radiation exposure from radionuclides in regional diet, 2003

Nuclide[a]	Exposure, mSv[b]
Man-made radionuclides	
Tritium	0.0001
Sulphur-35	0.0004
Strontium-90	0.02
Caesium-137	0.0002
Plutonium-238	0.0001
Plutonium-239+240	0.0001
Americium-241	0.0003
Sub-total	0.023
Natural radionuclides	
Carbon-14	0.01
Lead-210	0.04
Polonium-210	0.08
Radium-226	0.008
Uranium	0.001
Thorium-232	0.0004
Sub-total	0.14
Total	0.17

[a] *Tritium is also produced by natural means and carbon-14 by man. Levels of natural radionuclides may be enhanced by man's activities*

[b] *To a 1 year old child consuming at average rates. Exposures due to the potassium-40 content of food are not included here because they do not vary according to the potassium-40 content of food. Levels of potassium in the body are homeostatically controlled. The average annual dose from potassium-40 in general diet is 0.17 mSv, which is in addition to the above figures*

Table 9.8. Concentrations of radionuclides in canteen meals, 2003[a]

Region	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}				
		^{14}C	^{40}K	^{90}Sr	^{137}Cs	Total U
England	4	<25	90	<0.40	<0.06	<0.023
Northern Ireland	4	38	91	<0.53	<0.05	<0.023
Scotland	4	38	90	<0.45	<0.06	<0.021
Wales	4	33	95	<0.40	<0.05	<0.022

[a] *Results are available for other artificial nuclides detected by gamma spectrometry. All such results were less than the limit of detection*

Regional/ research

Table 9.9. Concentrations of radionuclides in milk remote from nuclear sites, 2003

Location	Selection[a]	No. of sampling observ-ations[b]	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs
Co. Antrim		1				0.028	0.20
Co. Armagh		1	<4.0	17		0.026	0.077
Cambridgeshire		1	<1.9	<13		0.015	0.052
Cheshire		1	<4.5	15		<0.019	0.090
Clwyd		1	<4.0	18		0.026	0.055
Cornwall		1	<4.0	27		0.034	0.058
Devon		1	<4.0	12		0.040	0.055
Co. Down		1				0.037	0.11
Co. Fermanagh		1				<0.023	0.096
Gloucestershire		2	<4.0	19		<0.019	0.052
	max			24		<0.022	0.053
Guernsey		1	<1.8	11		0.026	0.057
Gwent		1	<1.9	15		0.024	0.062
Gwynedd		1	<3.5	8.0		0.034	0.045
Hampshire		1	<4.0	18		0.031	0.050
Kirkcudbrightshire		1	<5.0	<15	<0.50	<0.10	<0.065[c]
Kent		2	<4.5	24		0.022	0.057
	max		<5.0	30		0.024	0.060
Lanarkshire		1	<6.1	<15	<0.50	<0.10	<1.1[c]
Lancashire		2	<4.3	13		<0.023	0.065
	max		<4.5	15		0.024	
Leicestershire		1	<4.0	15		<0.015	0.055
Lincolnshire		1	<3.3	14		<0.015	0.050
Middlesex		1	<4.0	16		0.021	0.054
Midlothian		1	<5.3	<16	<15	<0.10	<0.059[c]
Nairnshire		1	<5.0	<18	<0.50	<0.10	<0.064[c]
Norfolk		1	<4.0	19		<0.017	0.059
Renfrewshire		1	<5.0	<16	<1.4	<1.0	<0.070[c]
Somerset		1	<4.0	12		<0.025	0.052
Suffolk		1	<4.0	27		<0.011	0.063
Tyneside		1	<4.0	31		0.032	0.071
Co. Tyrone		2	<2.3	19		<0.026	0.10
	max		<4.0	17		0.027	
Yorkshire		3	<4.0	16		<0.020	0.056
	max		<5.0	32		<0.021	0.059
Mean Values							
Channel Isles			<1.8	11		0.026	0.057
England			<3.6	<17		<0.022	0.058
Northern Ireland			<2.5	19		<0.027	0.11
Wales			<2.4	15		0.028	0.054
Scotland			<5.3	<16	<3.6	<0.10	<0.27[c]
United Kingdom			<3.9	<16	<3.6	<0.035	<0.096

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima where more than one form is sampled. If no 'max' is given then the mean is also the maximum.*

[b] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime.*

[c] *^{137}Cs only*

Table 9.10. Concentrations of radionuclides in crops remote from nuclear sites, 2003[a]

Location	Material	No. of samples	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po
Bedfordshire									
Bedford	Blackcurrants	1	<4.0	15		0.17	<0.032	<0.047	0.062
	Cabbage	1	<4.0	10		0.15	<0.025	0.099	0.034
Cardiganshire									
Aberystwyth	Blackcurrants	1	<2.0	17		0.72	0.067	0.068	0.31
	Chard	1	<2.0	5.0		1.2	0.091	2.3	0.83
Channel Islands									
Guernsey	Apples	1	<1.0	13	0.40	0.078	<0.029		
	Calabrese	1	2.0	4.0	0.70	0.11	0.061		
Cheshire									
Middlewich	Blackcurrants	1	<4.0	32		0.14	<0.032	0.15	0.10
	Cabbage	1	<4.0	5.0		0.34	0.046	0.063	0.062
Cornwall									
Bodmin	Cabbage	1	<1.0	<3.0		0.28	0.10	<0.044	0.0079
	Raspberries	1	<2.0	19		0.075	0.081	<0.045	0.028
Cumberland									
Penrith	Cabbage	1	5.0	9.0		0.30	0.060	<0.044	0.018
	Potatoes	1	<4.0	26		0.034	0.10	<0.050	0.011
Devon									
Paignton	Lettuce	1	<2.0	4.0		0.28	0.14	0.69	0.21
	Potatoes	1	<2.0	34		0.020	0.042	<0.049	0.035
Dorset									
Bridport	Gooseberries	1	<2.0	15		0.071	<0.028	0.11	0.032
	Lettuce	1	<1.0	<3.0		0.17	0.038	0.29	0.15
Durham									
Durham	Brocolli	1	6.0	<3.0		0.38	<0.030	<0.035	0.029
	Potatoes	1	<4.0	16		0.047	0.074	0.069	0.12
	Raspberries	1	<1.0	33		0.11	<0.031	<0.043	0.027
Dumfriesshire									
Dumfries	Lettuce	4	<5.0	<15	<1.0	<0.10	<0.050[b]		
East Lothian									
North Berwick	Lettuce	4	<5.0	<15	<0.50	<0.11	<0.050[b]		
Glamorgan									
Swansea	Chard	1	<2.0	<3.0		0.40	0.18	1.5	0.51
	Swede	1	<2.0	13		0.21	<0.026	0.13	0.022
Gloucestershire									
Newent	Cabbage	1	<4.0	25		0.068	<0.028	<0.048	0.0064
	Stawberries	1	<4.0	20		<0.016	0.075	<0.040	0.0088
Lincolnshire									
Scunthorpe	Cabbage	1	<4.0	15		0.74	0.10	0.77	0.26
	Carrots	1	<4.0	23		0.20	<0.033	<0.043	0.012
Norfolk									
Kings's Lynn	Cabbage	1	<4.0	14		0.21	0.033	0.037	0.028
	Potatoes	1	<4.0	25		0.032	<0.026	<0.034	0.0066
Northampton									
Newark	Runner Beans	1	<4.0	14		0.038	<0.027	0.13	0.013
	Strawberries	1	<4.0	14		0.12	<0.025	<0.039	0.034
Oxfordshire									
Witney	Cabbage	1	<2.0	<3.0		0.043	<0.034	<0.039	0.0061
	Potatoes	1	<2.0	13		0.23	<0.048	<0.048	0.024
Renfrewshire									
Paisley	Lettuce	4	<5.0	<15	<0.65	<0.11	<0.050[b]		
Ross-shire									
Dingwall	Lettuce	4	<5.7	<15	<0.50	<0.10	<0.050[b]		
Shropshire									
Shrewsbury	Lettuce	1	<4.0	<3.0		0.14	0.11	0.18	0.090
	Potatoes	1	<4.0	43		0.036	0.065	<0.042	0.012
Sussex									
Burgess Hill	Blackberries	1	<2.0	16		0.15	<0.030	0.082	0.055
	Spinach	1	2.0	4		0.35	0.10	0.77	0.29
Warwickshire									
Warwick	Runner Beans	1	<2.0	<3.0		0.044	<0.026	<0.056	0.014
	Potatoes	1	<2.0	13		0.047	0.079	<0.046	0.014
Wiltshire									
Swindon	Lettuce	1	<2.0	<3.0		0.14	0.14	0.22	0.15
	Turnips	1	<2.0	11		0.14	<0.031	<0.041	0.0099
Yorkshire									
Beverley	Cabbage	1	<4.0	16		0.29	0.04	0.18	0.082
	Carrots	1	<4.0	21		<0.019	0.042	<0.036	0.013
Mean Values									
Channel Isles			<1.5	8.5	0.55	0.094	<0.045		
England			<3.1	<15		<0.16	<0.056	<0.13	0.058
Wales			<2.0	<9.5		0.63	<0.092	1.2	0.42
Scotland			<5.2	<15	<0.67	<0.11	<0.050[b]		
Great Britain			<3.6	<14	<0.66	<0.18	<0.056	<0.24	0.095

Table 9.10. continued

Location	Material	No. of samples	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha
Bedfordshire									
Bedford	Blackcurrants	1	0.013	0.0052	<0.027	0.00020	0.00020	0.00040	
	Cabbage	1	0.020	<0.0013	<0.027	0.00010	<0.00010	0.00020	
Cardiganshire									
Aberystwyth	Blackcurrants	1	0.022	0.0037	<0.025	<0.00010	0.00010	<0.00020	
	Chard	1	0.14	0.017	<0.026	0.00030	0.00030	0.00070	
Channel Islands									
Guernsey	Apples	1							
	Calabrese	1							
Cheshire									
Middlewich	Blackcurrants	1	0.032	0.0016	<0.027	0.00010	<0.00010	<0.00030	
	Cabbage	1	<0.010	0.0024	<0.026	<0.00010	0.00020	0.00040	
Cornwall									
Bodmin	Cabbage	1	0.015	0.0011	<0.026	0.00010	<0.00010	0.00050	
	Raspberries	1	0.0060	0.0011	<0.024	0.00010	<0.00010	<0.00030	
Cumberland									
Penrith	Cabbage	1	0.028	0.0019	<0.026	<0.00010	0.00010	<0.00020	
	Potatoes	1	<0.0070	0.0056	<0.026	<0.00010	<0.00010	0.00050	
Devon									
Paignton	Lettuce	1	<0.0090	0.0070	<0.026	0.00010	0.00020	0.00040	
	Potatoes	1	0.0040	0.0021	<0.027	0.00010	<0.00010	<0.00020	
Dorset									
Bridport	Gooseberries	1	0.0080	0.0045	<0.025	0.00020	<0.00010	0.00020	
	Lettuce	1	0.031	0.026		0.00010	0.00020	0.00030	
Durham									
Durham	Brocolli	1	0.028	<0.00090	<0.026	0.00010	0.00010	<0.00030	
	Potatoes	1	0.047	0.084	0.11	<0.00010	0.00060	0.00060	
	Raspberries	1	0.0050	0.0011	<0.027	0.00010	<0.00020	0.00030	
Dumfriesshire									
Dumfries	Lettuce	4							<0.29
East Lothian									
North Berwick	Lettuce	4							<0.22
Glamorgan									
Swansea	Chard	1	0.063	0.0070	<0.027	0.00010	<0.00040	0.00020	
	Swede	1	0.015	0.0042	<0.026	<0.00020	<0.00020	0.00020	
Gloucestershire									
Newent	Cabbage	1	0.020	0.00050	<0.026	<0.00020	<0.00010	0.00030	
	Stawberries	1	0.022	0.0014	<0.024	<0.00010	<0.00010	0.00040	
Lincolnshire									
Scunthorpe	Cabbage	1	0.033	0.023	0.038	0.00020	0.00020	0.00050	
	Carrots	1	0.012	0.0055	<0.027	<0.00010	<0.00010	<0.00020	
Norfolk									
Kings's Lynn	Cabbage	1	<0.012	0.0016	<0.026	<0.00020	0.00010	0.00030	
	Potatoes	1	<0.0060	0.0061	<0.025	<0.00020	<0.00010	0.00020	
Northampton									
Newark	Runner Beans	1	<0.011	0.0015	<0.028	<0.00010	0.00010	<0.00020	
	Strawberries	1	0.040	0.0018	<0.025	<0.00010	<0.00010	0.00020	
Oxfordshire									
Witney	Cabbage	1	<0.012	<0.00060	<0.024	<0.00020	<0.00010	0.00010	
	Potatoes	1	0.020	0.022	0.047	<0.00010	0.00020	0.00090	
Renfrewshire									
Paisley	Lettuce	4							<0.23
Ross-shire									
Dingwall	Lettuce	4							<0.28
Shropshire									
Shrewsbury	Lettuce	1	0.010	0.013	0.047	<0.00020	0.00020	0.00050	
	Potatoes	1	<0.0050	0.012	<0.026	0.00010	0.00010	0.00040	
Sussex									
Burgess Hill	Blackberries	1	0.022	0.00060	<0.026	<0.00020	0.00030	<0.00040	
	Spinach	1	0.079	0.013	0.044	0.00030	0.00020	0.0018	
Warwickshire									
Warwick	Runner Beans	1	<0.0050	0.017	0.033	<0.00010	0.00010	0.00050	
	Potatoes	1	0.011	0.015	0.031	0.00020	0.00020	0.00040	
Wiltshire									
Swindon	Lettuce	1	0.019	0.021	0.039	<0.00020	0.00020	0.00030	
	Turnips	1	0.013	0.0051	<0.025	0.00010	<0.00010	0.00030	
Yorkshire									
Beverley	Cabbage	1	0.043	0.0038	<0.026	<0.00020	<0.00020	<0.00030	
	Carrots	1	0.0070	0.0026	<0.027	0.0001	<0.00020	0.00020	
Mean Values									
Channel Isles									
England			<0.019	<0.0089	<0.031	<0.00014	<0.00016	<0.00039	
Wales			0.059	0.0079	<0.026	<0.00018	<0.00025	<0.00033	
Scotland									<0.26
Great Britain			<0.023	<0.0088	<0.028	<0.00014	<0.00017	<0.00038	<0.26

[a] *Results are available for other artificial nuclides detected by gamma spectroscopy. All such results are less than the limit of detection*
[b] ^{137}Cs *only*

Table 9.11. Concentrations of radionuclides in bread and meat in Scotland, 2003

Area	Sample	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway	Bread	4	<5.0	73	<0.51	66	<0.10	<0.05	<0.75
(Dumfries)	Meat	4	<5.3	53	4.2	80	<0.10	<0.06	<0.38
East Lothian	Bread	4	<5.0	71	<0.88	65	<0.14	<0.05	<0.79
(North Berwick)	Meat	4	<6.6	40	<1.9	100	<0.10	<0.05	<0.43
Highland	Bread	4	<5.0	68	<1.7	73	<0.12	<0.06	<0.83
(Dingwall)	Meat	4	<8.3	40	2.9	100	<0.10	0.30	<0.45
Renfrewshire	Bread	4	<5.5	77	<3.4	61	<0.11	<0.05	<0.93
(Paisley)	Meat	4	<5.5	60	1.7	70	<0.10	<0.05	<0.34

