RIFE - 10

Radioactivity in Food and the Environment, 2004

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2005

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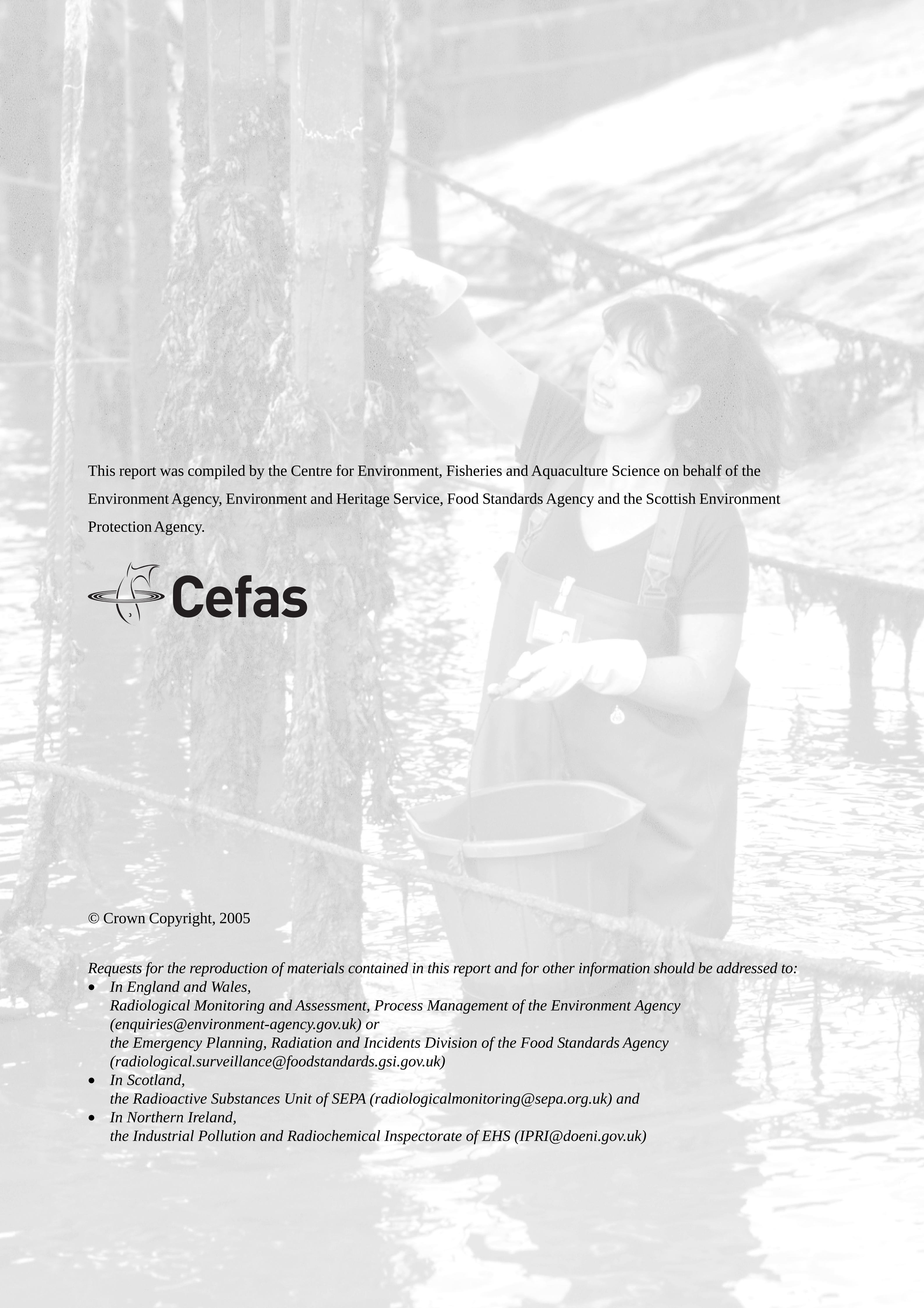

This report was compiled by the Centre for Environment, Fisheries and Aquaculture Science on behalf of the Environment Agency, Environment and Heritage Service, Food Standards Agency and the Scottish Environment Protection Agency.

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- *In Northern Ireland,*
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FOREWORD

We are pleased to present the 10th annual Radioactivity in Food and the Environment report, which contains radiological monitoring data for 2004. As a result of our four agencies working together we are able to present a complete picture of the levels of radioactivity found in food and the environment in the UK and provide an assessment of their impact on public health.

In 2004, there were no major changes in levels of radioactivity in food or environmental materials compared to those in our report for 2003. There were no major changes in radiation doses to people, which remain below national and international limits in all parts of the UK.

The downward trend in discharges and environmental concentrations seen during the last 10 years has continued. This is a result of a range of factors including regulatory action by the agencies, new discharge treatment plants, and the shut down of a number of the older Magnox nuclear power stations.

At the 1998 OSPAR Ministerial meeting the UK committed itself to making “progressive and substantial reductions in [radioactive] discharges and emissions”. Major reductions in discharges of technetium-99 from Sellafield are beginning to be reflected in reducing environmental concentrations in the Irish Sea. In addition, concentrations of tritium in the Severn Estuary Cardiff have begun to decline as a result of reducing discharges from the GE Healthcare Cardiff site. Taking a slightly longer forward look, as envisaged by OSPAR, further reductions in discharges will be required.

Regulatory pressure on discharges is being maintained, and regular reviews of discharge authorisations are carried out. During such reviews the environment agencies work with the Food Standards Agency to identify potential reductions in discharges and discharge limits. During 2004, new, more stringent authorisations came into force at the nuclear sites at Sellafield, Dounreay, Springfields, Cardiff and Amersham. We will continue to monitor and to report levels of radioactivity in food and the environment in our annual reports, in order to assess the effectiveness of these new authorisations on public health.

Sir John Harman
Chairman, Environment Agency

Mr Ken Ledgerwood
Chief Industrial Pollution and Radiochemical Inspector, Environment and Heritage Service for Northern Ireland

Dame Deirdre Hutton
Chair, Food Standards Agency

Sir Ken Collins
Chairman, Scottish Environment Protection Agency

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EXECUTIVE SUMMARY

This report presents the results of our work to monitor the amount of radioactivity in food and the environment in the United Kingdom, the Channel Islands and the Isle of Man.

We did not find any major changes in levels of radioactivity in food or environmental materials in 2004.

We have two main aims for our monitoring programmes:
- to independently check the effects of discharges of radioactive materials in the United Kingdom,
- to ensure that any radioactivity in food and the environment due to discharges does not compromise public health or the environment .

This report is a full summary of the results from the monitoring programmes that our agencies sponsor in the United Kingdom.

These results show that in 2004, as a result of authorised discharges even the most exposed members of the public received radiation doses from food, the environment and direct radiation that were below the legal European Union and UK statutory limit.

We have based many of the dose estimates in this report on levels of radioactivity that are below the limits of detection, which means the doses are likely to be overestimated.

TECHNICAL SUMMARY

The technical summary is divided into sections, which bring out the highlights within the report under a number of topics. These topics are radioactivity exposures (doses) to people living around nuclear sites, radioactivity levels (concentrations) in samples collected around nuclear sites, dose rates around nuclear sites, site incidents and non-routine surveys and finally, radiation exposures and radioactivity levels at other UK locations not associated with nuclear sites.

Radioactivity exposures around nuclear sites

A group of high-rate consumers of fish and shellfish in Cumbria received the highest doses of radiation. Their dose was estimated to be 0.63 mSv in 2004. The doses resulted from a combination of liquid discharges from 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 consumers (which includes the contribution from external doses) from Sellafield discharges was estimated to be 0.22 mSv in 2004, similar to the dose in 2003, of 0.21 mSv. Most of the seafood and external exposure doses that we can attribute to Sellafield were from historic liquid discharges of caesium-137, plutonium isotopes and americium-241. Recent and current discharges of technetium-99 contributed 0.026 mSv, which is around 12% of the 0.22 mSv dose to the Sellafield seafood consumers, a reduction from 2003 when technetium-99 contributed 15% of the dose. The trend in the last five years of increasing doses has been driven largely by local people eating more seafood (using five-year averaged habit data), and this has resulted in an increase of about 75% in calculated dose since 2000. This trend has continued, but at a greatly reduced rate in the last three years of the period. In addition to the dose from Sellafield discharges, the same group of consumers also received 0.41 mSv from technologically enhanced naturally-occurring radionuclides due to the legacy of previous industrial operations at the Rhodia Consumer Specialties Ltd. works at Whitehaven. Taken together, their total dose was 0.63 mSv was in 2004, which was less than the EU limit of 1 mSv.