Table 9.12. Concentrations of radionuclides in rainwater and air 2003

Location	Sample	No. of sampling obser-vations	Mean radioactivity concentration[a] in rainwater and air								
			^{3}H	^{7}Be	^{90}Sr[b]	^{137}Cs	^{210}Pb	^{210}Po	^{228}Th	alpha[b]	beta[b]
Ceredigion											
Aberporth	Rainwater	4	<2.4	<1.6		<0.053	0.10				
	Air	4		0.0022		<0.00000052	0.00017				
Co. Down											
Conlig	Rainwater	4		<1.5		<0.022	*				
	Air	4		0.0022		<0.00000063	0.00015				
Dumfries and Galloway											
Eskdalemuir	Rainwater	4	<2.7	1.2		<0.0098	0.094				
	Air	4		0.0018		<0.00000043	0.00013				
North Yorkshire											
Dishforth	Rainwater	4		<2.2		<0.039					
	Air	4		0.0016		<0.00000055	0.00014				
Oxfordshire											
Chilton	Rainwater	4		<1.5	<0.00064	<0.032	0.32				
	Air	4		0.0018		<0.00000034	0.00027	<0.000014		0.074	0.17
Shetland											
Lerwick	Rainwater	4		1.6		<0.017					
	Air	4		0.0015		<0.00000052	0.00010				
Suffolk											
Orfordness	Rainwater	4	<2.2	<2.4		<0.048			5.2		
	Air	4		0.0022		<0.00000053					

** Not detected by the method used*
[a] Bq l^{-1} for rainwater and Bq kq^{-1} for air
[b] Annual bulk analysis

Table 9.13. Concentrations of radionuclides in sources of drinking water in Scotland, 2003

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Total alpha	Total beta
Angus	Loch Lee	11	<1.5	<0.0088	<0.012		
Argyll and Bute	Auchengaich	1	1.1	<0.0050		<0.010	0.058
Argyll and Bute	Helensburgh Reservoir	2			<0.010	<0.010	<0.044
Argyll and Bute	Loch Ascog	3			<0.010	<0.010	0.14
Argyll and Bute	Loch Eck	1	<1.0	0.0064		<0.010	<0.010
Argyll and Bute	Loch Finlas	2			<0.010	<0.010	0.062
Argyll and Bute	Lochan Ghlas	2			<0.017	<0.029	<0.11
Clackmannanshire	Gartmorn	1	<1.0	0.0074		<0.010	<0.075
Dumfries and Galloway	Black Esk	1	3.4	0.0053		<0.010	0.032
Dumfries and Galloway	Winterhope	1	6.7	<0.011		<0.014	0.052
Dumfries and Galloway	Purdomstone	3			<0.010	<0.017	<0.083
East Lothian	Hopes Reservoir	1	1.6	<0.0050		<0.010	0.035
East Lothian	Thorters Reservoir	1	1.5	<0.0050		<0.015	0.049
East Lothian	Whiteadder	2			<0.010	<0.010	0.054
Fife	Holl Reservoir	1	1.2	<0.0050		<0.010	0.051
Highland	Loch Baligill	1	<1.0	<0.0050		<0.010	0.060
Highland	Loch Calder	3			<0.010	<0.012	<0.080
Highland	Loch Glass	12	<1.3	<0.010	<0.010		
Highland	Loch Shurrerey	1	<1.0	<0.0050		<0.010	0.048
North Ayrshire	Camphill	1	1.2	<0.0050		<0.013	0.037
North Ayrshire	Knockendon Reservoir	3			<0.010	<0.010	<0.042
North Ayrshire	Munnoch Reservoir	1	1.4	0.0067		<0.010	<0.075
North Ayrshire	Outerwards	1	<1.0	0.0063		<0.014	0.037
Orkney Islands	Heldale Water	1	<1.0	<0.0050		<0.011	0.065
Perth and Kinross	Castlehill	2			<0.010	<0.010	0.032
Scottish Borders	Knowsdean	12	<1.1	<0.0088	<0.0093		
Stirling	Loch Katrine	11	<1.0	<0.0095	<0.0093		
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0	0.0081		<0.010	0.44
West Lothian	Morton No. 2	1	<1.0	<0.0050		<0.010	0.088

Table 9.14. Concentrations of radionuclides in sources of drinking water in England and Wales, 2003

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}					
			^{3}H	^{40}K	^{90}Sr	^{125}I	^{137}Cs	^{210}Po
England								
Buckinghamshire	Bourne End, Groundwater	4	<4.0	0.034	0.0015		<0.0010	<0.010
Cambridgeshire	Grafham Reservoir	4	<4.0	0.26	0.0025		<0.0010	<0.010
Cheshire	River Dee	4	<4.0	0.13	0.0024	<0.010	<0.0010	<0.010
Cornwall	River Fowey	4	<4.0	0.056	0.0019	<0.010	<0.0011	<0.098
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.057	0.0035		<0.0010	<0.010
County Durham	River Tees	4	<4.0	0.035	0.0047	<0.010	<0.0010	<0.010
County Durham	Tunstall Reservoir	4	<4.0	0.030	<0.0030		<0.0010	<0.010
Cumbria	Haweswater Reservoir	3	<4.0	0.018			<0.0010	<0.010
Cumbria	Ennerdale Lake	4	<4.0	0.018	<0.0020		<0.0010	<0.010
Derbyshire	Meerbrook Sough groundwater	4	<4.0	0.039	0.0027		<0.0012	<0.010
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	0.034	<0.0021		<0.0010	<0.010
Devon	River Exe	4	<4.0	0.069	<0.0023	<0.010	<0.0010	<0.010
Gloucestershire	River Severn, Tewkesbury	4	<4.0	0.17	0.0028	<0.010	<0.0010	<0.010
Greater London	River Lee, Chingford	4	<4.0	0.23	0.0016	<0.010	<0.0010	<0.010
Hampshire	River Avon, Christchurch	4	<4.0	0.073	0.0012	<0.010	<0.0010	<0.010
Humberside	Littlecoates, Groundwater	3	<4.0	0.085	<0.0020		<0.0010	<0.010
Kent	Denge, Shallow Groundwater	4	<4.0	0.12	0.0030		<0.0010	<0.010
Kent	Deep Groundwater	4	<4.0	0.057	<0.0014		<0.0010	<0.010
Lancashire	Corn Close, Groundwater	4	<4.0	0.066	<0.0017		<0.0011	<0.010
Norfolk	Stoke-Ferry, River	4	<4.0	0.097	0.0025	<0.010	<0.0010	<0.010
Northumbria	Kielder Reservoir	4	<4.5	0.023	<0.0031		<0.0015	<0.010
Oxfordshire	River Thames, Oxford	4	<4.0	0.16	0.0021	<0.010	<0.0010	<0.010
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.068	0.0017		<0.0010	<0.010
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.12	0.0035		<0.0010	<0.010
Surrey	River Thames, Walton	4	<4.0	0.19	0.0036	<0.010	<0.0010	<0.010
Yorkshire	Eccup No.1 Works Inlet	4	<4.0	0.064	0.0051		<0.0010	<0.010
Yorkshire	Chellow Heights, Bradford	4	<4.0	0.024	0.0046		<0.0010	<0.010
Wales								
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	0.016	0.0069		<0.0015	<0.010
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	0.018	0.0022		<0.0010	<0.010
Powys	Elan Valley Reservoir	4	<4.0	0.011	<0.0029		<0.0010	<0.010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta[1]	Total beta[2]
England									
Buckinghamshire	Bourne End, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.054	<0.051
Cambridgeshire	Grafham Reservoir	4	<0.010	0.012	<0.010	0.0088	<0.026	0.35	0.27
Cheshire	River Dee	4	<0.010	0.0090	<0.010	<0.010	<0.021	0.21	0.17
Cornwall	River Fowey	4	<0.017	<0.016	<0.010	<0.016	0.034	0.086	0.074
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.089	0.080
County Durham	River Tees	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.065	<0.055
County Durham	Tunstall Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.060	<0.055
Cumbria	Haweswater Reservoir	3	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050
Cumbria	Ennerdale Lake	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050
Derbyshire	Meerbrook Sough groundwater	4	<0.014	0.043	<0.010	0.023	0.14	0.12	0.11
Derbyshire	Arnfield Water Treatment Plant	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.051	<0.050
Devon	River Exe	4	<0.010	<0.011	<0.010	<0.010	<0.025	0.12	0.11
Gloucestershire	River Severn, Tewkesbury	4	<0.010	0.023	<0.010	0.013	<0.035	0.20	0.18
Greater London	River Lee, Chingford	4	<0.010	<0.010	<0.010	<0.0095	<0.025	0.26	0.23
Hampshire	River Avon, Christchurch	4	<0.010	<0.010	<0.010	<0.010	<0.025	0.097	0.081
Humberside	Littlecoates, Groundwater	3	<0.010	<0.010	<0.010	<0.010	<0.039	<0.12	<0.094
Kent	Denge, Shallow Groundwater	4	<0.010	<0.010	<0.010	<0.010	0.031	0.15	0.13
Kent	Deep Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.027	<0.065	<0.057
Lancashire	Corn Close, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.023	<0.082	<0.067
Norfolk	Stoke-Ferry, River	4	<0.010	0.011	<0.010	<0.011	<0.025	0.14	0.12
Northumbria	Kielder Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.021	<0.053	<0.050
Oxfordshire	River Thames, Oxford	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.29	0.22
Somerset	Ashford Reservoir, Bridgwater	4	<0.010	0.098	<0.010	<0.010	<0.032	0.091	0.077
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.010	0.011	<0.010	<0.0093	<0.033	0.17	0.15
Surrey	River Thames, Walton	4	<0.010	<0.0095	<0.010	<0.010	<0.026	0.21	0.19
Yorkshire	Eccup No.1 Works Inlet	4	<0.010	<0.010	<0.010	<0.010	<0.021	0.081	0.067
Yorkshire	Chellow Heights, Bradford	4	<0.010	<0.010	<0.010	<0.010	<0.021	<0.051	<0.050
Wales									
Gwynedd	Cwm Ystradllyn Treatment Works	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.022	<0.050	<0.050
Powys	Elan Valley Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050

[1] *Using ^{137}Cs standard*
[2] *Using ^{40}K standard*

Table 9.15. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2003

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}									
			^{3}H	^{90}Sr	^{137}Cs	^{210}Po	^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
Co. Londonderry	R Faughan	4	<1.0	0.0051	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.14
Co. Antrim	Lough Neagh	4	<1.0	0.0042	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.14
Co. Down	Silent Valley	4	<1.0	0.0046	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	0.024	<0.08

Table 9.16. Estimates of maximum radiation exposure from radionuclides in drinking water, 2003[a]

Country	Exposure, mSv Man-made radionuclides[b]	Natural radionculides[c]	All radionuclides
England	<0.001	0.23	0.23
Northern Ireland	<0.001	0.026	0.026
Scotland	<0.001	[d]	[d]
Wales	<0.001	0.013	0.013

[a] *The maximum dose is selected for each nuclide group from data for individual sampling locations. Many estimates of dose are based on concentration results at limits of detection.*
[b] *Including tritium*
[c] *Including carbon-14*
[d] *Analysis of natural radionuclides was not undertaken*

Table 9.17. Concentrations of radionuclides in seawater, 2003

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}											
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Cs	^{241}Am	Total alpha	Total beta
Dounreay (Sandside Bay)	4	<1.1		<0.10			<0.26	<0.10	<0.10	<0.16	<0.10		
Hartlepool (North Gare)	2			<0.17			<1.6	<0.20	<0.17	<1.5	<0.91	<4.3	<7.0
Hartlepool (North Gare)	2[F]	4.7											
Sizewell	2			<0.20			<1.8	<0.20	<0.20	<1.9	<0.77	<3.7	14
Aldeburgh	2[F]	<2.4											
Bradwell	2			<0.14			<1.2	<0.15	<0.14	<0.89	<0.63	<3.7	13
Dungeness (inlet)	2[F]	3.1											
Dungeness south	2			<0.30			<1.7	<0.15	<0.22	<1.3	<0.50	<3.3	15
Winfrith (Arish Mell)	2			<0.20			<1.7	<0.18	<0.21	<1.5	<1.2	<2.9	<8.0
Alderney	4[F]	7.3						*	0.002				
Jersey	1[F]							*	0.002				
Guernsey	4[F]							*	0.003				
Devonport (Tor Point South)	2	<4.0	<4.0	<0.34									
Devonport (Millbrook Lake)	2	<13	<4.0	<0.27									
Hinkley	2			<0.20			<1.7	<0.26	<0.59	<1.3	<0.51	<9.0	9.8
Hinkley (inlet)	2[F]	18											
Berkeley and Oldbury	2			<0.10			<1.6	<0.07	<0.14	<1.4	<0.70	<2.6	6.8
Cardiff (Orchard Ledges East)	2[F]	5.9											
Cardiff (Orchard Ledges)[b]	2	6.5	<4.0										
Holyhead	4[F]	<1.9						*	0.01				
Wylfa (Cemlyn Bay)	2			<0.31			<2.4	<0.28	<0.30	<0.10	<0.51	<1.7	4.5
Wylfa (Cemaes Bay)	2			<0.21			<1.8	<0.18	<0.27	<1.2	<1.2	<1.4	6.6
Llandudno	1[F]							*	0.04				
Prestatyn	1[F]							*	0.07				
New Brighton	1[F]							*	0.08				
Ainsdale	1[F]							0.003	0.12				
Rossal (Fleetwood)	1[F]							0.005	0.20				
Heysham (inlet)	2			<0.39			<2.8	<0.27	<0.41	<1.0	<0.53	<2.4	15
Heysham (inlet)	2[F]	28											
Half Moon Bay	1[F]							*	0.14				
Walney- west shore	4[F]	75						0.003	0.11				
Silecroft	1[F]							0.002	0.11				
Seascale	4[F]							<0.004	0.17				
Seascale (Particulate)	2			<0.12	<0.01		<0.60	<0.08	<0.08	<0.54	<0.18	0.14	0.10
Seascale (Filtrate)	2			<0.34	0.11	<6.9	<3.2	<0.38	<0.29	<1.7	<0.35	<1.9	12
St. Bees	12[F]	21				0.23		0.004	0.12				
St. Bees (Particulate)	2			<0.12	<0.01		<0.80	<0.08	<0.10	<0.54	<0.26	0.26	0.22
St. Bees (Filtrate)	2			<0.27	0.17	<7.7	<2.0	<0.25	<0.23	<0.87	<0.23	<4.7	<9.5
Whitehaven	1[F]							0.003	0.11				
Maryport	1[F]							0.004	0.18				
Silloth	1[F]							0.004	0.20				
Seafield	4	10		<0.10			<0.20	<0.10	<0.12	<0.12	<0.10		
Seafield (high water)	4	7.5		<0.10			<0.26	<0.10	<0.14	<0.17	<0.10		
Carsethorn	2	13											
Southerness[a]	4	9.7		<0.10			<0.26	<0.10	<0.14	<0.17	<0.0011		
Auchencairn	4	6.5											
Ross Bay	1[F]							*	0.09				
Isle of Whithorn	1[F]							*	0.08				
Drummore	1[F]							*	0.04				
Knock Bay	4	<2.4		<0.10			<0.25	<0.10	<0.10	<0.16	<0.10		
Knock Bay	4[F]	2.7						*	0.02				
North of Larne	12[F]					0.031		*	0.02				
Faslane (Carnban)	1	2.4											

* *Not detected by the method used*

[a] *The concentrations of ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were 0.00047, 0.0018, <0.00095 and <0.00095 Bq l^{-1} respectively*

[b] *The concentration of Organic ^{3}H was 4.8 Bq l^{-1}*

[E] *Measurements are made on behalf of the Environment agencies unless labelled "F"*
In that case they are made on behalf of the Food Standards Agency

10. RESEARCH IN SUPPORT OF THE MONITORING PROGRAMMES

The Food Standards Agency and the environment agencies have programmes of special investigations and supporting research and development studies to complement the routine monitoring programmes. This additional work is primarily directed at the following objectives:

- to evaluate the significance of potential sources of radionuclide contamination of the food chain and the environment;
- to identify and investigate specific topics or pathways not currently addressed by the routine monitoring programmes and the need for their inclusion in future routine monitoring;
- to develop and maintain site-specific habit and agricultural practice data, in order to improve the realism of dose assessment calculations;
- to develop more sensitive and/or efficient analytical techniques for measurement of radionuclides in natural matrices;
- to evaluate the competence of laboratories' radiochemical analytical techniques for specific radionuclides in food and environmental materials;
- to develop improved methods for handling and processing monitoring data.