In terms of radiation exposure, the second most significant group of people were those living near Dungeness nuclear power stations. Their dose was 0.11 mSv, the same as in 2003. Most of the dose was from the gaseous plume formed from discharges of argon-41.

Other significant sites in terms of doses included Springfields in Lancashire, where people living in houseboats in the Ribble estuary received 0.058 mSv in 2004. Most of this was from Sellafield-derived radionuclides in intertidal sediments.

At Heysham, we estimated that high-rate seafood consumers received 0.068 mSv and most of this was attributable to Sellafield discharges.

The fifth most significant site in terms of dose was the Sizewell power stations where gaseous discharges gave a dose of 0.040 mSv.

Doses due to gaseous discharges from Sellafield were 0.036 mSv, slightly more than the dose in 2003 of 0.034 mSv.

We found relatively high concentrations of tritium in food and the environment near Cardiff, where radiochemicals for life science research are produced. However, we estimated doses to high-rate seafood consumers were relatively low (due to tritium having a low radiotoxicity) at 0.017 mSv in 2004, a reduction from 0.024 mSv in 2003. This is due to lower discharges of organic tritium from GE Healthcare in Cardiff. Most of the dose was due to tritium and carbon-14 in fish from the Severn Estuary.

The highest exposures in Scotland were to the group of seafood consumers on the Dumfries and Galloway coast who received an annual dose of 0.038 mSv largely as a result of liquid discharges from Sellafield. In 2003, this group was estimated to have received a dose of 0.036 mSv.

The dose estimates above apply to discharges from nuclear and other sites. There is another source of public radiation exposure near some of these facilities. This is radiation coming directly from buildings due to operations on the site. The Health and Safety Executive, which is the relevant regulatory authority, has estimated direct radiation doses at sites in the UK, using information from the site operator.

In 2003, a new method was introduced to assess the total radiation dose to the public around the UK's nuclear sites. The new method takes account of all exposure routes in a realistic way and for the first time takes into account doses from direct radiation from nuclear sites. In 2004, total dose at 10 nuclear sites was assessed, including Amersham (Grove Centre), Devonport, Hunterston and Wylfa. In 2004, the total doses at these 10 sites were less than the EU limit of 1 mSv. We will extend these assessments to all sites in future Radioactivity in Food and the Environment reports, as the required data become available.

Assessed doses for all major sites in the UK are shown in Figure S and listed in the Summary Table.

Radioactivity levels in samples collected around nuclear sites

The UK Discharge Strategy was published in 2002. It describes how the UK will implement the agreements of the 1998 and later meetings of the Oslo and Paris Convention. One of the aims is to progressively and substantially reduce the amount of liquid radioactive discharges and discharge limits. This means that nuclear sites need action plans to achieve these goals, which will have a real impact on the amount of radioactive materials near the sites in future years. In 2004, the Environment Agency and the Scottish Environment Protection Agency took steps towards introducing more stringent limits on discharges from Sellafield, Springfields, Dounreay, Cardiff and some other minor sites.

During 2004, discharges of technetium-99 from Sellafield were reduced due to a successful trial of abatement technology. We expect discharges of this radionuclide to reduce even more in the future. Technetium-99 from Sellafield can be detected in the Irish Sea, in Scottish waters and the North Sea. Levels of technetium-99 in the marine environment near to Sellafield have begun to decline and we expect they will continue to do so in future years. Abatement technology is being introduced at Cardiff. This will reduce discharges of organic tritium to the environment and concentrations of tritium around Cardiff in the future.

We did not find any major changes in levels of radioactivity in food or environmental materials in 2004. Concentrations of tritium (as organically bound tritium (OBT)) in seafood near Cardiff remained at levels of more than 10,000 Bq kg^{-1} (fresh weight), although we saw some reductions compared to 2003. Tritium concentrations in seafood at other coastal locations around the UK were above the expected background tritium concentration of 1 Bq kg^{-1}. However, the degree of bioaccumulation was of little significance and much lower than the levels found near to Cardiff.

Levels of tritium and carbon-14 in seafood from around Sellafield showed an increase over levels in 2003. However, the assessed dose from these radionuclides was less than 10% of the total from man-made radionuclides and the increase in dose was small, from 0.010 mSv to 0.012 mSv.

Concentrations of technetium-99 and ruthenium-106 in shellfish were reduced. 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, however, there was no evidence for significant transfers of technetium-99 through animals feeding on seaweed. Further research on this topic is planned.

Marine sediment samples are a useful indicator of trends in the environment. The radionuclide content of the sediments is also a source of external radiation to people who spend time on beaches. Near Sellafield, the environmental concentrations of most radionuclides have declined substantially over the last 20 years. In recent years, there has been a small increasing trend in the concentrations of caesium-137, plutonium isotopes and americium-241 in some mud samples at Sellafield. The trend is not associated with changes in discharges. For americium-241, there is a contribution due to 'in-growth' from plutonium-241 in the environment. Remobilisation of historical sediments containing higher activity concentrations or the

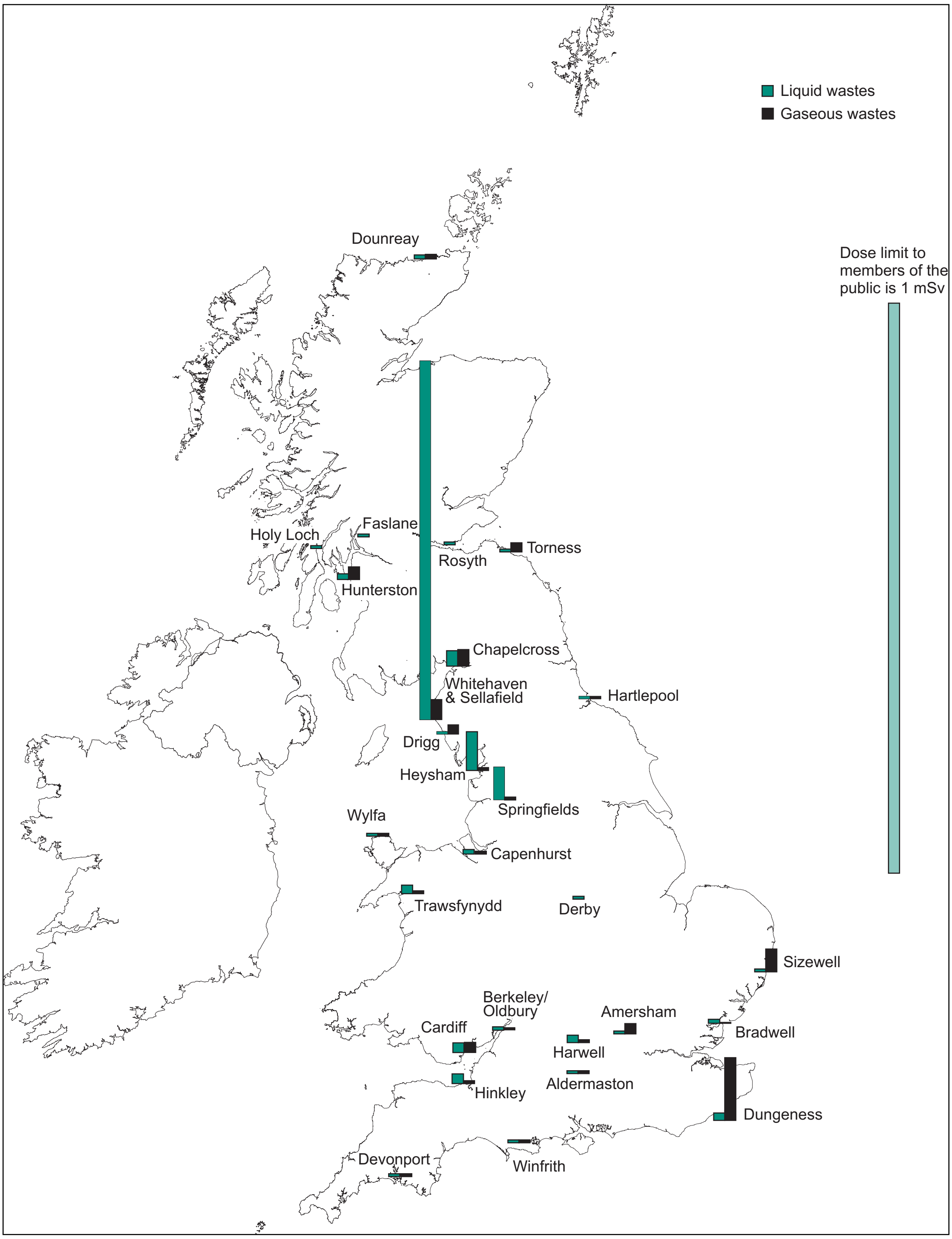

***Figure S. Radiation exposures in the UK due to radioactive waste discharges, 2004** (Exposures at Whitehaven and Sellafield are mostly due to the legacy of enhanced natural radioactivity from the non-nuclear industry)*

Summary Table: Radiation doses due to discharges of radioactive waste in the United Kingdom, 2004

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	0.008	Ext
	Terrestrial foods[i]	G	<0.005	U
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (2000-2004 surveys) (excluding natural radionuclides)[k]	L	0.22	$^{239/240}Pu$ ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2000-2004 surveys) (including natural radionuclides)[l]	L	0.63	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2004 surveys)	L	0.27	$^{239/240}Pu$ ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	G	0.036	^{90}Sr
	Terrestrial foods at Ravenglass[i]	G/L	0.022	
	External in intertidal areas (Ravenglass)[a]	L	0.039	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)[a]	L	0.058	Ext ^{241}Am
	External (skin) to anglers	L	0.24[f]	Beta
	Handling of fishing gear	L	0.080[f]	Beta
	Porphyra/laverbread consumption in South Wales	L	<0.005	
	Seaweed/crops at Sellafield	L	0.015	^{99}Tc
Springfields	External (skin) to fishermen	L	0.32[f]	Beta
	Fish and shellfish consumption	L	0.023	$^{239/240}Pu$ ^{241}Am
	Terrestrial foods	G	<0.005[h]	^{90}Sr
	External in intertidal areas (children playing)[g,a]	L	<0.005	Ext ^{234}Th
	Occupancy of houseboats[a]	L	0.058	Ext ^{241}Am
	External in intertidal areas (anglers)	L	0.011	Ext
Research establishments				
Culham	Drinking water[n]	L	<0.005	
Dounreay	Fish and shellfish consumption	L	<0.005	^{14}C $^{239/240}Pu$
	External in intertidal areas	L	0.007	Ext
	Terrestrial foods	G	0.008	
Harwell	Fish consumption and external to anglers	L	0.013	Ext
	Terrestrial foods[i]	G	<0.005	^{3}H
Winfrith	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.006	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	0.007	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Chapelcross	Fish and shellfish consumption and external in intertidal areas	L	0.027	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.029	^{35}S
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.013	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
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.068	Ext ^{241}Am
	Terrestrial foods[i]	G	0.005	^{14}C ^{137}Cs
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.017	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Hunterston	Fish and shellfish consumption	L	<0.005	^{137}Cs ^{241}Am
	External in intertidal areas	L	0.010	Ext
	Terrestrial foods[i]	G	0.022	^{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	0.040	^{14}C ^{41}Ar
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods[i]	G	0.016	^{90}Sr
Trawsfynydd	Fish consumption and external to anglers	L	0.015	Ext ^{137}Cs
	Terrestrial foods[i]	G	0.005	^{90}Sr ^{137}Cs
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	<0.005	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]	U
Derby	Drinking water[n]	L	<0.005	
Devonport	Fish and shellfish consumption	L	<0.005	Ext
and external in intertidal areas				
	Terrestrial foods	G	<0.005	
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{137}Cs
Holy Loch	External in intertidal areas	L	<0.005	Ext
Rosyth	External in intertidal areas	L	<0.005	Ext
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.017	^{75}Se ^{222}Rn
Cardiff	Fish and shellfish consumption and external in intertidal areas	L	0.017	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	0.018	^{3}H ^{14}C
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	^{137}Cs
Industrial and landfill				
Drigg	Terrestrial foods[i]	G	0.017	^{90}Sr
	Drinking water[n]	L	<0.005	
Whitehaven	Fish and shellfish consumption[j]	L	0.41	^{210}Po ^{210}Pb
	Fish and shellfish consumption[m]	L	0.63	^{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 assessments for contributions are based on data being wholly at limits of detection. Where this is the case the contributor is not listed in the table. The source of the radiation listed as contributing to the dose may not be discharged from the site specified, but those from an adjacent site*
[d] *Dominant source of exposure. G for gaseous wastes. L for liquid wastes or surface water near solid waste sites. See also footnote 'c'*
[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*

increased presence of finer-grained sediments with high activity concentrations will also play a part in this trend. The increases are small and are not readily observed in fish and shellfish samples from Cumbria.

Releases of argon-41 gas from Dungeness and Sizewell Magnox power stations continued to have a significant local effect on concentrations in air near to the station. As it is not practicable to monitor for argon-41, we have estimated the effects of the discharges using dispersion modelling.

Dose rates from around nuclear sites

We did not find any major changes in external dose rates in 2004. Dose rates measured in intertidal areas in Scotland in 2004, are slightly lower than in 2003. However, these values are not unusual in that they are similar to those observed in 2001 and 2002.

Site incidents and non-routine surveys

During 2004, further radioactive fragments were recovered near Dounreay. Nine radioactive fragments were recovered from the site foreshore, five from Sandside Bay and 73 from the seabed near to the Dounreay site. The fishing restrictions under the Food and Environment Protection Act 1985 are therefore still in force.

There were 11 other occasions where ‘special’ sampling (referred to as *ad hoc* sampling) was required because of concerns raised about site operations or because of higher than normal gaseous discharges, triggering reporting procedures that are a condition of the operator’s authorisation. Most cases involved higher than normal gaseous releases of radioactivity. These cases occurred at Bradwell, Dungeness, Oldbury, Hartlepool, Sizewell and Wylfa. Each time, samples in the routine monitoring programme were collected earlier, and analysed more quickly than scheduled. We did not detect any increases above normal levels except at Oldbury and Sizewell. In both these cases the increases were small and had negligible effects on local public radiation doses.

Ad hoc sampling was also required at Hartlepool to try and establish the extent of the enhancement of natural radionuclides from sources other than the nuclear power station. Enhanced gamma dose rates have been observed for some time on the south bank of the Tees. This year, to investigate the enhancement further, we analysed seafood for lead-210 and polonium-210. Taken at face value, the results in 2004 indicate a significant enhancement of these radionuclides, which, with a worst case dose assessment, would give rise to a radiation exposure of 0.18 mSv. However, the results are at odds with earlier data for the area and they are based on very limited sampling. We will obtain more data in 2005.

In 2004, we surveyed the diets and occupancy habits of people near nuclear sites at Sellafield, Amersham, Devonport and Wylfa. We used the results to improve radiological assessments of the monitoring programmes.

Radiation doses and levels at other locations in the UK

We also analysed food and drinking water in the general diet and in sources of public drinking water across the United Kingdom. Our results showed that radioactivity from natural sources was the most significant source of exposure to communities in areas remote from nuclear sites. Man-made radionuclides only contributed a small proportion of the total public radiation dose.

Monitoring artificially-produced radioactivity on the Isle of Man and in Northern Ireland showed that doses were all less than 3% 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 earlier, concentrations of natural radionuclides in fish and shellfish near the Rhodia Consumer Specialties Ltd. site continued to be elevated above normal levels. Phosphogypsum used to be discharged from this site 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). This site stopped operating at the end of 2001 and the plant is now demolished. The dose to high-rate seafood consumers, including the effects of artificial radionuclide discharges from the Sellafield site nearby, was estimated to be 0.63 mSv for the critical group. The contributions from artificial and TNORM radionuclides were 0.22 and 0.41 mSv, respectively.

The programme of monitoring the effects of discharging wastes at other non-nuclear industrial sites reduced in 2004. This was because in previous years there had been little or no evidence for increased concentrations of radionuclides in the environmental samples from studied sites. However, we did investigate the effects of releases of natural radionuclides from the cleaning of offshore oil/gas industry equipment at Aberdeen by Scotoil Ltd. This was to confirm the results of earlier studies. We sampled intertidal and sub-tidal sediments; the results showed that there was an enhancement of natural radionuclides in some sediments. However, there were no consequential implications in radiation exposure terms for beach users.

We found tritium in leachate from some landfill sites but only at levels that were of very low radiological significance. We think this is due to the legacy of past disposals of gaseous tritium light devices, such as fire exit signs and other similar items.

A small programme of monitoring of the effects of the Chernobyl accident continued in 2004. Some upland areas of the UK still have restrictions on the movement, sale and slaughter of sheep.

Monitoring of distributions of radionuclides in coastal seas away from nuclear sites continues. This supports the UK's 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 UK's coastal seas. These surveys, together with the results of monitoring at nuclear sites, form an essential evidence base for the UK submissions to the OSPAR Commission, which manages an international convention to prevent pollution of the seas of the north-east Atlantic. They also help us measure our progress towards the UK Government's targets for improving the state of our seas.