Other studies include projects relating to effects on wildlife, emergency response and planning and development of new environmental models and data.

The contents of the research programmes are regularly reviewed and open meetings are held each year to discuss ongoing, completed and potential future projects. Occasionally specific topics are the subject of dedicated workshops (e.g. Ould-Dada, 2000). A summary of all the research and development undertaken by the Environment Agency between 1996 and 2001 was published in 2002 (Environment Agency, 2002c). A review of research funded by the Food Standards Agency was published in 2004 (Food Standards Agency, 2004a).

A list of related projects completed in 2003 is presented in Table 10.1. Those sponsored by the Environment Agency and the Food Standards Agency are also listed on the internet (www.environment-agency.gov.uk, www.food.gov.uk, respectively). Copies of the final reports for each of the projects funded by the Food Standards Agency are available from the Emergency Planning, Radiation and Incidents Division, Aviation House, 125 Kingsway, London WC2B 6NH. Further information on studies funded by SEPA and the Scotland and Northern Ireland Forum for Environmental Research is available from Greenside House, 25 Greenside Place, Edinburgh, EH1 3AA. Environment Agency reports are available from www.eareports.com. A charge may be made to cover costs. Table 10.1 also provides information on projects that are currently underway. The results of these projects will be made available in due course. A short summary of the key points from specific monitoring projects that have recently been completed is given here.

Total diet studies – R03019

In addition to the results of analyses of total diet presented in Section 9, the Food Standards Agency also undertakes occasional surveys of contaminants in specific foods. Most recently the outcome of a study of uranium-238 in food groups from the 2001 Total Diet Study (TDS) has been published (Food Standards Agency, 2004b). Concentrations of uranium-238 were reported for each of 20 food groups and it was found that fish and bread had the highest concentrations. Cereals and bread were the main source of uranium-238 in the UK diet. Toddlers aged 1.5 to 2.5 years were the critical age group. It was estimated that toddlers eating above average amounts of food would receive 16% of the WHO guideline daily limit value for uranium-238 and on this basis it was concluded that there were no health concerns.

The primary potential health risk from ingestion of uranium is not from its radioactivity but from its chemical toxicity as a heavy metal. This was taken into account in the study.

Disposals to inland waters – R01041

Radioactive waste is released directly from some non-nuclear sites to sewers. Such releases are controlled by the environment agencies and the Food Standards Agency considers any possible effects on food. This project compiled a database of information relating to non-nuclear sites and associated sewage treatment works to enable the Food Standards Agency to assess the radiological impact of aquatic discharges from these sites (Venter, 2004).

Accumulation and remobilisation of technetium-99 in eastern Irish Sea sediments – R01055

This experimental study examined the importance of the reservoir of technetium-99 in the seabed of the Irish Sea in terms of its potential for remobilisation. There were three strands to the work: (i) seabed cores were collected from research vessels and analysed to determine the degree of association of technetium-99 with the seabed of the Irish Sea, (ii) distribution coefficients for suspended particles were determined and (iii) laboratory experiments examined the processes for technetium-99 remobilisation. A report describes the main findings (Leonard and McCubbin, 2004). In short these were:

- technetium-99 is present in the seabed to a significant extent and has penetrated below 30 cm
- new higher values for distribution coefficients were determined
- remobilisation varied according to sediment type
- the half-time for redissolution of technetium-99 from the seabed was considered as possibly mimicking that of caesium-137, that is being in the order of several tens of years.

Further work is planned to determine the effects of remobilisation on food pathways.

Calibration of mobile and airborne gamma spectrometry – UKRSR02

Airborne detection systems can be a powerful tool for coverage of large areas in a short period of time.

This project was part of the Scottish and Northern Ireland Forum for Environmental Research programme (SNIFFER). It was managed on behalf of the Scottish Executive, EHS, SEPA and the Environment Agency and was supported by CEC EURATOM Framework funding.

The project aimed to demonstrate the traceability of airborne gamma spectrometry to international standards, in addition to increasing the accuracy and awareness of the technique. A network of European teams and user groups were formed and took part in an intercalibration exercise in Dumfries and Galloway. A report of the main findings has been published (Sanderson *et al.*, 2003).

A software package to optimise the Food Standards Agency terrestrial surveillance programme – R02004

In order to optimise the resources and direct the terrestrial monitoring programme towards the pathways resulting in the highest doses to consumers, a computer-based decision-aiding software was developed. The software programme assesses the food type and the specific radionuclides that need to be monitored around nuclear sites which discharge gaseous radioactivity. The output from “Optimum T” is a recommendation for the number of measurements required for each different food type sampled at each nuclear site to optimise the use of the radiological monitoring programme. Optimisation is the maximisation of the combined value of different measurements, taking account of the differences in the radiological impact of different foods on the consumer, the radionuclides present and the cost of each measurement (Higgins *et al*., 2004).

Speciation and remobilisation of plutonium in the northern Irish Sea – AIR(99)01

This study examined experimentally the association of plutonium with sediments from the Irish Sea. Its importance is related to the need to establish the rate of remobilisation of the seabed inventory of plutonium, particularly since, with Sellafield inputs having reduced substantially, it now represents the largest source in the Irish Sea. Monitoring of plutonium bound to individual mineral phases of anoxic sediment was carried out using a selective leaching technique (Lucey *et al.*, 2003). The results showed that plutonium was predominantly bound to exchangeable and acid-soluble geochemical phases. It was concluded that plutonium bound to sediment in the Irish Sea was potentially more bioavailable than hitherto believed.

10. Research

Table 10.1. Extramural projects

Topic	Reference	Further details	Target completion date
Enhancement to Optimon-T software	R02004	F	Complete
Data relevant to the assessment of radioactive waste discharges into inland waters	R01041	F	Complete
Solid speciation and remobilisation of radionuclides in the Northern Irish Sea and the SW coast of Scotland	AIR (99) 01	S	Complete
European calibration and co-ordination of mobile and airborne gamma spectrometry (ECCOMAGS)	UKRSR02	S	Complete
Dietary and occupancy surveys	230/2350	S	Complete
Total diet studies	R03019	F	Complete
Industrial site surveillance	R03020	F	Complete
Accumulation and remobilisation of Tc-99 in Eastern Irish Sea sediments	R01055	F	Complete
The feasibility, effectiveness and response implications of presenting the results of a prospective dose assessment to the public	R01056	F	Complete
RIFE Trend studies	R03011	F	Ongoing
Presentation of probabilistic dose estimates: Extension of stage 1 pilot study to cover uncertainty	R01058	F	Ongoing
Bottled waters	R03021	F	Ongoing
Soil and herbage survey	UKRSR01	S	Sep-04
International Radionuclide Flux Database (RADFLUX)	R01051	F	Nov-04
Assessing the suitability of controlled landfills to accept radioactive waste	UKRSR03	S	Dec-04
Development of a regulatory framework to assess the application of best practicable means for the management of radioactive wastes	UKRSR05	S	Dec-04
Measurement of radioactivity in canteen meals for Euratom article 35	R03022	F	Jun-05
Assessment of organically bound tritium (OBT) in the environment	R01034	F	Nov-05
Recovery handbook - response to nuclear incidents	C05032	F, E, S	Dec-05
Total diet studies	R03024	F	Mar-07

E Environment Agency
F Food Standards Agency
S Scotland and Northern Ireland Forum for Environmental Research or SEPA

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APPENDIX 1. DISPOSALS OF RADIOACTIVE WASTE*

Table A1.1. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2003

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003	
			TBq[a]	% of limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Rivacre Brook)	Tritium[r]	78	0.102	<1
	Uranium	0.02	$9.20\ 10^{-4}$	4.6
	Uranium daughters	0.02	$9.20\ 10^{-4}$	4.6
	Non-uranic alpha	0.003	$6.70\ 10^{-6}$	<1
	Technetium-99	0.1	$9.20\ 10^{-4}$	<1
Sellafield[u] (sea pipelines)	Alpha	1	0.407	41
	Beta	400	83.3	21
	Tritium	$2.5\ 10^{4}$	3900	16
	Carbon-14	20.8	17.0	82
	Cobalt-60	13	0.43	3.3
	Strontium-90	48	14.0	29
	Zirconium-95+Niobium-95	9	0.306	3.4
	Technetium-99	90	37.0	41
	Ruthenium-106	63	11.5	18
	Iodine-129	1.6	0.554	35
	Caesium-134	6.6	0.392	5.9
	Caesium-137	75	6.24	8.3
	Cerium-144	8	0.885	11
	Plutonium alpha	0.7	0.358	51
	Plutonium-241	27	10.1	37
	Americium-241	0.3	0.0590	20
	Uranium[d]	2040	484	24
Sellafield (factory sewer)	Alpha	0.0033	$7.01\ 10^{-5}$	2.1
	Beta	0.0135	$4.64\ 10^{-4}$	3.4
	Tritium	0.132	0.0268	20
Springfields	Alpha	4	0.180	4.5
	Beta	240	97.0	40
	Technetium-99	0.6	0.0520	8.7
	Thorium-230	2	0.0670	3.4
	Thorium-232	0.2	$6.00\ 10^{-4}$	<1
	Neptunium-237	0.04	0.00180	4.5
	Uranium	0.15	0.0560	37
Research establishments				
Dounreay	Alpha[c]	0.27	0.00275	1.0
	Beta[e]	49	0.367	<1
	Tritium	30.8	0.0948	<1
	Cobalt-60	0.46	$2.49\ 10^{-4}$	<1
	Strontium-90	7.7	0.129	1.7
	Zirconium-95+Niobium-95	0.4	$2.37\ 10^{-4}$	<1
	Ruthenium-106	4.1	$5.48\ 10^{-4}$	<1
	Silver-110m	0.13	$9.61\ 10^{-5}$	<1
	Caesium-137	23	0.0126	<1
	Cerium-144	0.42	$4.46\ 10^{-4}$	<1
	Plutonium-241	2.3	$2.05\ 10^{-4}$	<1
	Curium-242	0.04	$4.04\ 10^{-7}$	<1
Harwell (pipeline)[w]	Alpha	$5\ 10^{-5}$	$1.20\ 10^{-5}$	24
	Beta[e]	0.0033	$3.50\ 10^{-4}$	11
	Tritium	0.3	0.00530	1.8
	Cobalt-60	$1.2\ 10^{-4}$	$4.60\ 10^{-6}$	3.8
	Caesium-137	$5.4\ 10^{-4}$	$5.60\ 10^{-5}$	10

* *As reported to SEPA and the Environment Agency*

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003	
			TBq[a]	% of limit[b]
Harwell (Lydebank Brook)[w]	Alpha	1 10^{-4}	2.70 10^{-5}	27
	Beta[e]	6 10^{-4}	2.40 10^{-4}	40
	Tritium	0.08	0.012	15
Winfrith (inner pipeline)	Alpha	0.3	0.00151	<1
	Tritium	650	12.7	2.0
	Cobalt-60	10	0.00115	<1
	Zinc-65	6	2.17 10^{-4}	<1
	Other radionuclides	80	0.0773	<1
Winfrith (outer pipeline)	Alpha	0.004	6.33 10^{-5}	1.6
	Tritium	1	0.00964	<1
	Other radionuclides	0.01	1.31 10^{-4}	1.3
Minor sites				
Imperial College Reactor Centre Ascot	Tritium	1 10^{-4}	5.5 10^{-6}	5.5
	Other radioactivity	4 10^{-5}	3.0 10^{-6}	7.5
Imperial Chemical Industries plc Billingham	Tritium	0.36	Nil	Nil
	Beta/gamma	0.36	Nil	Nil
	Thorium	3 10^{-4}	Nil	Nil
Scottish Universities Research Environmental Centre East Kilbride	Total activity	[y]	[y]	[y]
Nuclear power stations				
Berkeley[v]	Tritium	2	3.00 10^{-4}	<1
	Caesium-137	0.2	1.57 10^{-4}	<1
	Other radionuclides	0.4	1.11 10^{-4}	<1
Bradwell[v]	Tritium	7	0.127	1.8
	Caesium-137	0.7	0.373	53
	Other radionuclides	0.7	0.285	41
Chapelcross	Alpha	0.1	8.01 10^{-4}	<1
	Beta[e]	25	0.178	<1
	Tritium	5.5	0.249	4.5
Dungeness[v] 'A' Station	Tritium	8	0.335	4.2
	Caesium-137	1.1	0.308	28
	Other radionuclides	0.8	0.166	21
Dungeness 'B' Station	Tritium	650	446	69
	Sulphur-35	2	0.794	40
	Cobalt-60	0.03	0.00171	5.7
	Other radionuclides	0.25	0.0252	10
Hartlepool	Tritium	1200	360	30
	Sulphur-35	3	1.30	43
	Cobalt-60	0.03	0.00170	5.7
	Other radionuclides	0.3	0.013	4.3
Heysham Station 1	Tritium	1200	360	30
	Sulphur-35	2.8	0.370	13
	Cobalt-60	0.03	8.40 10^{-4}	2.8
	Other radionuclides	0.3	0.0430	14