The monitoring programmes and additional research

The monitoring programmes in this report 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 by the Environment Agency, the Environment and Heritage Service, the Food Standards Agency and the Scottish Environment Protection Agency and are independent of the industries discharging radioactive effluents. The programmes include monitoring 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, we completed more than 20,000 analyses or dose rate measurements in 2004.

The results of the analysis of food samples collected near nuclear sites in England and Wales are published as quarterly summaries on the Food Standards Agency's website (www.food.gov.uk). There is more information about all programmes described in this report from the sponsoring agencies. These details are on the back cover.

The routine monitoring programmes were supported by a number of research studies investigating specific issues such as the uptake and retention of radionuclides in animals and the levels of radioactivity in bottled water. Results of the completed studies are in Section 10. The agencies are also funding work to improve the methods for estimating public exposure including site-specific surveys of people's 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 2004 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, the Food Standards Agency and the Scottish Environment Protection Agency.

The data in this report cover the calendar year of 2004. This is the third 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 Environment and Heritage Service 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 data reported here are also used to assess the environmental impact of radioactive discharges. The purpose of the programmes is to demonstrate that any radioactivity present in foods does not compromise food safety and to check that public radiation exposure more generally are 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, the Environment and Heritage Service and the Scottish Environment Protection Agency, 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 the Scottish Environment Protection Agency 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 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 an independent check on the 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. For example, the most recent summary of the scope of all radioactivity monitoring programmes 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 2004 are addressed first 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, i.e. those who receive the largest dose from artificially produced radionuclides due to their habits, diet or where they spend their time. Where practicable, the estimated doses 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 (Watson *et al*., 2005). Dose limits are based on recommendations made by the International Commission on Radiological Protection (ICRP), which are embodied in EU and UK law.

A glossary of abbreviations is provided in Appendix 3.

This report primarily considers the effects of the UK nuclear industry and its discharges on the public at large. Radiation exposures to workers and from other sources such as medicine and radon in homes are reviewed by Watson *et al* (2005).

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 the low-level waste repository 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 2004 from the nuclear sites and disposals at the low-level waste repository at Drigg and Dounreay is included in Appendix 1. Following a consultation process (Environment Agency, 2003a) the Environment Agency introduced a mandatory reporting scheme for RSA 93 activities on 1st January 2004 to improve access to information. Discharge information is published on the Environment Agency web site as part of its pollution inventory.

The sites that are the principal sources of waste containing man-made radionuclides are shown in Figure 1.1. The programmes reported here 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 also 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 2004. 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 very much 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 actually discharged in 2004 are also stated in the tables.

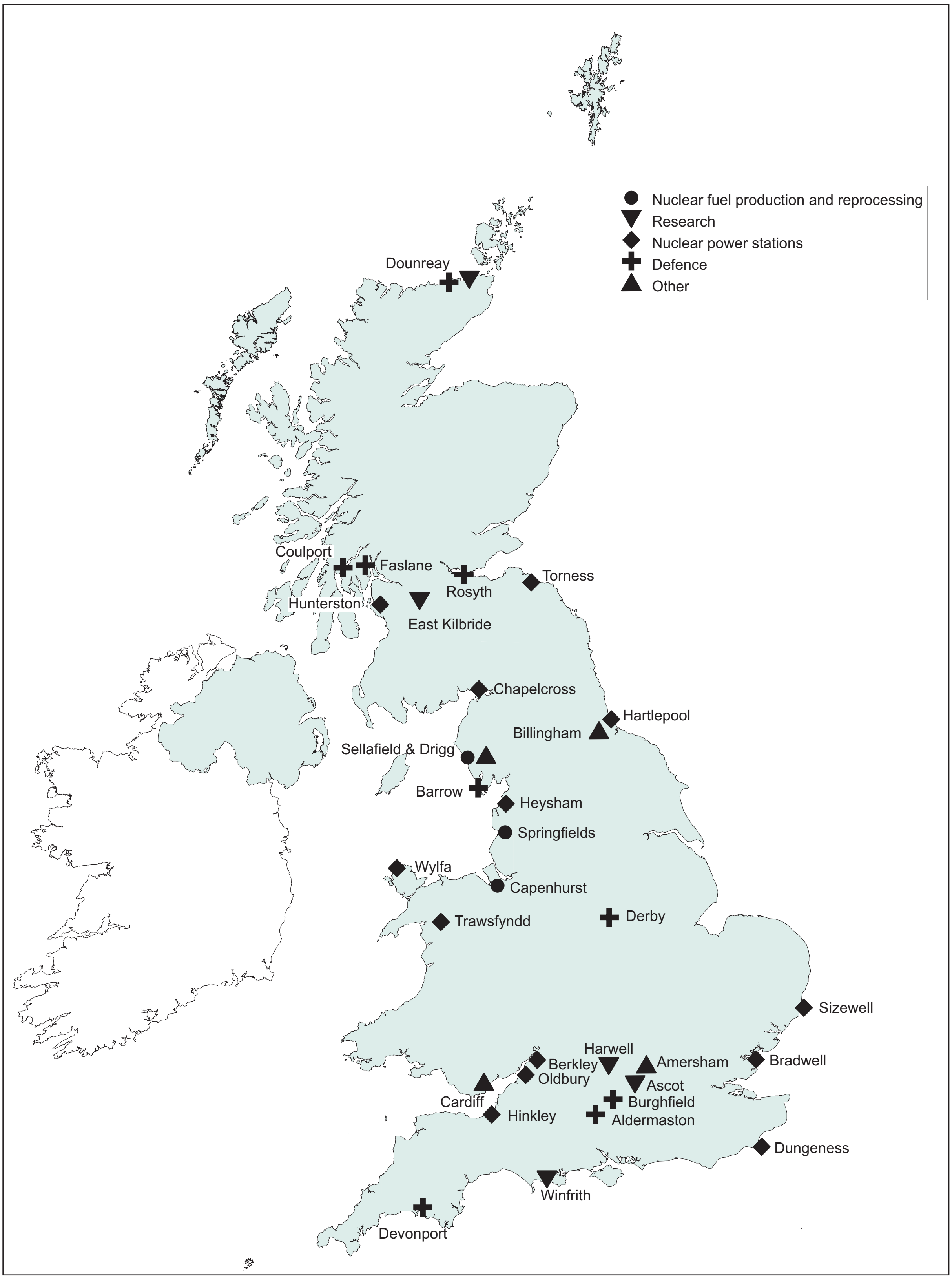

Figure 1.1 Principal sources of radioactive waste disposal in the UK. *(Showing main initial operation. Some operations are undergoing decommissioning)*

Where changes in discharge in 2004 have affected the levels of radioactivity in the environment, this is discussed in the relevant section of the report.

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 provides 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 strategy stated that due to the diverse nature of other minor sources of radioactive discharges, no discharge profile or target would be 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). A recent report from the OSPAR Radioactive Substances Committee records work completed and planned relating to reporting of discharges, environmental measurements, standards and quality assurance (OSPAR, 2005). It also considers the relationship between OSPAR and its work on radioactivity and the separate initiative to develop a European Marine Strategy. Progress by contracting parties with the implementation of controls on radioactive discharges has been published (OSPAR, 2003). The European Commission (EC) is considering the outcome of a consultation process concerning development of the European Marine Strategy (Commission of the European Communities, 2005a).

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). TheEC has 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 completed a fully integrated assessment of the marine environment in 2005 (Department for Environment, Food and Rural Affairs, 2005a and 2005b; Department for Environment, Food and Rural Affairs, Department of the Environment (Northern Ireland), Scottish Executive, Welsh Assembly Government, 2005).

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, has enabled the establishment of the Nuclear Decommissioning Authority (NDA) which began operation in April 2005. The NDA has taken 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 is 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 legislation has also provided for improvements to the Radioactive Substances Act 1993, by streamlining the regulatory processes for transferring radioactive waste discharge authorisations relating to nuclear sites.

In 2000, the Water Framework Directive (WFD) took effect (Commission of the European Communities, 2000b). Subsequently, legislation was enacted to transpose the Directive in the UK (see for example United Kingdom-Parliament, 2003). Defra, the Scottish Executive, Welsh Assembly Government and the Department of the Environment Northern Ireland have policy responsibility for the implementation of the WFD in the UK. Implementation is largely the responsibility of the Environment Agencies as competent authorities.

The aim of the Directive is to improve the quality of the aquatic environment of the European Community. It provides a framework for member states to work within and establishes a planning process with key stages for development towards reaching “good status” by 2015 for inland and coastal waters. The UK has undertaken the first stage which involved characterising the quality of freshwater, estuarine and coastal environments of the UK paying particular attention to describing ecosystems and to reviewing the presence of hazardous substances (Department for Environment, Food and Rural Affairs, 2005c). In relation to radioactivity, the Environment Agencies have characterised the aquatic environment using a screening tool which forecasts the environmental impact of radioactive waste sources. The outcome of the assessment has been published and provided to the Commission (Environment Agency, 2005d). Subsequent stages within this framework involve the design and implementation of monitoring programmes optimised to reflect the results of the initial characterisation, a subsequent review of environmental quality made with the benefit of the output from the monitoring programmes, the development of standards and the production of management plans to attain an improved environmental status for the UK aquatic environment.

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 2004 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. 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 has recently published a system of assessment which can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003). In 2004, a specific assessment of the disposal of dredge material from Whitehaven Harbour was carried out. The harbour sediments contain artificial radionuclides due to discharges from BNFL Sellafield and from other widespread sources such as weapon test fallout. Samples of the material were taken and analysed and the results are given in Table 1.1. The assessment showed that the impact of the radioactivity associated with the disposal operation was very low and exposures were below 0.010 mSv.

1.2.4 Other sources of radioactivity

There are several other man-made sources of radioactivity that may affect the 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, 2004). 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 2004. Low levels of 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 Food and Environment Protection Act 1990 provides a regulatory regime for the identification and remediation of contaminated land. Implementation of the regime has initially focused on non-radioactive contamination. However, Defra has now begun a consultation exercise to take forward implementation for land contaminated with radioactivity (Department for Environment, Food and Rural Affairs, 2005d).

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 that 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.

A review of all sources of ionising radiation exposure of the UK population has been published (Watson *et al*., 2005). Sources of natural and medical radiation predominate. The average annual dose from natural radiation was found to be 2.2 mSv and about half of this was from radon exposure indoors. The average annual dose from artificial radiation was 0.42 mSv, mainly derived from the use of x-rays in medical procedures. The overall average annual dose was 2.7 mSv. Exposures from non-medical man-made sources were very low and discharges of radioactive wastes contributed less than 0.1% of the total. These data represent the exposures of the average person. Much of the information in this RIFE report is directed at establishing the exposures of critical groups in the population who might have above average doses due to radioactive waste discharges as a result of their age, diet, location or habits. It is these people who form the basis for comparisons with dose limits in EU and UK law.

Table 1.1. Concentrations of radionuclides in sediment from Whitehaven Harbour, Cumbria, 2004

Area	Core No.	Depth (m)	Radioactivity concentration (dry), Bq kg^{-1}						
			^{60}Co	^{137}Cs	^{154}Eu	^{226}Ra (via ^{214}Pb) (1)	^{232}Th (via ^{228}Ac) (1)	^{238}U (via ^{234}Th) (1)	^{241}Am
A	1	Surface	4.4	640	5.6	110	36	180	660
A	1	1	<1.0	8.6	<2.0	29	31	48	9.0
A	1	2.4	<1.0	<1.0	<2.0	16	17	26	<3.0
A	2	Surface	2.4	5400	20	210	42	380	2400
A	2	1	<1.0	55	<2.0	45	36	91	21
A	2	2	<1.0	7.4	<2.0	31	37	58	7.8
A	3	Surface	5.0	1300	2.9	120	33	360	960
A	3	1	<1.0	110	<2.0	120	36	240	180
A	3	2.3	<1.0	7.5	<2.0	31	35	62	8.0
A	4	Surface	9.0	870	5.9	90	27	190	1200
A	4	1	1.7	5000	14	200	39	480	2100
A	4	2.5	<1.0	970	4.7	170	44	360	1700
B	5	Surface	11	590	6.9	50	30	86	880
B	5	1	2.0	1500	12	110	35	340	1400
B	6	Surface	11	720	7.1	55	35	93	1000
B	6	1	2.3	3700	15	240	43	490	2700

(1) Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products

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 whose decay produces 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 the relevant labelling and food control of irradiation legislation (Food Standards Agency, 2002). 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”.

1. Introduction

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. The bulk of the programmes and assessment methods and data have continued from 2003 unchanged. The main differences are:

- Sampling at industrial sites in the UK has reduced because the results of work already undertaken have shown a very low radiological impact
- Sampling at nuclear sites has been adjusted to reflect changes in discharges and environmental pathways. For example, sulphur-35 is no longer analysed in foods around Sellafield because the main source of discharge of this radionuclide, Calder Hall power station, has ceased operation.
- Special sampling was introduced at sites where there were unusual short-term increases in discharges and inadvertent releases.
- Data presentation has been improved by reporting data for nuclides that have had a positive result in previous RIFE reports in the last five years, but which are currently only detectable at limits of detection. This is to allow for possible assessment of any trends.
- A further four sites have been assessed using a new Total Dose assessment methodology. This brings together information on all sources of exposure at nuclear sites, including direct radiation. Currently 11 sites are assessed in this manner and it should be possible to assess all sites in this way within the next four years.
- Maps of sites and sampling locations have been revised and updated.
- Dose coefficients have been reviewed and updated with new information.
- Consumption and occupancy rates for critical groups have been updated with the benefit of recent habit survey results
- Data presented for Sellafield has been reordered and segmented into geographical areas to aid interpretation.

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 demonstrate 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
- demonstration of compliance with OSPAR obligations

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 also be affected by disposals of radioactive waste from nuclear sites abroad and show the legacy of atmospheric fallout from both past nuclear weapons testing and the nuclear reactor accident in 1986 at Chernobyl in the Ukraine.

The programmes 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. In the case of Sellafield some radionuclides discharged in liquid effluent can be detected in the marine environment in many parts of north-European waters and so 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). It is assumed that if the most exposed group have a dose below the legal limit then all others should be at an even lower level of risk. For liquid wastes, the pathways that are the most relevant to discharges 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 (which is considered separately in Section 4.2).

The impacts of two industrial sites were studied in 2004. They were at Aberdeen (offshore equipment decontamination) and Whitehaven (chemical manufacturers). In both cases the sampling and analysis was directed at marine materials potentially containing enhanced natural radionuclides (i.e. TNORM).

About fifty landfill sites were monitored in England, Scotland and Wales. The distribution of landfill sites considered in 2004 is shown in Figure 2.1. 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 significant site is the engineered facility operated by British Nuclear Group at the low-level waste repository at Drigg in Cumbria.