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003	
			TBq[a]	% of limit[b]
Heysham Station 2	Tritium	1200	390	33
	Sulphur-35	2.3	0.130	5.7
	Cobalt-60	0.03	$2.80\ 10^{-4}$	<1
	Other radionuclides	0.3	0.016	5.3
Hinkley Point[v] 'A' Station	Tritium	1.8	0.536	30
	Caesium-137	1	0.486	49
	Other radionuclides	0.7	0.134	19
Hinkley Point 'B' Station	Tritium	620	400	65
	Sulphur-35	5	0.431	8.6
	Cobalt-60	0.033	$7.20\ 10^{-4}$	2.2
	Other radionuclides	0.235	0.0146	6.2
Hunterston 'A' Station	Alpha	0.04	$1.79\ 10^{-4}$	<1
	Beta	0.6	0.0498	8.3
	Tritium	0.7	$9.40\ 10^{-4}$	<1
	Plutonium-241	1.0	$1.76\ 10^{-4}$	<1
Hunterston 'B' Station	Alpha	0.001	$1.14\ 10^{-4}$	11
	Beta[e,g,p]	0.45	0.0146	3.2
	Tritium	800	446	56
	Sulphur-35	10	1.47	15
	Cobalt-60	0.03	$6\ 10^{-4}$	2.0
Oldbury	Tritium	1	0.334	33
	Caesium-137	0.7	0.449	64
	Other radionuclides	0.7	0.224	32
Sizewell 'A' Station[v]	Tritium	11	2.83	26
	Caesium-137	1	0.558	56
	Other radionuclides	0.7	0.334	48
Sizewell 'B' Station	Tritium	80	68.9	86
	Other radionuclides	0.2	0.0442	22
Torness	Alpha	0.001	$5.18\ 10^{-6}$	<1
	Beta[e,g,p]	0.45	0.0018	<1
	Tritium	800	314	39
	Sulphur-35	10	0.0216	<1
	Cobalt-60	0.03	$1.42\ 10^{-4}$	<1
Trawsfynydd[v]	Other radionuclides[e,i,j]	0.17	0.0042	2.5
	Tritium	0.5	0.0358	7.2
	Strontium-90	0.05	0.00220	4.4
	Caesium-137	0.03	0.00193	6.4
Wylfa[v]	Tritium	15	8.60	57
	Other radionuclides	0.11	0.0584	53
Defence establishments				
Aldermaston (River Thames)	Alpha	$6\ 10^{-5}$	$7.51\ 10^{-6}$	13
	Tritium	0.05	0.0115	23
	Plutonium-241	$2.4\ 10^{-4}$	$3.00\ 10^{-5}$	13
	Other radionuclides	$6.0\ 10^{-5}$	$4.76\ 10^{-6}$	7.9

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003 TBq[a]	% of limit[b]
Aldermaston (Silchester)	Alpha	4 10^{-5}	2.37 10^{-6}	5.9
	Beta	1.2 10^{-4}	1.47 10^{-5}	12
	Tritium	0.05	2.65 10^{-4}	<1
Barrow[l]	Tritium	0.02	8.01 10^{-6}	<1
	Manganese-54	2.5 10^{-7}	8.72 10^{-11}	<1
	Cobalt-58	7 10^{-7}	5.71 10^{-11}	<1
	Cobalt-60	7 10^{-8}	7.16 10^{-11}	<1
	Tin-113	2.5 10^{-7}	8.15 10^{-11}	<1
	Antimony-124	2.0 10^{-6}	1.17 10^{-10}	<1
	Other radionuclides	3.5 10^{-6}	Nil	Nil
Derby[h]	Alpha[s]	0.00666	4.61 10^{-4}	6.9
	Alpha[t]	1.85 10^{-4}	9.67 10^{-8}	<1
	Beta[t]	0.0094	1.91 10^{-6}	<1
Devonport[m,n] (sewer)	Beta		Nil	
	Tritium		Nil	
	Cobalt-60		Nil	
Devonport[o,k] (sewer)	Tritium	0.002	1.71 10^{-4}	8.6
	Cobalt-60	3.5 10^{-4}	1.28 10^{-5}	3.7
	Other radionuclides[e,p]	6.5 10^{-4}	2.95 10^{-4}	45
Devonport[o,k] (pipeline)	Tritium	0.7	0.0956	14
	Carbon-14	0.0017	4.05 10^{-4}	24
	Cobalt-60	8 10^{-4}	1.74 10^{-4}	22
	Other radionuclides[e,p,x]	3 10^{-4}	1.89 10^{-4}	63
Faslane	Alpha activity	2 10^{-4}	1.46 10^{-5}	7.3
	Beta activity[e,p]	5 10^{-4}	2.66 10^{-6}	<1
	Tritium	1	0.0937	9.4
	Cobalt-60	5 10^{-4}	8.19 10^{-6}	1.6
Rosyth[q]	Alpha	1 10^{-6}	2.40 10^{-8}	2.4
	Beta[e,p]	5 10^{-4}	4.95 10^{-5}	9.9
	Tritium	0.04	0.00146	3.7
	Cobalt-60	0.005	1.08 10^{-4}	2.2
Radiochemical production				
Amersham	Alpha	3 10^{-4}	1.58 10^{-5}	5.3
	Beta >0.4 MeV	0.1	7.35 10^{-4}	<1
	Tritium	0.2	0.00111	<1
	Iodine-125	0.2	1.81 10^{-4}	<1
	Caesium-137	0.005	3.90 10^{-7}	<1
	Other radionuclides	0.3	0.0139	4.6
Cardiff (Amersham plc)	Tritium	900	30.2	3.4
	Carbon-14	2	0.143	7.2
	Phosphorus-32/33	0.01	3.48 10^{-6}	<1
	Iodine-125	0.05	2.36 10^{-5}	<1
	Others	5 10^{-4}	5.19 10^{-7}	<1

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003	
			TBq[a]	% of limit[b]
Industrial and landfill sites				
Drigg (sea pipeline)	Alpha	0.1	$6.04\ 10^{-5}$	<1
	Beta[e]	0.3	$8.67\ 10^{-4}$	<1
	Tritium	120	0.204	<1
Drigg (stream[f])	Alpha	$9\ 10^{4}$	51.2	<1
	Beta[e]	$1.2\ 10^{6}$	459	<1
	Tritium	$6\ 10^{8}$	$2.80\ 10^{4}$	<1

[a] *Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 3 significant figures except where fewer significant figures are provided in source documents*
[b] *Data quoted to 2 significant figures except when values are less than 1%*
[c] *Excluding curium-242*
[d] *The limit and discharge data are expressed in kg*
[e] *Excluding tritium*
[f] *Discharges and limits are expressed in terms of concentrations of activity in Bq m^{-3} (discharges are expressed as the annual mean)*
[g] *Excluding sulphur-35*
[h] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[i] *Excluding caesium-137*
[j] *Excluding strontium-90*
[k] *Discharge authorisation at Devonport was revised with effect from 13th March 2002.*
[l] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[m] *Discharges were made by the Ministry of Defence*
[n] *The current authorisation includes limits on concentrations of total activity (MOD $2\ 10^{-6}$ TBq m^{-3}). At no time did the concentrations exceed the limits*
[o] *Discharges were made by Devonport Royal Dockyard Ltd*
[p] *Excluding cobalt-60*
[q] *Discharges were made by Rosyth Royal Dockyard Ltd*
[r] *The limit for tritium is derived from a limit on activity concentration in Rivacre Brook of 111 Bq ml^{-1} and a flow rate of 90 $m^3\ h^{-1}$*
[s] *Discharge limit is for Nuclear Fuel Production Plant*
[t] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[u] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[v] *Discharge authorisations were revised with effect from 18th December 2002.*
[w] *Discharge authorisation at Harwell was revised with effect from 1st May 2003, discharges quoted are for 1st May-31st December 2003*
[x] *Excluding carbon-14*
[y] *Not available*

Table A1.2 Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2003

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003 TBq	Discharges during 2003 % of limit
Nuclear fuels production and reprocessing				
Capenhurst (BNFL)	Tritium	1600	0.0105	<1
	Uranium[d]		$1.02\ 10^{-5}$	
Capenhurst (Urenco)	Uranium	$2.5\ 10^{-6}$	$3.27\ 10^{-7}$	13
Sellafield[a,b]	Alpha	0.00246	$1.18\ 10^{-4}$	4.8
	Beta	0.341	$1.19\ 10^{-3}$	<1
	Tritium	1440	373	26
	Carbon-14	7.3	0.711	9.7
	Sulphur-35	0.21	0.00651	3.1
	Argon-41	3700	153	4.1
	Cobalt-60	$9.2\ 10^{-4}$	$1.89\ 10^{-6}$	<1
	Krypton-85	$3.5\ 10^{5}$	$1.20\ 10^{5}$	34
	Strontium-90	0.0094	$5.26\ 10^{-5}$	<1
	Ruthenium-106	0.056	0.00143	2.6
	Antimony-125	0.005	0.00106	21
	Iodine-129	0.069	0.0170	25
	Iodine-131	0.055	$6.00\ 10^{-4}$	1.1
	Caesium-137	0.0183	$4.95\ 10^{-4}$	2.7
	Plutonium (alpha)	0.00122	$6.51\ 10^{-5}$	5.3
	Plutonium-241	0.0174	$3.94\ 10^{-4}$	2.3
	Americium-241 and curium-242	$7.40\ 10^{-4}$	$3.82\ 10^{-5}$	5.2
Springfields	Uranium	0.006	$8.90\ 10^{-4}$	15
Research establishments				
Dounreay (Fuel Cycle Area)	Alpha[e]	$9.8\ 10^{-4}$	$6.24\ 10^{-5}$	6.4
	Beta[k]	0.045	$3.36\ 10^{-4}$	<1
	Tritium	2	0.270	13
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	$1.97\ 10^{-4}$	4.7
	Ruthenium-106	0.0039	$6.71\ 10^{-6}$	<1
	Iodine-129	0.0011	$7.16\ 10^{-5}$	6.5
	Iodine-131	$1.5\ 10^{-4}$	$2.84\ 10^{-5}$	19
	Caesium-134	$8.4\ 10^{-4}$	$7.38\ 10^{-7}$	<1
	Caesium-137	0.007	$1.05\ 10^{-4}$	1.5
	Cerium-144	0.007	$5.13\ 10^{-6}$	<1
	Plutonium-241	0.0033	$2.60\ 10^{-5}$	<1
	Curium-242	$2.7\ 10^{-4}$	$3.75\ 10^{-7}$	<1
	Curium-244[i]	$5.4\ 10^{-5}$	$7.93\ 10^{-8}$	<1
Dounreay (Fast Reactor)	Alpha[l]	10^{-5}	$1.69\ 10^{-9}$	<1
	Beta[k]	0.0015	$5.84\ 10^{-9}$	<1
	Tritium	4.5	$5.98\ 10^{-4}$	<1
	Krypton-85	$4\ 10^{-4}$	Nil	Nil
Dounreay (Prototype Fast Reactor)	Alpha[l]	$6\ 10^{-6}$	$3.88\ 10^{-8}$	<1
	Beta[k]	$5.1\ 10^{-5}$	$1.18\ 10^{-6}$	2.3
	Tritium	10.5	0.12	1.2
	Krypton-85	4	Nil	Nil
Dounreay (PFR minor sources)	Alpha[l]	$6\ 10^{-8}$	Nil	Nil
	Beta[k]	$5\ 10^{-7}$	Nil	Nil
	Tritium	0.2	0.0495	25

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003 TBq	% of limit
Dounreay (East minor sources)	Alpha[l]	1.37 10^{-5}	1.29 10^{-7}	<1
	Beta[h]	3.71 10^{-4}	4.32 10^{-7}	<1
	Krypton-85	1	Nil	Nil
Dounreay (West minor sources)	Alpha[l]	3 10^{-7}	6.01 10^{-10}	<1
	Beta[o]	7.5 10^{-5}	5.54 10^{-9}	<1
	Tritium	0.01	2.22 10^{-4}	2.2
Dounreay (LSA Descaling Facility)	Alpha	4 10^{-7}	2.54 10^{-9}	<1
	Beta	10^{-6}	8.92 10^{-8}	8.9
Dounreay (Sodium Disposal Facility)	Tritium	7.1 10^{-4}	3.67 10^{-5}	5.2
Harwell (AEA Technology)				
	Alpha	7 10^{-7}	Nil	Nil
	Beta	3 10^{-5}	Nil	Nil
	Tritium	2 10^{-4}	Nil	Nil
Harwell[q] (UKAEA)				
	Alpha	8 10^{-7}	6.3 10^{-8}	7.9
	Beta	2 10^{-5}	3.5 10^{-6}	18
	Tritium	15	1.1	7.3
	Krypton-85	2	0.11	5.5
	Radon-220	100	11.4	11
	Radon-222	3	0.36	12
	Iodine	0.01	1.30 10^{-8}	<1
	Other radionuclides	0.1	7.30 10^{-8}	<1
Windscale	Alpha	1.2 10^{-5}	1.44 10^{-7}	1.2
	Beta	5 10^{-4}	2.59 10^{-6}	<1
	Tritium	2.3	0.00853	<1
	Krypton-85	14	0.100	<1
	Iodine-131	0.0012	2.16 10^{-6}	<1
Winfrith (AEA Technology)	Alpha	2 10^{-7}	Nil	Nil
	Beta	2.5 10^{-5}	7.32 10^{-6}	29
	Tritium	10	3.53	35
Winfrith (UKAEA)	Alpha	2 10^{-6}	6.00 10^{-10}	<1
	Beta	2.5 10^{-5}	1.08 10^{-7}	<1
	Tritium	5	0.135	2.7
	Carbon-14	0.3	6.16 10^{-4}	<1
	Krypton-85	150	Nil	Nil
Minor sites				
Imperial College Reactor Centre Ascot	Tritium	5 10^{-4}	7.68 10^{-5}	15
	Argon-41	2.5	0.326	13
Imperial Chemical Industries plc Billingham	Tritium, argon-41, krypton-85 and xenon-133	2.3	Nil	Nil
	Thorium	3 10^{-5}	"	"
Scottish Universities Environmental Research Centre East Kilbride	Beta	[t]	[t]	[t]
	Tritium	[t]	[t]	[t]

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003 TBq	Discharges during 2003 % of limit
Nuclear power stations				
Berkeley[p]	Alpha and beta[m]	3 10^{-5}	3.81 10^{-7}	1.3
	Tritium	0.0754	0.00371	4.9
	Carbon-14	0.011	2.51 10^{-4}	2.3
	Sulphur-35	n/a	n/a	n/a
Bradwell[p]	Beta	6 10^{-4}	2.01 10^{-5}	3.4
	Tritium	1.5	8.50 10^{-2}	5.7
	Carbon-14	0.6	0.00376	<1
	Sulphur-35	0.02	8.50 10^{-5}	<1
	Argon-41	n/a	n/a	n/a
Chapelcross	Tritium	5000	410	8.2
	Sulphur-35	0.05	0.00371	7.4
	Argon-41	4500	748	17
Dungeness[p]				
‘A’ Station	Beta	5.5 10^{-4}	2.25 10^{-4}	41
	Tritium	2.6	0.478	18
	Carbon-14	5	3.41	68
	Sulphur-35	0.15	0.0356	24
	Argon-41	1700	1050	62
Dungeness				
‘B’ Station	Beta[j]	0.001	7.84 10^{-6}	<1
	Tritium	15	11.0	73
	Carbon-14	5	0.714	14
	Sulphur-35	0.45	0.0889	20
	Argon-41	150	18.7	12
	Iodine-131	0.005	2.10 10^{-6}	<1
Hartlepool	Beta[j]	0.001	8.76 10^{-6}	<1
	Tritium	6	2.54	42
	Carbon-14	5	1.80	36
	Sulphur-35	0.16	0.121	76
	Argon-41	60	30.3	51
	Iodine-131	0.005	2.49 10^{-5}	<1
Heysham				
Station 1	Beta[j]	0.001	7.89 10^{-6}	<1
	Tritium	6	1.36	23
	Carbon-14	4	1.67	42
	Sulphur-35	0.12	0.0262	22
	Argon-41	60	14.3	24
	Iodine-131	0.005	1.15 10^{-4}	2.3
Heysham				
Station 2	Beta[j]	0.001	1.37 10^{-5}	1.4
	Tritium	15	1.13	7.5
	Carbon-14	3	1.21	40
	Sulphur-35	0.3	0.0160	5.3
	Argon-41	85	18.0	21
	Iodine-131	0.005	3.95 10^{-5}	<1
Hinkley Point[p]				
‘A’ Station	Beta	1.5 10^{-4}	3.04 10^{-6}	2.0
	Tritium	1.5	0.0126	<1
	Carbon-14	0.6	0.00263	<1
	Sulphur-35	n/a	n/a	n/a
	Argon-41	n/a	n/a	n/a

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003 TBq	% of limit
Hinkley Point 'B' Station	Beta[j]	0.001	3.88 10^{-5}	3.9
	Tritium	30	7.18	24
	Carbon-14	8	1.22	15
	Sulphur-35	0.4	0.193	48
	Argon-41	300	15.1	5.1
	Iodine-131	0.005	4.07 10^{-6}	<1
Hunterston[p] 'A' Station	Beta[j]	6 10^{-5}	4.5 10^{-7}	<1
	Tritium	0.02	0.00159	8.0
	Carbon-14	0.002	1.88 10^{-4}	9.4
Hunterston 'B' Station	Beta[j]	0.002	9 10^{-5}	4.5
	Tritium	20	6.07	30
	Carbon-14	3	1.62	54
	Sulphur-35	0.8	0.0675	8.4
	Argon-41	220	39.4	18
Oldbury[p]	Beta	1 10^{-4}	4.85 10^{-5}	49
	Tritium	9	3.29	37
	Carbon-14	4	1.91	48
	Sulphur-35	0.45	0.168	37
	Argon-41	500	75.7	15
Sizewell[p] 'A' Station	Beta	8.5 10^{-4}	2.05 10^{-4}	24
	Tritium	3.5	1.93	55
	Carbon-14	2	1.26	63
	Sulphur-35	0.35	0.179	51
	Argon-41	3000	2030	68
Sizewell 'B' Station[a]	Noble gases	300	4.3	1.4
	Halogens	0.003	0.00119	40
	Beta[j]	0.01	1.15 10^{-5}	<1
	Tritium	8	0.882	11
	Carbon-14	0.6	0.282	47
Torness	Beta[j]	0.002	4.49 10^{-6}	<1
	Tritium	20	2.35	12
	Carbon-14	3	0.652	22
	Sulphur-35	0.8	0.0212	2.7
	Argon-41	220	5.26	2.4
Trawsfynydd[p]	Beta	5 10^{-5}	4.77 10^{-7}	<1
	Tritium	0.75	0.0555	7.4
	Carbon-14	0.01	0.00140	14
	Sulphur-35	n/a	n/a	n/a
	Argon-41	n/a	n/a	n/a
Wylfa[p]	Beta	7 10^{-4}	3.01 10^{-5}	4.3
	Tritium	18	4.50	25
	Carbon-14	2.3	1.41	61
	Sulphur-35	0.45	0.180	40
	Argon-41	100	41.1	41
Defence establishments				
Aldermaston[a,n]	Alpha	4.5 10^{-7}	7.60 10^{-8}	17
	Other beta and gamma emitters[f]	5 10^{-6}	1.26 10^{-7}	2.5
	Tritium	170	13.5	7.9
	Krypton-85	1	0.00372	<1
	Plutonium-241	1.68 10^{-6}	2.59 10^{-7}	15
Barrow[g]	Tritium	3.2 10^{-6}	Nil	Nil
	Argon-41	0.08	"	"

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2003	
			TBq	% of limit
Burghfield[a,n]	Tritium	0.05	Nil	Nil
	Uranium	2 10^{-8}	1.53 10^{-9}	7.7
Coulport	Tritium	0.05	0.00253	5.1
Derby[s]	Alpha	[d]	1.56 10^{-6}	
Devonport[r]	Beta/gamma[j]	3 10^{-7}	4.20 10^{-8}	14
	Tritium	0.004	0.00149	37
	Carbon-14	0.043	0.00335	7.8
	Argon-41	0.015	1.07 10^{-4}	<1
Dounreay (Vulcan)	Alpha[j]	10^{-6}	4.7 10^{-8}	4.7
	Beta[j]	10^{-4}	1.2 10^{-6}	1.2
	Noble gases	0.027	3.46 10^{-4}	1.3
	Iodine-131	3.7 10^{-4}	2.70 10^{-5}	7.0
Faslane	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	1.20 10^{-5}	<1
Rosyth[c]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	1.2 10^{-6}	<1
Radiochemical production				
Amersham	Alpha	2 10^{-6}	7.50 10^{-8}	3.8
	Other (penetrating)	0.05	9.80 10^{-5}	<1
	Other (non-penetrating)	0.5	0.00600	1.2
	Tritium	40	Nil	Nil
	Selenium-75	0.03	2.80 10^{-4}	<1
	Iodine-125	0.1	0.00200	2.0
	Iodine-131	0.05	5.00 10^{-4}	1.0
	Radon-222	10	1.4	14
Cardiff (Amersham plc)	Soluble tritium	400	114	28
	Insoluble tritium	1000	475	48
	Carbon-14	6	1.70	28
	Phosphorus-32/33	2 10^{-4}	1.15 10^{-4}	57
	Iodine-125	5 10^{-4}	4.75 10^{-6}	<1
	Other activity	0.04	Nil	Nil
Cardiff (Ortho-Clinical Diagnostics Ltd)	Iodine-125	0.0150	4.46 10^{-5}	<1
	Other activity	5 10^{-4}	Nil	Nil

[a] *Some discharge limits and discharges are aggregated from data for individual locations on the site. Percentages are given as a general guide to usage of the limits but should strictly be calculated for individual locations. All discharges were below the appropriate limit for each location*
[b] *Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP*
[c] *Discharges were made by Rosyth Royal Dockyard Ltd*
[d] *There are no numerical limits for this discharge. However, the authorisation stipulates that the Best Practicable Means should be used to control the discharge*
[e] *Excluding curium-242 and 244*
[f] *Excluding tritium and plutonium-241*
[g] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[h] *Excluding krypton-85*
[i] *Data includes any curium-243 present*
[j] *Particulate activity*
[k] *Excluding tritium and krypton-85*
[l] *Excluding radon and daughter products*
[m] *Combined data for Berkeley Power Station and Berkeley Technology Centre*
[n] *Discharges were made by AWE plc*
[o] *Excluding tritium*
[p] *Discharge authorisations were revised with effect from 18th December 2002.*
[q] *Discharge authorisation at Harwell was revised with effect from 1st May 2003, discharges quoted are for 1st May - 31 December 2003*
[r] *Discharges were made by Devonport Royal Dockyard Ltd*
[s] *Discharges were made by Rolls Royce Marine Power Operations Ltd*

Table A1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2003

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 2003	
			TBq	% of limit
Drigg	Tritium	10	1.10	11
	Carbon-14	0.05	0.0130	26
	Cobalt-60	2	0.00900	4.5
	Iodine-129	0.05	$1.80\ 10^{-4}$	<1
	Radium-226 plus thorium-232	0.03	0.0170	57
	Uranium	0.3	0.0370	12
	Other alpha[a]	0.3	0.0540	18
	Others[a,b]	15	1.80	12
Dounreay[c]	Alpha		$3.94\ 10^{-4}$	
	Beta/gamma		0.0116	

[a] *With half-lives greater than three months*
[b] *Other beta emitting radionuclides but including iron-55 and cobalt-60*
[c] *The current authorisation includes limits on concentrations of activity. At no time did the concentrations exceed the limits*

APPENDIX 2. MODELLING OF CONCENTRATIONS OF RADIONUCLIDES IN FOODSTUFFS AND AIR

A2.1 Foodstuffs

At Sellafield, Drigg, Ravenglass and the Isle of Man, a simple food chain model has been used to provide concentrations of activity in milk and livestock for selected radionuclides to supplement data obtained by direct measurements. This is done where relatively high limits of detection exist or where no measurements were made.

Activities in milk, meat and offal were calculated for ^{99}Tc, ^{106}Ru, ^{144}Ce, ^{147}Pm and ^{241}Pu using the equations:

$$C_m = F_m Ca\, Q_f \quad \text{and}$$

$$C_f = F_f\, Ca\, Q_f \quad \text{where}$$

C_m is the concentration in milk (Bq l^{-1}),

C_f is the concentration in meat or offal (Bq kg^{-1} (wet)),

F_m is the fraction of the animal's daily intake by ingestion transferred to milk (d l^{-1}),

F_f is the fraction of the animal's daily intake by ingestion transferred to meat or offal (d kg^{-1}(wet)),

Ca is the concentration in fodder (Bq kg^{-1}(dry)),

Q_f is the amount of fodder eaten per day (kg(dry) d^{-1})

No direct account is taken of radionuclide decay or the intake by the animal of soil associated activity. The concentration in fodder is assumed to be the same as the maximum observed concentration in grass, or in the absence of such data, in leafy green vegetables. The food chain data for the calculations are given in Table A2.1 (Simmonds *et al*., 1995; Brenk *et al*., unpublished) and the estimated concentrations in milk, meat and offal are presented in Table A2.2.

Table A2.1 Data for food chain model

Parameter	Nuclide	Food				
		Milk	Beef	Beef offal	Lamb	Sheep offal
Q_f		13	13	13	1.5	1.5
F_m or F_f	^{99}Tc	10^{-2}	10^{-2}	$4\ 10^{-2}$	10^{-1}	$4\ 10^{-1}$
	^{106}Ru	10^{-6}	10^{-3}	10^{-3}	10^{-2}	10^{-2}
	^{144}Ce	$2\ 10^{-5}$	10^{-3}	$2\ 10^{-1}$	10^{-2}	2
	^{147}Pm	$2\ 10^{-5}$	$5\ 10^{-3}$	$4\ 10^{-2}$	$5\ 10^{-2}$	$3\ 10^{-1}$
	^{241}Pu	10^{-6}	10^{-4}	$2\ 10^{-2}$	$4\ 10^{-4}$	$3\ 10^{-2}$

Table A2.2 Predicted concentrations of radionuclides from food chain model used in assessments of exposures

Foodstuff	Location	Radioactivity concentration (wet weight), Bq kg^{-1}			
		^{99}Tc	^{106}Ru	^{144}Ce	^{241}Pu
Milk	Sellafield	[a]	$1.52\ 10^{-4}$	[b]	$4.30\ 10^{-6}$
	Ravenglass	[a]	$1.22\ 10^{-4}$	$2.14\ 10^{-3}$	$1.25\ 10^{-5}$
	Isle of Man	[a]	$2.95\ 10^{-4}$	[b]	$1.11\ 10^{-5}$
Beef	Sellafield	$3.68\ 10^{-2}$	$1.52\ 10^{-1}$	[b]	$4.30\ 10^{-4}$
	Ravenglass	[a]	$1.22\ 10^{-1}$	$1.07\ 10^{-1}$	$1.25\ 10^{-3}$
	Drigg	$1.56\ 10^{-1}$	[b]	[b]	[b]
	Isle of Man	$5.72\ 10^{-2}$	$2.95\ 10^{-1}$	[b]	$1.11\ 10^{-3}$
Lamb	Sellafield	[a]	$1.76\ 10^{-1}$	[b]	$1.99\ 10^{-4}$
	Ravenglass	[a]	$1.41\ 10^{-1}$	$1.24\ 10^{-1}$	$5.79\ 10^{-4}$
	Isle of Man	$6.60\ 10^{-2}$	$3.40\ 10^{-1}$	[b]	$5.12\ 10^{-4}$
Beef offal	Sellafield	[a]	$1.52\ 10^{-1}$	[b]	$8.61\ 10^{-2}$
	Ravenglass	[a]	$1.22\ 10^{-1}$	[a]	[a]
	Drigg	$6.24\ 10^{-1}$	[b]	[b]	[b]
	Isle of Man	$2.29\ 10^{-1}$	$2.95\ 10^{-1}$	[b]	$2.22\ 10^{-1}$
Lamb offal	Sellafield	[a]	$1.76\ 10^{-1}$	[b]	$1.49\ 10^{-2}$
	Ravenglass	[a]	$1.41\ 10^{-1}$	[a]	$4.34\ 10^{-2}$
	Isle of Man	$2.64\ 10^{-1}$	$3.40\ 10^{-1}$	[b]	$3.84\ 10^{-2}$

[a] *Positive result used, or LoD result used because modelling result greater than LoD*
[b] *No grass or leafy green vegetable or sample LoD data available*

A2.2 Air

For some sites, in particular the steel pressure vessel power stations, non-food exposure pathways are significant. For these types of power stations, discharges of argon-41 to air are significant whilst the reactors are operating. Argon-41 is a noble gas with a short radioactive half-life of about 1.8 h. It does not become incorporated into food produce, but people working or living within the plume may be exposed to external radiation from argon-41 as it disperses downwind of the discharge point. The dose from argon-41, along with the dose from the inhalation of other radionuclides released to air, has been assessed.

The power stations considered for this assessment are Chapelcross, Dungeness A, Oldbury, Sizewell A and Calder Hall at Sellafield. The additional radionuclides discharged to air from the Sellafield site have been included in the assessment, with the assumption that all argon-41 and sulphur-35 are released by the Calder Hall reactors and the other radionuclides are released from THORP. An assessment has also been made of discharges from the Cardiff site. The Gaussian plume model within the assessment code PC CREAM (Mayall *et al*., 1997) has been used to derive air concentrations at the locations of nearest habitation around these sites from the reported discharges of radionuclides to air. Site-specific meteorological data have been used in the assessment and other key modelling assumptions (ie discharge height, exposure location) are shown in Table A2.3.

PC CREAM has also been used to calculate the external radiation doses from radionuclides in the plume and from deposited activity and internal radiation doses from inhalation of discharged radionuclides. Doses have been assessed for three age groups: infants (1 y), children (10 y) and adults. The inhalation and occupancy rates assumed in this assessment are shown in Table A2.4. Adults and infants are assumed to have year-round occupancy at the nearest habitation, whilst children are assumed to spend time away at school.