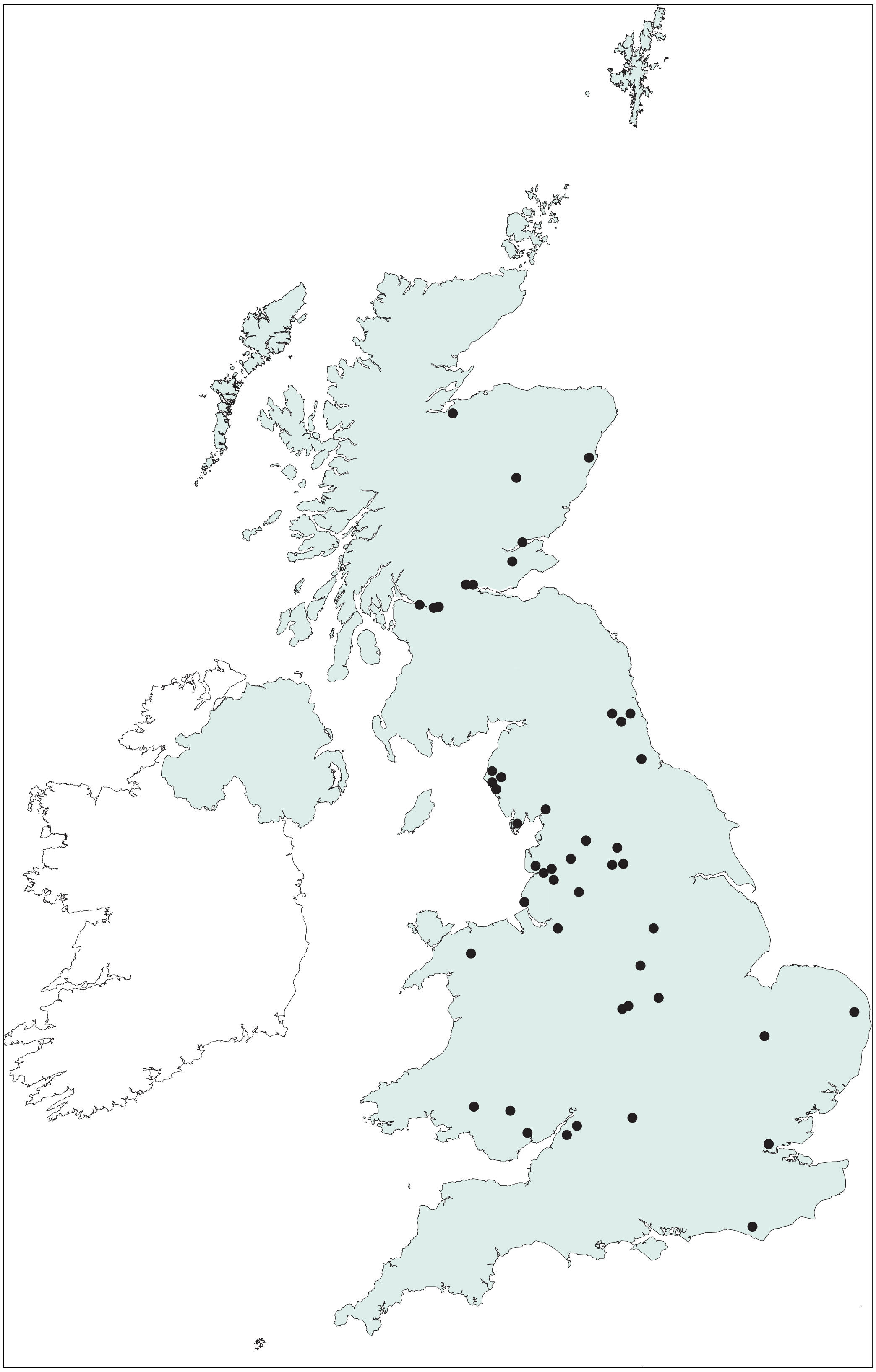

Figure 2.1 Landfill sites monitored in 2004

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.

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, crops 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. Some of these data are also supplied to the EC 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 1996-2000 (Joint Research Centre, 2005). The TDS was supplemented with a study of canteen meals in 2004. Together they account for the 'dense' and 'sparse' networks for mixed diet (Commission of the European Communities, 2000a) required by the EC.

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

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.

Milk sampling took place at dairies throughout the UK in 2004. 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 1996-2000 (Joint Research Centre, 2005).

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, the Environment and Heritage Service 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 OSPAR 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).

2. Sampling, measurement, presentation and assessment

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

- HPA Health Protection Agency*,
  gamma-ray spectrometry and radiochemistry of samples from Scotland, Total Diet and canteen meals 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 certifies that they meet the requirements of the international standard ISO 17025 (International Organization for Standardisation, 2005). 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 Cerenkov 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 some of the 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. Although some activity may be lost, these generally reflect the effects of the normal cooking process for

**On 1st April 2005 the National Radiological Protection Board merged with the Health Protection Agency to form its Radiation Protection Division* shellfish. Most other foodstuffs are analysed raw because of the variation in methods of cooking and the possible use of liquors in sauces and soups.

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 others. In this report we have presented the total gamma dose rate. The Health Protection Agency (HPA) reports terrestrial gamma dose rates to the Scottish Environment Protection Agency. 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 2004, 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 small radioactive fragments. Further information regarding Dounreay is provided in Section 4.

2.3 Presentation of results

The following tables of monitoring results 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 sampled for 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

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* *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.*

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 2004 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 results presented in the tables (i) positive values and (ii) values preceded by a 'less than' symbol. Where the results are not averages, they are positive values, or values at the limit of detection (LoD) or minimum reporting level (MRL) respectively. Where the results are an average of more than one datum, and each datum is positive, the result is positive. Where there is a mixture of data, or all data are at the LoD or MRL, the result is preceded by a 'less than' symbol. Gamma spectrometry can provide a large number of 'less than' results. In order to minimise the presentation of redundant information for gamma spectrometry, 'less than' values are only reported when (i) either the radionuclide is one which is in the relevant authorisation, (ii) or it has been analysed by radiochemistry, (iii) or it has been reported in that table in the previous 5 years, (iv) or a positive result is detected in any other sample presented in the table in 2004.

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).

There are also a few results quoted as 'not detected' (ND) by the methods used. This refers to the analysts' judgement that there is insufficient evidence to determine whether the radionuclide is present or absent.

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 the Scottish Environment Protection Agency 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 for 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.

The ICRP is currently revising its recommendations and is undergoing a consultation process on its proposals. The draft documents, which provide the foundation for the system of protection, can be viewed at www.icrp.org. When the new ICRP recommendations are issued, the implications concerning EU and UK radiation protection standards will be taken into account in future issues of this report.

For drinking water, the World Health Organisation (WHO) has provided screening levels to compare with the results of measurements of total alpha and total beta activity (WHO, 2004). The screening levels are 0.5 and 1.0 Bq l^{-1}, for gross alpha and gross beta 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. The EC has prepared a directive on the quality of water intended for human consumption, which sets parameters for tritium (with a reference value of 100 Bq l^{-1}) and total indicative dose (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 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 (CCFAC) considered draft guidelines at its meeting in March 2004 (CODEX Alimentarius Commission, 2004). The proposals were the subject of a consultation in the UK led by the Food Standards Agency. The responses to the Food Standards Agency have been published on www.food.gov.uk and, taking these into account, the UK commented on the current draft at the CCFAC meeting held on 25th April 2005. Subsequently, a drafting group led by the IAEA and the EC has been set up to revise the draft guidelines for further consideration by CCFAC in 2006.

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 2004 shown in this report. 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.

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

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.
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, the low-level waste repository at 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 (see Section 2.7.5).

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 (gaseous or liquid) or (ii) when a positive determination for that radionuclide is found in another sample from the same sector of the environment at the site (aquatic or terrestrial). 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. New survey data were introduced at Amersham, Devonport, Sellafield and Wylfa in 2004. 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 (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. A preliminary assessment has confirmed that in no case would foetal doses approach the dose limit. However, the HPA has recently issued guidance in relation to assessments of foetal doses and recommends that critical group assessments should be extended to include the developing foetus. The RIFE assessments procedure will be revised to take this into account in its next report for 2005.

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 tritium, 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 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.

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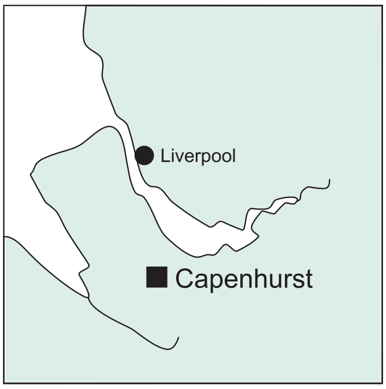
3. NUCLEAR FUEL PRODUCTION AND REPROCESSING

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). As from 1st April 2005 British Nuclear Group Sellafield Ltd. (BNGSL), part of the BNFL plc group holds the main authorisations for waste disposal at Sellafield (including Calder Hall) Drigg and Capenhurst. Springfields Fuels Ltd. (SFL), also part of BNFL, holds the authorisations to dispose of radioactive waste from the Springfields site. Small amounts of gaseous wastes are discharged by Urenco (Capenhurst) Ltd. at Capenhurst and from the UKAEA Windscale site at Sellafield. The low-level waste repository at Drigg is discussed in Section 8.1.

3.1 Capenhurst, Cheshire

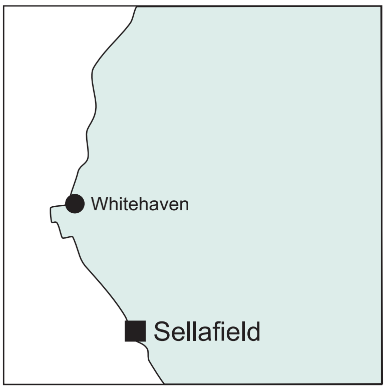


The main functions undertaken on the Capenhurst site are enrichment of uranium and dismantling of redundant plant. Both Urenco and BNGSL undertake operations on this site. The enrichment facility is operated by Urenco (Capenhurst) Ltd. In 2004, BNGSL had authorisations to dispose of small amounts of radioactivity in gaseous wastes via stacks and in liquid wastes to the Rivacre Brook. Urenco (Capenhurst) Ltd. also had a gaseous discharge authorisation. Radioactive waste arisings consist of tritium, uranium plus its daughter products, technetium-99 and neptunium-237 (from recycled fuel). 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 2004 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 2003 though there have been and continue to be variations in concentrations in sediment in the Brook. This is likely to be due to variations in the size distribution of the particles that make up the sedimentary material. 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 0.008 mSv in 2004 (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 2004.

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 BNGSL 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.

The Environment Agency completed its review of the Sellafield radioactive waste authorisations in 2004 and new limits were introduced to take effect from 1st October 2004 (Environment Agency, 2004a). The review process began in 1999 and in August 2002, following an extensive public consultation exercise, the Environment Agency published its proposals for future regulation of disposals from the site and submitted them for ministerial review. Taking into account developments since August 2002, and following further consultation with the Health & Safety Executive and the Food Standards Agency, the Environment Agency revised its 2002 proposals and issued a report explaining its final decisions (Environment Agency, 2004b).