Allowance has been made for time spent indoors and outdoors. During the time people are assumed to be indoors, the standard assumption that the dose from radionuclides in the plume will be reduced by 80 per cent (ie shielding factor of 0.2) has been made.

The predicted concentrations of radioactivity in air are given in Tables A2.5 and A2.6.

Table A2.3 Air concentration modelling assumptions

Nuclear site	Stack height, m	Exposure location	Distance to exposure location, m	Bearing to exposure location
Cardiff	20	Dwelling	400	270°
Chapelcross	30	Dwelling	1200	60°
Dungeness A	17	Dwelling	300	70°
Oldbury	20	Farm	700	90°
Sizewell A	18	Dwelling	300	180°
Sellafield (argon-41 and sulphur-35 from Calder Hall)	25	Farm	500	100°
Sellafield (other radionuclides from THORP)	92.5	Farm	1200	90°

Table A2.4 Inhalation and occupancy data for dose assessment of discharges to air

Age group, y	Inhalation rates, $m^3 h^{-1}$	Occupancy at exposure location, h y^{-1}	Fraction of time indoors
Cardiff, Chapelcross, Dungeness A and Sizewell A (dwellings)			
1	0.22	8760	0.9
10	0.64	7500	0.8
Adult	0.92	8760	0.7
Oldbury and Sellafield (farm locations)			
1	0.22	8760	0.9
10	0.64	7500	0.8
Adult	0.92	8760	0.5

Table A2.5 Predicted concentrations of radionuclides in air at highest exposure locations in the vicinity of Magnox power stations and Cardiff

Site	Radioactivity concentration in air, Bq m^{-3}						
	Tritium	^{14}C	^{32}P	^{35}S	^{41}Ar	^{60}Co	^{125}I
Cardiff	15	0.16	1.1 10^{-5}				4.4 10^{-7}
Chapelcross	8			7.3 10^{-5}	14		
Dungeness A	9.1 10^{-2}	0.65		6.8 10^{-3}	2.0 10^{2}	4.3 10^{-5}	
Oldbury	0.19	0.11		9.9 10^{-3}	4.4	2.80 10^{-6}	
Sizewell A	0.13	8.2 10^{-2}		1.2 10^{-2}	1.3 10^{2}	1.3 10^{-5}	

Table A2.6 Predicted concentrations of radionuclides in air at most exposed location in vicinity of Sellafield

Radionuclide	Radioactivity concentration in air, Bq m^{-3}
Tritium	0.77
Carbon-14	1.5 10^{-3}
Sulphur-35	2.3 10^{-4}
Argon-41	5.3
Cobalt-60	3.9 10^{-9}
Krypton-85	2.5 10^{2}
Strontium-90	1.1 10^{-7}
Ruthenium-106	2.9 10^{-6}
Antimony-125	2.2 10^{-6}
Iodine-129	3.5 10^{-5}
Iodine-131	1.2 10^{-6}
Caesium-137	1.0 10^{-6}
Plutonium-239	1.3 10^{-7}
Plutonium-241	8.1 10^{-7}
Americium-241	7.8 10^{-8}

APPENDIX 3. ABBREVIATIONS

AEA	Atomic Energy Authority
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BNFL	British Nuclear Fuels plc
BNS	Babcock Naval Services
CAC	Codex Alimentarius Commission
CEC	Commission of the European Communities
CEDA	Consultative Exercise on Dose Assessments
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DPAG	Dounreay Particles Advisory Group
DSTL	Defence Science and Technology Laboratory
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EHS	Environment and Heritage Service
EU	European Union
FEPA 85	Food and Environment Protection Act 1985
FSA	Food Standards Agency
GDL	Generalised Derived Limit
GE	General Electrics
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IC	Imperial College
ICRP	International Commission on Radiological Protection
LoD	Limit of Detection
MAC	Medium Active Concentrate
MAFF	Ministry of Agriculture, Fisheries and Food
MOD	Ministry of Defence
MOD(N)	Ministry of Defence (Navy)
MRL	Minimum reporting level
ND	Not detected
NDA	Nuclear Decommissioning Authority
NDAWG	National Dose Assessment Working Group
NEA	Nuclear Energy Agency
NII	Nuclear Installations Inspectorate
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NRTE	Nuclear reactor test establishment
OBT	Organically bound tritium
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Convention
QNL	Quarterly Notification Limit
RIFE	Radioactivity in Food and the Environment
RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
SL	Scientifics Ltd
SNIFFER	Scottish and Northern Ireland Forum for Environmental Research
SURRC	Scottish Universities Research Reactor Centre
TDS	Total Diet Study

THORP	Thermal Oxide Reprocessing Plant
TNORM	Technologically Enhanced Naturally Occurring Radioactive Material
TPP	Tetraphenylphosphonium bromide
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
USA	United States of America
VLA	Veterinary Laboratories Agency
WELL	Winfrith Environmental Level Laboratory
WHO	World Health Organisation
YP	Ystradyfodwg and Pontpridd

APPENDIX 4. CONSUMPTION, INHALATION, HANDLING AND OCCUPANCY RATES

This appendix gives the consumption, handling and occupancy rate data used in the routine assessment of exposures from terrestrial consumption and aquatic pathways. Further data are presented in Appendix 7 for the assesment of total dose integrated across pathways. Consumption rates for terrestrial foods are based on Byrom *et al.* (1995) and are given in Table A4.1. These are derived from national statistics and are taken to apply at each site. Site-specific data for aquatic pathways based on local surveys are given in Table A4.2. Occupancy over intertidal areas and rates of handling from local surveys have been reassessed to take account of a change in the factor used to determine the range of rates within the critical group. Previously, when using the ‘cut-off’ method to define the critical group (Hunt *et al.*, 1982; Preston, *et al.*, 1974), a factor of 1.5 was used to describe the ratio of the maximum to the minimum rate within the group. The factor has now changed to 3 to make the selection process consistent with that used for consumption pathways. From 2002, sites in England and Wales with new local surveys were adjusted to adopt the new factor. From 2003, all sites in Scotland were adjusted. Data used for routine assessments of external and inhalation pathways from gaseous discharges are given in Appendix 2.

Table A4.1 Consumption rates for terrestrial foods

Food Group	Consumption rates (kg y^{-1})					
	Average			Above average consumption rate*		
	Adult	10 year old	Infant	Adult	10 year old	Infant
Beef	15	15	3	45	30	10
Cereals	50	45	15	100	75	30
Eggs	8.5	6.5	5	25	20	15
Fruit	20	15	9	75	50	35
Game	6	4	0.8	15	7.5	2.1
Green Vegetables	15	6	3.5	45	20	10
Honey	2.5	2	2	9.5	7.5	7.5
Lamb	8	4	0.8	25	10	3
Legumes	20	8	3	50	25	10
Milk	95	110	130	240	240	320
Mushrooms	3	1.5	0.6	10	4.5	1.5
Nuts	3	1.5	1	10	7	2
Offal	5.5	3	1	20	10	5.5
Pork	15	8.5	1.5	40	25	5.5
Potatoes	50	45	10	120	85	35
Poultry	10	5.5	2	30	15	5.5
Root crops	10	6	5	40	20	15
Wild fruit	7	3	1	25	10	2

* *These rates are the 97.5th percentile of the distribution across all consumers*

Table A4.2 Consumption, inhalation, handling and occupancy rates for aquatic pathways

Site (Year of last survey)	Group[a]	Rates
Aldermaston (2002)	A	1 kg y^{-1} pike
		320 h y^{-1} over riverbank
	B	1.2 kg y^{-1} crayfish
Amersham (1991)		1 kg y^{-1} pike
		1600 h y^{-1} over riverbank
Berkeley and Oldbury (2001)		18 kg y^{-1} salmonids and other fish
		2.3 kg y^{-1} shrimps
		520 h y^{-1} over mud
Bradwell	A (1999)	44 kg y^{-1} fish
		3.1 kg y^{-1} crustaceans
		6.5 kg y^{-1} molluscs
		2900 h y^{-1} over mud
	B (NA)	300 h y^{-1} over sediment
Capenhurst (NA)	10 year old children	500 h y^{-1} over sediment
		5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		20 l y^{-1} water by inadvertent ingestion

Table A4.2. continued

Site	Group[a]	Rates
Cardiff	A (2003)	24 kg y^{-1} fish
		3.8 kg y^{-1} prawns and lobster
		500 h y^{-1} over mud
	B (NA)	500 h y^{-1} over bank of the River Taff
		2.5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		34 l y^{-1} water by inadvertent ingestion
	C (2003)	5.6 kg y^{-1} wildfowl
Channel Islands (1997)		62 kg y^{-1} fish
		30 kg y^{-1} crustaceans
		30 kg y^{-1} molluscs
		1400 h y^{-1} over mud and sand
Chapelcross (2000)	A	20 kg y^{-1} salmonids (80%) and other fish (20%)
		12 kg y^{-1} shrimps
		3.0 kg y^{-1} mussels
		790 h y^{-1} over mud and sand
	B	280 h y^{-1} over salt marsh
	C	920 h y^{-1} handling nets
Culham (NA)		600 l y^{-1} water
Derby (NA)		600 l y^{-1} water
Devonport (1992)		14 kg y^{-1} salmonids
		13 kg y^{-1} fish
		5 kg y^{-1} crustaceans
		2000 h y^{-1} over mud
Dounreay (2003)	A	1500 h y^{-1} handling fishing gear
	B	30 kg y^{-1} fish
		8.9 kg y^{-1} crab and lobster
		0.5 kg y^{-1} mussels and winkles
	C	410 h y^{-1} over rock and sand
	D	8 h y^{-1} in a Geo
Drigg (NA)		35 l y^{-1} water
Drinking water (NA)	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness (1999)		59 kg y^{-1} fish
		17 kg y^{-1} crustaceans
		15 kg y^{-1} molluscs
		1500 h y^{-1} over mud and sand
Faslane (2000)	A	200 h y^{-1} over mud
	B	9.9 kg y^{-1} fish
		690 h y^{-1} over mud and sand
Hartlepool (2002)		32 kg y^{-1} fish
		15 kg y^{-1} crab and lobster
		12 kg y^{-1} winkles and whelks
		910 h y^{-1} over mud
Harwell (1991)		1 kg y^{-1} pike
		650 h y^{-1} over river bank
Heysham (2001)		36 kg y^{-1} fish
		18 kg y^{-1} shrimps
		19 kg y^{-1} cockles and other molluscs
		1200 h y^{-1} over mud and sand
Hinkley Point (2000)		43 kg y^{-1} fish
		9.8 kg y^{-1} shrimps and prawns
		1.8 kg y^{-1} whelks
		960 h y^{-1} over mud

Table A4.2. continued

Site	Group[a]	Rates
Holy Loch (1989)		730 h y^{-1} over mud
Hunterston (2001)	A	29 kg y^{-1} fish
		22 kg y^{-1} Nephrops and squat lobsters
		2 kg y^{-1} queen scallops
	B	1200 h y^{-1} over mud and sand
Landfill		1.5 l y^{-1} water
Rosyth (1999)	A	21 kg y^{-1} fish
		6.6 kg y^{-1} crustaceans
		5.6 kg y^{-1} molluscs
	B	850 h y^{-1} over mud and sand
Sellafield	A (Sellafield fishing community) (2003)	41 kg y^{-1} cod (60%) and other fish (40%)
		27 kg y^{-1} crab (80%), lobster (10%) and *Nephrops* (10%)
		34 kg y^{-1} winkles (40%) and other molluscs (60%)
		870 h y^{-1} over mud and sand
	B (Fishermen's nets and pots) (2003)	730 h y^{-1} handling nets and pots
	C (Bait digging and mollusc collecting) (2003)	1000 h y^{-1} handling sediment
	D (Whitehaven commercial) (1998)	40 kg y^{-1} plaice and cod
		9.7 kg y^{-1} Nephrops
		15 kg y^{-1} whelks
	E (Morecambe Bay)	See Heysham
	F (Fleetwood) (1995)	93 kg y^{-1} plaice and cod
		29 kg y^{-1} shrimps
		23 kg y^{-1} whelks
	G (Dumfries and Galloway) (2002)	43 kg y^{-1} fish
		20 kg y^{-1} Nephrops, crab and lobster
		11 kg y^{-1} whelks and king scallop
		700 h y^{-1} over mud and sand
	H (Laverbread) (1972)	47 kg y^{-1} laverbread
	I (Trout) (NA)	6.8 kg y^{-1} rainbow trout
	J (Typical fish consumer) (NA)	15 kg y^{-1} cod and plaice
	K (Isle of Man) (NA)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	L (Northern Ireland) (2000)	99 kg y^{-1} haddock and other fish
		34 kg y^{-1} Nephrops and crabs
		7.7 kg y^{-1} mussels and other molluscs
		1100 h y^{-1} over mud and sand
	M (North Wales) (NA)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
		300 h y^{-1} over mud and sand
	N (Sellafield fishing community 1999-2003) (2003)	39 kg y^{-1} fish
		13 kg y^{-1} crabs
		5.7 kg y^{-1} lobsters
		2.8 kg y^{-1} Nephrops
		12 kg y^{-1} winkles
		12 kg y^{-1} mussels
		990 h y^{-1} over mud and sand
	O (Ravenglass recreational use) (NA)	300 h y^{-1} over mud and sand
		1.5 10^{-3} kg y^{-1} mud and sand by inadvertent ingestion
		2.76 10^{-5} kg y^{-1} mud and sand by resuspension and inhalation
	P (Typical beach user) (NA)	30 h y^{-1} over sand
	Q (Ravenglass nature warden (2003))	400 h y^{-1} over salt marsh
		2.0 10^{-3} kg y^{-1} mud by inadvertent ingestion
		3.68 10^{-5} kg y^{-1} mud by resuspension and inhalation
Sizewell (2001)		40 kg y^{-1} fish
		8.4 kg y^{-1} crab and lobster
		6.4 kg y^{-1} Pacific oysters and mussels
		1000 h y^{-1} over mud

Table A4.2. continued

Site	Group[a]	Rates
Springfields	A (2000)	42 kg y^{-1} fish
		15 kg y^{-1} shrimps
		10 kg y^{-1} cockles and mussels
	B (2000)	860 h y^{-1} handling nets
	C (Ribble Estuary houseboats)	2400 h y^{-1} over mud
	(NA)	0.012 kg y^{-1} mud by inadvertent ingestion
		2.2 10^{-4} kg y^{-1} mud by resuspension and inhalation
	D (10 year old children) (NA)	30 h y^{-1} over mud
		3 10^{-4} kg y^{-1} mud by inadvertent ingestion
		1.92 10^{-6} kg y^{-1} mud by resuspension and inhalation
	E (Anglers) (NA)	840 h y^{-1} over mud
Torness (2001)	A	41 kg y^{-1} fish
		17 kg y^{-1} Nephrops, crab and lobster
		5.9 kg y^{-1} mussels
		360 h y^{-1} over sand
	B	1500 h y^{-1} handling fishing gear
Trawsfynydd (1994)		1.8 kg y^{-1} brown trout
		22 kg y^{-1} rainbow trout
		0.93 kg y^{-1} perch
		1000 h y^{-1} over lake shore
Upland lake (NA)		37 kg y^{-1} fish
Winfrith (2003)		40 kg y^{-1} fish
		15 kg y^{-1} crabs and lobsters
		14 kg y^{-1} scallops and whelks
		300 h y^{-1} over sand and stones
Wylfa (1988)		94 kg y^{-1} fish
		23 kg y^{-1} crab
		1.8 kg y^{-1} molluscs
		370 h y^{-1} over sand

[a] Where more than one group exists at a site the groups are denoted A, B, etc. Year of habits survey is given where appropriate
NA Not appropriate. Data sources include Environment Agency (2002a) and Smith and Jones (2003).

APPENDIX 5. DOSIMETRIC DATA

The dose coefficients used in assessments in this report are provided in Table A5.1 for ease of reference. They are based on generic data contained in International Commission on Radiological Protection Publication 72 (International Commission on Radiological Protection, 1996a). In the case of polonium, plutonium and americium radionuclides, dose coefficients have been adjusted according to specific research work of relevance to assessments in this report.

A5.1 Polonium

The current ICRP advice is that a gut uptake factor of 0.5 is appropriate for dietary intakes of polonium by adults (International Commission on Radiological Protection, 1994). A study involving the consumption of crabmeat containing natural levels of polonium-210 has suggested that the factor could be as high as 0.8 (Hunt and Allington, 1993). More recently, similar experiments with mussels suggested a factor in the range 0.30 to 0.61, close to the ICRP value of 0.5 (Hunt and Rumney, 2004). Further experiments are planned and until the outcome of these is assessed, estimates of the exposures due to polonium intake have been calculated using the conservative assumption that a factor of 0.8 applies to all seafood except mussels where specific data suggests 0.5 is more appropriate. We have retained a factor of 0.5 for other food.

A5.2 Plutonium and americium

Studies using adult human volunteers have suggested a gut uptake factor of 0.0002 is appropriate for the consumption of plutonium and americium in winkles from near Sellafield (Hunt *et al*., 1986, 1990). For these and other actinides in food in general, the NRPB considers a factor of 0.0005 to be a reasonable best estimate (National Radiological Protection Board, 1990) to be used when data for the specific circumstances under consideration are not available. In this report, when estimating doses to consumers of winkles from Cumbria, a gut uptake factor of 0.0002 is used for plutonium and americium and this is consistent with NRPB advice. For other foods and for winkles outside Cumbria, the factor of 0.0005 is used for these radioelements. This choice is supported by studies of cockle consumption (Hunt, 1998).

A5.3 Technetium-99 and tritium

Volunteer studies have been extended to consider the transfer of technetium-99 in lobsters across the human gut (Hunt *et al.,* 2001). Although values of the gut uptake factor found in this study were lower than the ICRP value of 0.5, dose coefficients are relatively insensitive to changes in the gut uptake factor. This is because the effective dose is dominated by ‘first pass’ dose to the gut (Harrison and Phipps, 2001). In this report, we have therefore retained use of the standard ICRP factor and dose coefficient for technetium-99.

Harrison *et al.* (2002) has reviewed dose coefficients for tritium associated with organic material. Although there was some uncertainty associated with the dose coefficient suggesting that the best estimate would be roughly twice that of the current ICRP recommendation, there was insufficient evidence on which to base any change in value at this stage. The NRPB is undertaking a further study to examine whether standard biokinetic assumptions for organically bound tritium are applicable in foodstuffs in the UK context (Fry, 2002). In this report, we have therefore continued to use the value recommended by ICRP (1996a).

Table A5.1. Dosimetric data

Radionuclide	Half Life (years)	Mean β energy (MeV per disintegration)	Mean γ energy (MeV per disintegration)	Dose per unit intake by ingestion using ICRP-60 methodology (Sv.Bq^{-1})		
				Adults	10 yr.	1 yr.
H-3	1.24E+01	5.683E-03	0.000E+00	1.80E-11	2.30E-11	4.80E-11
H-3 (f)	1.24E+01	5.683E-03	0.000E+00	4.20E-11	5.70E-11	1.20E-10
C-14	5.73E+03	4.945E-02	0.000E+00	5.80E-10	8.00E-10	1.60E-09
P-32	3.91E-02	6.950E-01	0.000E+00	2.40E-09	5.30E-09	1.90E-08
S-35 (g)	2.39E-01	4.884E-02	0.000E+00	7.70E-10	1.60E-09	5.40E-09
Ca-45	4.46E-01	7.720E-02	0.000E+00	7.10E-10	1.80E-09	4.90E-09
Mn-54	8.56E-01	4.220E-03	8.364E-01	7.10E-10	1.30E-09	3.10E-09
Fe-55	2.70E+00	4.201E-03	1.691E-03	3.30E-10	1.10E-09	2.40E-09
Co-57	7.42E-01	1.860E-02	1.250E-01	2.10E-10	5.80E-10	1.60E-09
Co-58	1.94E-01	3.413E-02	9.976E-01	7.40E-10	1.70E-09	4.40E-09
Co-60	5.27E+00	9.656E-02	2.500E+00	3.40E-09	1.10E-08	2.70E-08
Zn-65	6.67E-01	6.870E-03	5.845E-01	3.90E-09	6.40E-09	1.60E-08
Se-75	3.28E-01	1.452E-02	3.946E-01	2.60E-09	6.00E-09	1.30E-08
Sr-90 †	2.91E+01	1.131E+00	3.163E-03	3.07E-08	6.59E-08	9.30E-08
Zr-95 †	1.75E-01	1.605E-01	1.505E+00	1.53E-09	2.99E-09	8.78E-09
Nb-95	9.62E-02	4.444E-02	7.660E-01	5.80E-10	1.10E-09	3.20E-09
Tc-99	2.13E+05	1.010E-01	0.000E+00	6.40E-10	1.30E-09	4.80E-09
Ru-103 †	1.07E-01	7.478E-02	4.685E-01	7.30E-10	1.50E-09	4.60E-09
Ru-106 †	1.01E+00	1.422E+00	2.049E-01	7.00E-09	1.50E-08	4.90E-08
Ag-110m †	6.84E-01	8.699E-02	2.740E+00	2.80E-09	5.20E-09	1.40E-08
Sb-125	2.77E+00	1.007E-01	4.312E-01	1.10E-09	2.10E-09	6.10E-09
Te-125m	1.60E-01	1.090E-01	3.550E-02	8.70E-10	1.90E-09	6.30E-09
I-125	1.65E-01	1.940E-02	4.205E-02	1.50E-08	3.10E-08	5.70E-08
I-129	1.57E+07	6.383E-02	2.463E-02	1.10E-07	1.90E-07	2.20E-07
I-131 †	2.20E-02	1.935E-01	3.813E-01	2.20E-08	5.20E-08	1.80E-07
Cs-134	2.06E+00	1.634E-01	1.550E+00	1.90E-08	1.40E-08	1.60E-08
Cs-137 †	3.00E+01	2.486E-01	5.651E-01	1.30E-08	1.00E-08	1.20E-08
Ba-140 †	3.49E-02	8.493E-01	2.502E+00	4.60E-09	1.00E-08	3.10E-08
Ce-144 †	7.78E-01	1.278E+00	5.282E-02	5.20E-09	1.10E-08	3.90E-08
Pm-147	2.62E+00	6.200E-02	4.374E-06	2.60E-10	5.70E-10	1.90E-09
Eu-154	8.80E+00	2.923E-01	1.237E+00	2.00E-09	4.10E-09	1.20E-08
Eu-155	4.96E+00	6.340E-02	6.062E-02	3.20E-10	6.80E-10	2.20E-09
Pb-210 †	2.23E+01	4.279E-01	4.810E-03	6.91E-07	1.90E-06	3.61E-06
Bi-210	1.37E-02	3.890E-01	0.000E+00	1.30E-09	2.90E-09	9.70E-09
Po-210 (c)	3.79E-01	0.000E+00	0.000E+00	1.20E-06	2.60E-06	8.80E-06
Po-210 (d)	3.79E-01	0.000E+00	0.000E+00	1.92E-06	4.16E-06	1.41E-05
Ra-226 †	1.60E+03	9.559E-01	1.765E+00	2.80E-07	8.00E-07	9.60E-07
Th-228 †	1.91E+00	9.130E-01	1.567E+00	1.43E-07	4.31E-07	1.10E-06
Th-230	7.70E+04	1.462E-02	1.553E-03	2.10E-07	2.40E-07	4.10E-07
Th-232	1.41E+10	1.251E-02	1.332E-03	2.30E-07	2.90E-07	4.50E-07
Th-234 †	6.60E-2	8.815E-01	2.103E-02	3.40E-9	7.40E-09	2.50E-08
U-234	2.44E+05	1.320E-02	1.733E-03	4.90E-08	7.40E-08	1.30E-07
U-235 †	7.04E+08	2.147E-01	1.815E-01	4.70E-08	7.10E-08	1.30E-07
U-238 †	4.47E+09	8.915E-01	2.235E-02	4.84E-08	7.54E-08	1.45E-07
Np-237 †	2.14E+06	2.668E-01	2.382E-01	1.10E-07	1.10E-07	2.10E-07
Pu-238 (a)	8.77E+01	1.061E-02	1.812E-03	2.30E-07	2.40E-07	4.00E-07
Pu-238 (b)				9.20E-08	9.60E-08	1.60E-07
Pu-239 (a)	2.41E+04	6.738E-03	8.065E-04	2.50E-07	2.70E-07	4.20E-07
Pu-239 (b)				1.00E-07	1.08E-07	1.68E-07
Pu-α (e)	2.41E+04	6.738E-03	8.065E-04	2.50E-07	2.70E-07	4.20E-07
Pu-240 (a)	6.54E+03	1.061E-02	1.731E-03	2.50E-07	2.70E-07	4.20E-07
Pu-240 (b)				1.00E-07	1.08E-07	1.68E-07
Pu-241 (a)	1.44E+01	5.246E-03	2.546E-06	4.80E-09	5.10E-09	5.70E-09
Pu-241 (b)				1.92E-09	2.04E-09	2.28E-09
Am-241 (a)	4.32E+02	5.207E-02	3.253E-02	2.00E-07	2.20E-07	3.70E-07
Am-241 (b)				8.00E-08	8.80E-08	1.48E-07
Cm-242	4.46E-01	9.594E-03	1.832E-03	1.20E-08	2.40E-08	7.60E-08
Cm-243	2.85E+01	1.384E-01	1.347E-01	1.50E-07	1.60E-07	3.30E-07
Cm-244	1.81E+01	8.590E-03	1.700E-03	1.20E-07	1.40E-07	2.90E-07

Table A5.1. continued

Radionuclide	Dose per unit intake by inhalation using ICRP-60 methodology (Sv.Bq^{-1})		
	Adults	10 yr.	1 yr.
H-3	4.50E-11	8.20E-11	2.70E-10
H-3 (f)	4.10E-11	5.50E-11	1.10E-10
C-14	2.00E-09	2.80E-09	6.60E-09
P-32	3.40E-09	5.30E-09	1.50E-08
S-35 (g)	1.40E-09	2.00E-09	4.50E-09
Ca-45	2.70E-09	3.90E-09	8.80E-09
Mn-54	1.50E-09	2.40E-09	6.20E-09
Fe-55	3.80E-10	6.20E-10	1.40E-09
Co-57	5.50E-10	8.50E-10	2.20E-09
Co-58	1.60E-09	2.40E-09	6.50E-09
Co-60	1.00E-08	1.50E-08	3.40E-08
Zn-65	1.60E-09	2.40E-09	6.50E-09
Se-75	1.00E-09	2.50E-09	6.00E-09
Sr-90 †	3.75E-08	5.37E-08	0.00E+00
Zr-95 †	6.29E-09	8.98E-09	0.00E+00
Nb-95	1.50E-09	2.20E-09	5.20E-09
Tc-99	4.00E-09	5.70E-09	1.30E-08
Ru-103 †	2.40E-09	3.50E-09	8.40E-09
Ru-106 †	2.80E-08	4.10E-08	1.10E-07
Ag-110m †	7.60E-09	1.20E-08	2.80E-08
Sb-25	4.80E-09	6.80E-09	1.60E-08
Te-125m	3.40E-09	4.80E-09	1.10E-08
I-125	5.10E-09	1.10E-08	2.30E-08
I-129	3.60E-08	6.70E-08	8.60E-08
I-131 †	7.40E-09	1.90E-08	7.20E-08
Cs-134	6.60E-09	5.30E-09	7.30E-09
Cs-137 †	4.60E-09	3.70E-09	5.40E-09
Ba-140 †	6.20E-09	9.60E-09	0.00E+00
Ce-144 †	3.60E-08	5.50E-08	1.60E-07
Pm-147	5.00E-09	7.00E-09	1.80E-08
Eu-154	5.30E-08	6.50E-08	1.50E-07
Eu-155	6.90E-09	9.20E-09	2.30E-08
Pb-210 †	1.19E-06	1.63E-06	0.00E+00
Bi-210	9.30E-08	1.30E-07	3.00E-07
Po-210	3.30E-06	4.60E-06	1.10E-05
Ra-226 †	3.50E-06	4.90E-06	1.10E-05
Th-228 †	4.32E-05	5.92E-05	0.00E+00
Th-230	1.40E-05	1.60E-05	3.50E-05
Th-232	2.50E-05	2.60E-05	5.00E-05
Th-234 †	7.70E-09	1.10E-08	3.10E-08
U-234	3.50E-06	4.80E-06	1.10E-05
U-235 †	3.10E-06	4.30E-06	1.00E-05
U-238 †	2.91E-06	4.01E-06	0.00E+00
Np-237 †	2.30E-05	2.20E-05	4.00E-05
Pu-238	4.60E-05	4.40E-05	7.40E-05
Pu-239	5.00E-05	4.80E-05	7.70E-05
Pu-α (e)	5.00E-05	4.80E-05	7.70E-05
Pu-240	5.00E-05	4.80E-05	7.70E-05
Pu-241	9.00E-07	8.30E-07	9.70E-07
Am-241	4.20E-05	4.00E-05	6.90E-05
Cm-242	5.20E-06	7.30E-06	1.80E-05
Cm-243	3.10E-05	3.10E-05	6.10E-05
Cm-244	2.70E-05	2.70E-05	5.70E-05

† *Energy and dose per unit intake data include the effects of radiations of short-lived daughter products*
(a) Gut transfer factor 5.00E-4 for consumption of all foodstuffs except Cumbrian winkles
(b) Gut transfer factor 2.00E-4 for consumption of Cumbrian winkles
(c) Gut transfer factor 0.5
(d) Gut transfer factor 0.8
(e) Pu-239 data used
(f) Organically bound tritium
(g) Organically bound sulphur