The key changes to the proposals published in 2002 are as follows:

- A reduction in the annual technetium-99 limit for discharges to sea from 90 TBq to 20 TBq
- A further reduction in this limit to 10 TBq expected to be no later than 2006
- A requirement to develop and optimize an integrated waste strategy to promote further environmental improvements during clean-up.
- The removal of plant and site limits for aerial discharges of argon-41 and sulphur-35 following the closure of the Calder Hall power station in 2003. Discharges of argon-41 to atmosphere from the power station were the main contributor to the radiation exposure of the local community.
- The postponement of a new site limit for antimony–125 to avoid constraining site clean-up work while BNGSL provides additional information on arisings of this radionuclide and how they could be reduced. Discharges of antimony-125 will be subject to a reduced site limit and a new plant limit on discharges of total beta radioactivity. The introduction of a new site limit specifically for antimony-125 will be reviewed by the Environment Agency before the end of 2007.
- The minor adjustment to several proposed limits for individual facilities ('plant limits') at the site, to reflect future clean-up and decommissioning programmes.

In April 2004, progress in reducing technetium-99 discharges was announced by the Environment Agency and HSE (Environment Agency, 2004c). Trial of the use of tetraphenylphosphonium bromide (TPP) in the Enhanced Actinide Removal Plant (EARP) was carried out by BNFL in 2003, to remove technetium-99 when Medium Active Concentrate (MAC) is treated in EARP. The trial was assessed by the Environment Agency and HSE and BNFL has subsequently implemented the new technique. As a result of this and of the earlier MAC diversion (Health and Safety Executive and Environment Agency, 2003), which re-routed new arisings of MAC into vitrification thus reducing the amount to be treated in EARP, discharges of technetium-99 will be reduced by around 90% from 2002 levels.

The Environment Agency has begun a review of disposals from the UKAEA Windscale site (Environment Agency, 2002b) and has announced a public consultation on its proposals to lower the permitted radioactive discharges (Environment Agency, 2005a).

In June 2004, the Environment Agency served an enforcement notice on BNFL (now BNGSL) over its failure to properly maintain the pipelines to discharge waste to the Irish Sea (Environment Agency, 2004d). This follows an incident earlier in the year when two pieces of rubber gasket, contaminated with radioactivity, were found by BNFL during routine surveys of local beaches. It was later discovered that both sections had become detached from the seaward end ('diffuser') of one of the operational pipelines. The notice requires BNFL to undertake a series of reviews of design, inspection and maintenance of the pipelines and to make improvements in these areas.

The Commission of the European Communities (CEC) 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 findings have now been published by the CEC (Commission of the European Communities, 2005b).

The main findings relating to the monitoring by the Environment Agency and the Food Standards Agency were that: (i) the inspection team considered that the monitoring programmes were globally satisfactory and (ii) the inspection activities performed did not give rise to any specific recommendations. In all respects, the inspection process was said to be successful and its objectives had been met. Monitoring of gaseous and liquid discharges and of levels of radioactivity in the environment were broadly satisfactory. However, some shortcomings were noted and recommendations were made with the aim to achieve improvements. These mainly concerned BNFL operations and their associated regulatory control. The UK government will make public its response to the findings and recommendations in 2005.

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

3.2.1 The effects of liquid discharges

Discharges from the Sellafield pipelines during 2004 are summarised in Appendix 1. Total alpha and total beta discharges were 0.291 and 73.3 TBq, respectively (2003: 0.407 and 83.3 TBq, respectively). Most of the reduction in total beta discharge was due to technetium-99. Discharges of it have steadily decreased in the last few years (2002: 85.4 TBq; 2003: 37.0 TBq; 2004: 14.3 TBq) and are now much lower than the peak reached in 1995 of 192 TBq. The reduction of technetium-99 was due to the continuing use of TPP which was introduced successfully in October-November 2003 (see above). Discharges of most other radionuclides varied by small amounts but were similar to those in recent years. Ruthenium-106 discharges reduced from 11.5 TBq (2003) to 4.42 TBq (2004). There has been an increasing trend in the discharge of a low impact radionuclide with a short half-life, antimony-125, over recent years as BNFL has worked to clear a backlog of corroded fuel in one of its fuel storage ponds (see Section 3.2). Discharges of carbon-14 to the marine environment are strongly related to the amount of Magnox fuel that is reprocessed and have increased over the last few years because of higher rates of reprocessing of Magnox spent fuel. No discharges exceeded the limits set in the authorisation.

Regular monitoring of the marine environment near Sellafield continued during 2004. 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 2004, 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.

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 2004 were generally similar to those in 2003. Data are listed by location of sampling or landing point, in areas of approximate order of increasing distance from Sellafield. Samples taken near other nuclear establishments that reflect Sellafield discharges are given elsewhere 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.

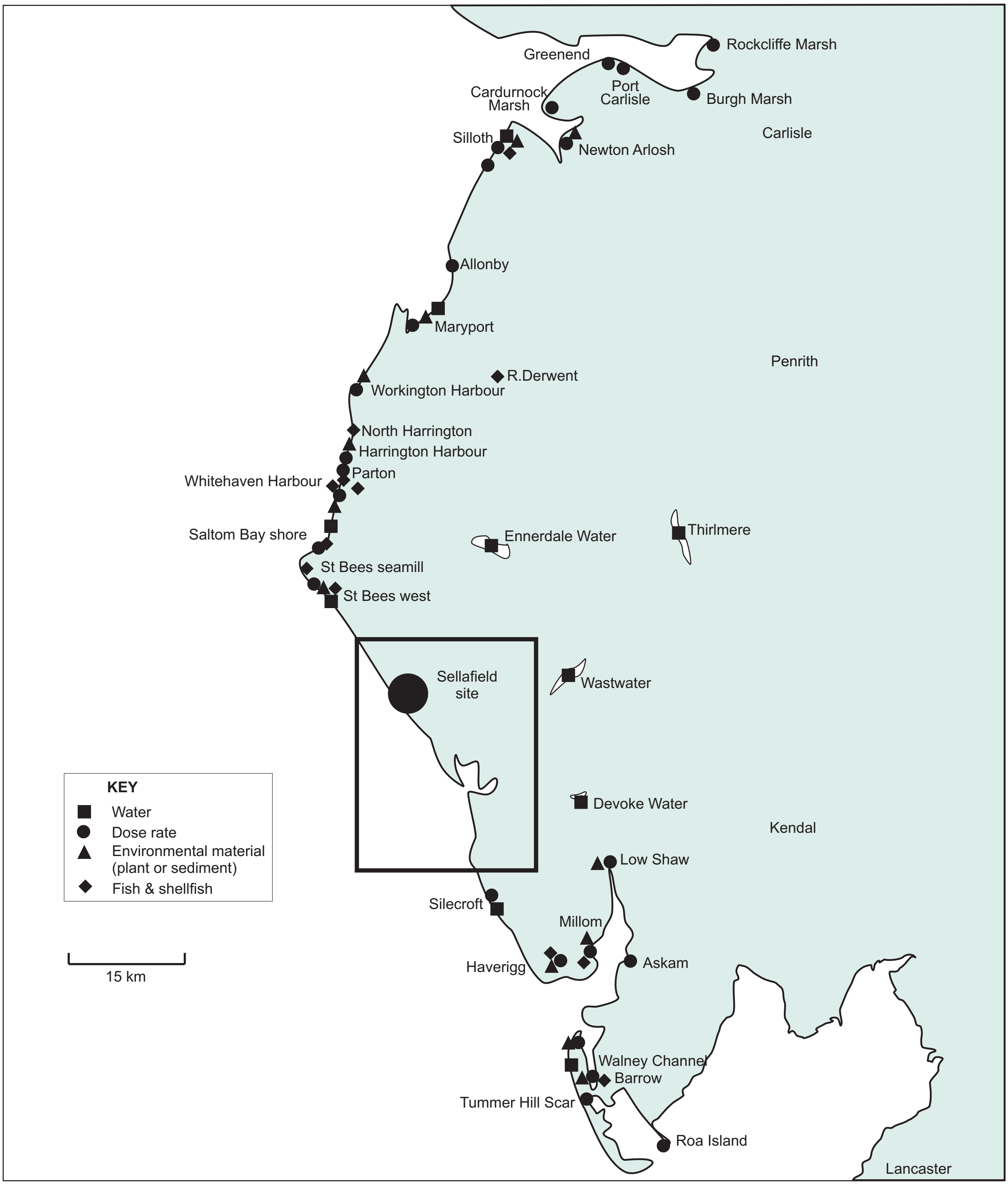


Figure 3.1 Monitoring locations in Cumbria (excluding farms)