APPENDIX 6. ESTIMATES OF CONCENTRATIONS OF NATURAL RADIONUCLIDES

6.1 Aquatic foodstuffs

Table A6.1 gives estimated values of concentrations of radionuclides due to natural sources in aquatic foodstuffs. The values are based on sampling and analysis carried out by CEFAS (Young *et al*., 2002 and unpublished studies). Data for lead-210 and polonium-210 are from a detailed study and are quoted as medians with minimum and maximum values given in brackets. Dose assessments for aquatic foodstuffs are based on activity concentrations of these radionuclides net of natural background. Similarly, natural levels of carbon-14 are subtracted when assessing exposures due to man-made sources of this radionuclide. The natural concentrations of carbon-14 are determined by measuring the carbon concentration in each sample and applying a specific activity of ^{14}C natural/kg C (Collins *et al*., 1995). Typical values are given in table A6.1

Table A6.1 Concentrations of radionuclides in seafood due to natural sources

Radionuclide	Concentration of radioactivity (Bq kg^{-1} (wet))									
	Fish	Crustaceans	Crabs	Lobsters	Molluscs	Winkles	Mussels	Cockles	Whelks	Limpets
Carbon-14	23	27			23					
Lead-210	0.042	0.02	0.24	0.080	1.2	1.5	1.6	0.94	0.39	1.5
	(0.0030-0.55)	(0.013-2.4)	(0.043-0.76)	(0.02-0.79)	(0.18-6.8)	(0.69-2.6)	(0.68-6.8)	(0.59-1.3)	(0.18-0.61)	(0.68-4.9)
Polonium-210	0.82	9.1	19	5.3	17	13	42	18	6.5	8.4
	(0.18-4.4)	(1.1-35)	(4.1-35)	(1.9-10)	(1.2-69)	(6.1-25)	(19-69)	(11-36)	(1.2-11)	(5.9-15)
Radium-226	0.04	0.03	0.03	0.06	0.08	0.08				
Thorium-228	0.0054	0.0096	0.04	0.0096	0.37	0.46		0.37		
Thorium-230	0.00081	0.0026	0.008	0.0026	0.19	0.26		0.19		
Thorium-232	0.00097	0.0014	0.01	0.0014	0.28	0.33		0.28		
Uranium-234	0.0045	0.040	0.055	0.040	0.99	0.99				
Uranium-238	0.0039	0.035	0.046	0.035	0.89	0.89				

6.2 Terrestrial foodstuffs

The values of carbon-14 in terrestrial foodstuffs due to natural sources that are used in dose assessments are given in Table A6.2 (MAFF, 1995).

Table A6.2 Carbon-14 in terrrestrial foodstuffs due to natural sources

Food Category	% Carbon content (wet)	Concentration of carbon-14 (Bq kg^{-1} (wet))
Milk	7	18
Bovine meat	17	44
Ovine meat	21	54
Pork	21	54
Poultry	28	72
Game	15	38
Offal	12	31
Eggs	15	38
Green vegetables	3	8
Root vegetables	3	8
Legumes/other domestic vegetables	8	20
Dry beans	20	51
Potato	9	23
Cereals	41	105
Cultivated fruit	4	10
Wild fruit	4	10
Mushrooms	2	5
Honey	31	79
Nuts	58	148

APPENDIX 7. ASSESSMENT OF TOTAL DOSE INTEGRATED ACROSS PATHWAYS

7.1 Introduction

This appendix describes the methods, data and results used to assess total dose integrated across pathways. The approach relies on the use of dietary and occupancy data collected from local habits surveys. The sites considered here are: Aldermaston and Burghfield, Cardiff, Dounreay, Hartlepool, Sellafield and Winfrith. Further sites will be added in future RIFE reports as and when new integrated surveys are undertaken.

7.2 Objectives

The dose limitation system formally requires doses to be assessed from all routine man made sources, except certain medical ones. This report is primarily directed at the effects of discharges of radioactive waste on food and environmental pathways to man. An additional source of significance for some of the major sites under consideration is direct radiation from operations on the sites.

The HSE takes the lead in regulation of this source of exposure and with the benefit of information provided by them, we have provided an integrated assessment of total dose including direct radiation.

7.3 Methods and data

The calculational method relies on the application of data from site specific habits surveys.
This is possible because more recent surveys have considered the habits of individuals in a holistic way, that is information for each individual has been recorded for all of the pathways of interest. Previously surveys were directed at particular sources of exposure related to direct radiation or discharges of liquid wastes or gaseous wastes.

Using the habits survey data, the people who are regarded as having the potential to receive the highest doses are identified for each major pathway at each site. The methodology may be summarised in four steps;

1) Starting with the first pathway, individuals are selected based on the 'Cut-off' method whereby all those who have a consumption or occupancy rate within a factor of three of the maximum observed for the pathway under consideration are defined as members of the potential critical group for that pathway (Hunt *et al*., 1982; Preston *et al*., 1974). Calculations are performed for three age groups represented by adults and 10 y old and 1 y old children.

2) A profile of habits is calculated for the potential critical group derived in 1) by averaging their habits for each pathway.

3) Repeat steps 1) and 2) for each pathway, thereby defining a potential critical group (and profile) corresponding to each pathway.

4) Once all pathway profiles have been determined, doses are calculated for each profile. The group with the highest dose becomes the critical group.

The consumption and occupancy rates which determined the important doses in this assessment of RIFE 2003 data are given in Table A7.1. Care should be taken in using these data in other circumstances because the important groups will change according to the measured or forecast concentrations and dose rates in other assessments.

Doses are calculated for each potential critical group using the same basic concentration and dose rate information used in the routine assessments earlier in this report. In addition, an allowance is made for direct radiation making use of information from operator assessments supplied by the HSE (Stephen, 2004).

Predictions of doses are made with the PC CREAM assessment code (Mayall *et al.*, 1997) so as to allow for pathways related to gaseous discharges which are not included in the routine monitoring programmes. A similar approach is used for the routine assessments and is described in Appendix 2.

Table A7.1. The consumption rates and occupancies of the dominant groups in RIFE assessments, 2003

Site	Critical Group[a]	Consumption (kg y^{-1}, l y^{-1}) or occupancy (h y^{-1}) rate												
		Crustaceans	Direct radiation	Eggs	Fish - Freshwater	Fish - Sea	Fruit - Domestic	Fruit and Nuts - Wild	Gamma radiation over sand and mud	Gamma radiation over sediment/saltmarsh	Honey	Meat - Cattle	Meat - Game	Meat - Offal
A Gaseous releases and direct radiation from the site														
Aldermaston														
and Burghfield	Milk consumers aged 1 y	0	1100	1.6	0	0	2.5	0	-	0	0	0.9	0	0
Cardiff	Milk consumers aged 1 y	0	0	0	0	0	1	0.1	-	0	0	7	0	0
Dounreay	Local adult inhabitants (0.5 - 1km)	0.6	8760	0	0	3.7	0	0	-	20	0	0	0	0
Hartlepool	Local adult inhabitants (0.25 - 0.5km)	0	8760	0	0	0	0	0	-	20	0	0	0	0
Sellafield	Milk consumers aged 1 y	0	3250	2.9	0	0	0.8	0	0	0	0	2.8	0	0
Winfrith	Milk consumers aged 1 y	0	1460	4.2	0	0	3.4	0	-	0	1.5	0.4	0	0
B Liquid releases from the site														
Aldermaston														
and Burghfield	Adult occupants of river bank	0	0	0	0	0	0	0	-	320	0	0	0	0
Cardiff	Adult fish consumers	0.1	0	0	0	24.3	0	0	-	50	0	0	0	0
Dounreay	Adult occupants over sediment	0	0	0	0	2.2	8.5	0	-	300	0	0	0	0
Hartlepool	Occupants over sediment aged 10 y	0.1	3750	0	0	0.5	0	0	-	460	0	0	0	0
Sellafield	Adult mollusc consumers	17	0	0	0	23.6	0	0	400	0	0	0	0	0
Winfrith	Adult occupants over sediment	0	2920	0	0	0.7	0.4	0	-	230	0	0	0	0
C Combined releases from the site														
Aldermaston														
and Burghfield	Milk consumers aged 1 y	0	1100	1.6	0	0	2.5	0	-	0	0	0.9	0	0
Cardiff	Adult fish consumers	0.1	0	0	0	24.3	0	0	-	50	0	0	0	0
Dounreay	Adult green vegetable consumers	0.2	0	0	0	13.5	66.4	0.8	-	140	0	0	2.6	0
Hartlepool	Local adult inhabitants (0 - 0.25km)	0	8760	0	0	0	0	0	-	230	0	0	0	0
Sellafield	Adult mollusc consumers	17	0	0	0	23.6	0	0	400	0	0	0	0	0
Winfrith	Adult occupants over sediment	0	2920	0	0	0.7	0.4	0	-	230	0	0	0	0

Table A7.1. continued

Site	Critical Group[a]	Meat - Pig	Meat - Poultry	Meat - Sheep	Milk	Molluscs	Mushrooms	Plume pathways (0-0.25 km)	Plume pathways (0.25-0.5 km)	Plume pathways (0.5-1km)	Vegetables - Green	Vegetables - Other Domestic	Vegetables - Potatoes	Vegetables - RootS
		Consumption (kg y^{-1}, l y^{-1}) or occupancy (h y^{-1}) rate												
A Gaseous releases and direct radiation from the site														
Aldermaston and Burghfield	Milk consumers aged 1 y	0	0	0	302.9	0	0	0	0	582	1.4	0.5	3.2	2.4
Cardiff	Milk consumers aged 1 y	0	0	0.3	225	0	0	0	0	0	1.6	2.8	2.4	6.2
Dounreay	Local adult inhabitants (0.5 - 1km)	0	0.6	0	0	0	0.1	0	0	7180	0	0	16.7	1.1
Hartlepool	Local adult inhabitants (0.25 - 0.5km)	0	0	0	0	0	0	0	2150	0	0	0	0	0
Sellafield	Milk consumers aged 1 y	0	0.2	0.2	338	0	0	820	620	280	0.2	0	4.8	1.4
Winfrith	Milk consumers aged 1 y	0.6	0.7	0	160.2	0	0	0	260	230	2.7	2.6	5.7	3.2
B Liquid releases from the site														
Aldermaston and Burghfield	Adult occupants of river bank	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardiff	Adult fish consumers	0	0	0	0	0	0	0	0	0	1.1	3.7	4.7	3.8
Dounreay	Adult occupants over sediment	0	0	0	28.2	0	0	0	0	0	10	0	19.4	10.3
Hartlepool	Occupants over sediment aged 10 y	0	0	0	0	0.4	0.4	70	350	0	0	0	0	0
Sellafield	Adult mollusc consumers	0	0	0	0	33.7	0	0	0	0	0	0	0	0
Winfrith	Adult occupants over sediment	0	0	0	0	0	0	0	0	2170	0.3	4.2	12.1	5.9
C Combined releases from the site														
Aldermaston and Burghfield	Milk consumers aged 1 y	0	0	0	302.9	0	0	0	0	580	1.4	0.5	3.2	2.4
Cardiff	Adult fish consumers	0	0	0	0	0	0	0	0	0	1.1	3.7	4.7	3.8
Dounreay	Adult green vegetable consumers	0	1	0	0	0	0	0	0	0	50	40	65.5	58.5
Hartlepool	Local adult inhabitants (0 - 0.25km)	0	0	0	0	3.8	1.9	1300	0	0	0	0	0	0
Sellafield	Adult mollusc consumers	0	0	0	0	33.7	0	0	0	0	0	0	0	0
Winfrith	Adult occupants over sediment	0	0	0	0	0	0	0	0	2170	0.3	4.2	12.1	5.9

[a] *Selected on the basis of providing the highest dose from the pathways associated with the sources as defined in A, B or C*

[b] *Occupancies are presented in distance bands from the site perimeter. Plume pathways relate to gaseous discharges and include the effects of airborne and deposited activity except for food pathways*

7.4 Results of the assessment of total dose

The results of the assessment are summarized in Table A7.2 for each site. The data are presented in three parts. The group receiving the highest dose from the pathways predominantly relating to gaseous discharges and direct radiation are shown in the upper half of the tables, part A; those for liquid discharges in the middle part, part B. Occasionally the group receiving the highest dose from all pathways is different from that in A and B. Therefore we have also presented this case in part C. The major contributions to dose are also presented.

In all cases, doses estimated for 2003 were less than the limit of 1mSv for members of the public. The most important group for gaseous discharges and direct radiation varied from site to site but was often milk consumers aged one year. Direct radiation was important at Hartlepool and Sellafield.

The most important groups for liquid discharges were adult seafood consumers or occupants over contaminated substrates. 60% of the dose at Sellafield is due to the legacy of discharges of natural radionuclides from a chemical works in Whitehaven. These broad results and the numerical values of dose are similar to those found in routine assessments earlier in this report, taking into account the additional effect of direct radiation where it is prominent.

Table A7.2. Individual radiation exposures integrated across pathways, 2003

Site	Critical group[c]	Exposure, mSv	
		Total	Dominant contributions[a]
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Milk consumers aged 1 y	<0.005	Milk, ^{3}H, ^{137}Cs, U
Cardiff	Milk consumers aged 1 y	0.007	Milk, ^{3}H, ^{14}C, ^{35}S, ^{125}I, ^{137}Cs
Dounreay	Local adult inhabitants (0.5 - 1km)	0.012	Direct radiation
Hartlepool	Local adult inhabitants (0.25 - 0.5km)	0.020	Direct radiation
Sellafield	Milk consumers aged 1 y	0.026	Direct radiation, milk, ^{14}C, ^{60}Co, ^{90}Sr, ^{137}Cs,
Winfrith	Milk consumers aged 1 y	<0.005	Milk, ^{14}C, ^{137}Cs
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants of river bank	<0.005	External dose rate from river bank
Cardiff	Adult fish consumers	0.019	Fish, ^{3}H, ^{14}C
Dounreay	Adult occupants over sediment	0.010	Gamma dose rate over sediment
Hartlepool	Occupants over sediment aged 10 y	0.009	Direct radiation
Sellafield	Adult mollusc consumers	0.71[b]	Molluscs, ^{210}Po, ^{241}Am
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
C Combined releases from the site			
Aldermaston and Burghfield	Milk consumers aged 1 y	<0.005	Milk, ^{3}H, ^{137}Cs, U
Cardiff	Adult fish consumers	0.019	Fish, ^{3}H, ^{14}C
Dounreay	Adult green vegetable consumers	0.012	Gamma dose rate over sediment, vegetables (root, green, potatoes), ^{90}Sr, ^{129}I, ^{241}Am
Hartlepool	Local adult inhabitants (0 - 0.25km)	0.021	Direct radiation
Sellafield	Adult mollusc consumers	0.71[b]	Molluscs, ^{210}Po, ^{241}Am
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment

[a] Pathways and radionuclides that contribute more than 10% of the total dose
[b] The doses from man-made and natural radionuclides were 0.25 and 0.46 mSv respectively. The source of natural radionuclides was a chemical works near Sellafield at Whitehaven
[c] Selected on the basis of providing the highest dose from the pathways associated with the sources as defined in A, B or C