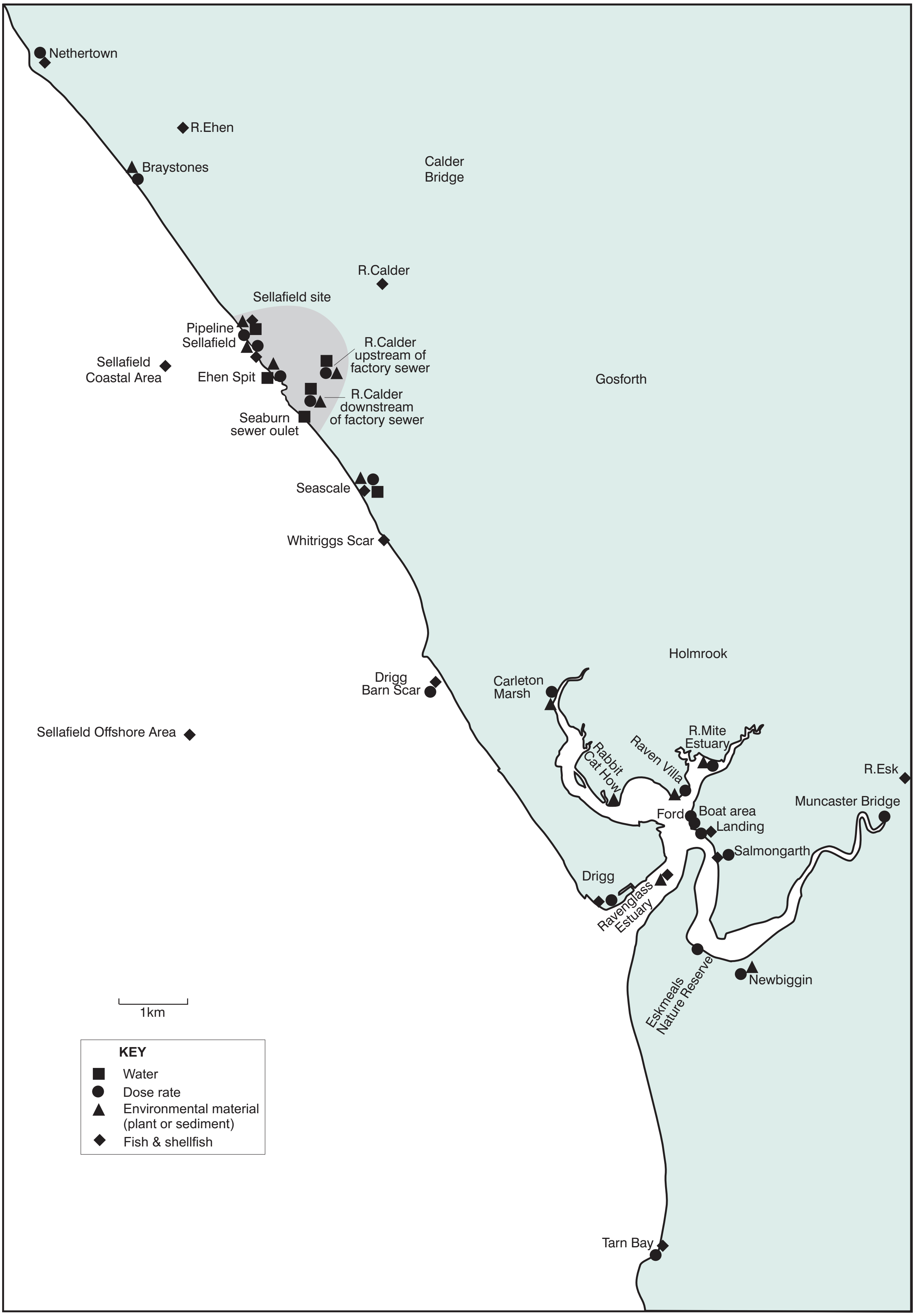


Figure 3.2 Monitoring locations at Sellafield (excluding farms)

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, when significant reductions in discharges were achieved some years ago. 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.

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. Samples were obtained from 14 fish farms in Scotland and 3 in Northern Ireland. They demonstrated that 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, 2003). Results in farmed salmon from the west of Scotland for 2004 in Tables 3.3 and 3.5 confirm that this remains the case.

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. In addition, relatively high 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. However, 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 discussed later in this report, is much less than that of other radionuclides.

There is some variability in concentrations between fish species, but data for cod from the 'Offshore Area' can be used to give a general indication of trends in fish (Figures 3.3 - 3.6). Unfortunately no cod samples were obtainable from the relevant area in 2004 and the changes in plaice concentrations at the same location have therefore been used to derive estimates of the expected concentrations in cod. The main broad long-term trends observed for beta/gamma emitters are (i) a slow progressive decline in caesium-137 concentrations, (ii) increases in concentrations of cobalt-60 and technetium-99 in the late 1990s and (iii) increases in carbon-14 over the period 2000-2004. In each case these changes reflect changes in levels of discharge though there is a significant variability about the expected concentration.

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.

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 2003 and 2004 data across a wide range of sampling locations and shellfish species, few major changes in concentrations

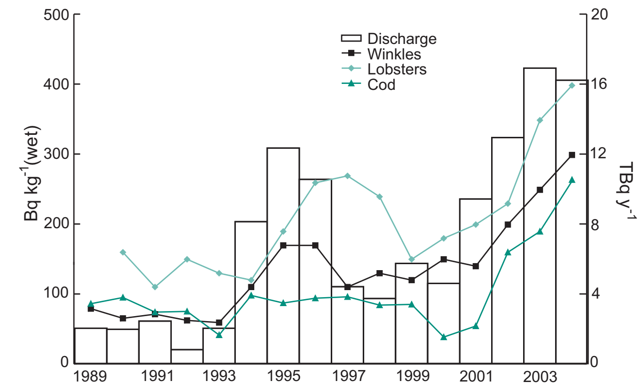


Figure 3.3 Carbon-14 liquid discharge from Sellafield and concentrations in cod*, lobsters and winkles near Sellafield

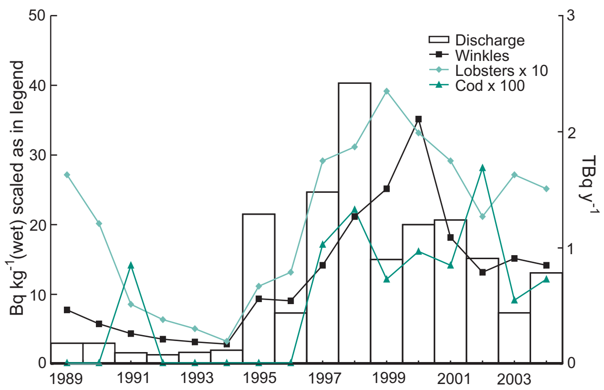


Figure 3.4 Cobalt-60 liquid discharge from Sellafield and concentrations in cod*, lobsters and winkles near Sellafield

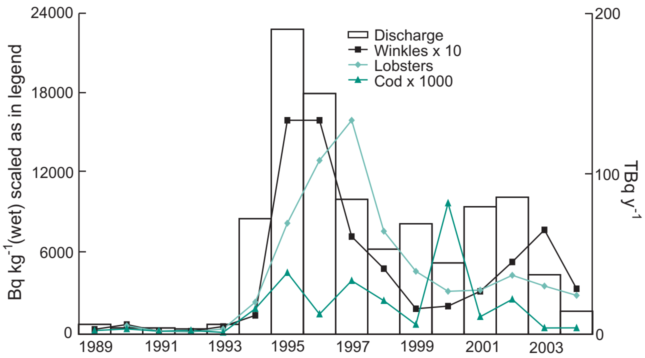


Figure 3.5 Technetium-99 liquid discharge from Sellafield and concentrations in cod*, lobsters and winkles near Sellafield

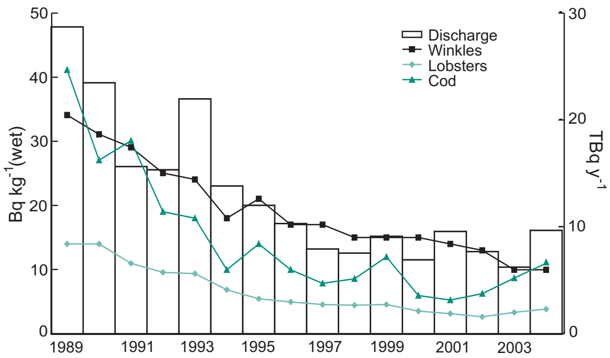


Figure 3.6 Caesium-137 liquid discharge from Sellafield and concentrations in cod*, lobsters and winkles near Sellafield

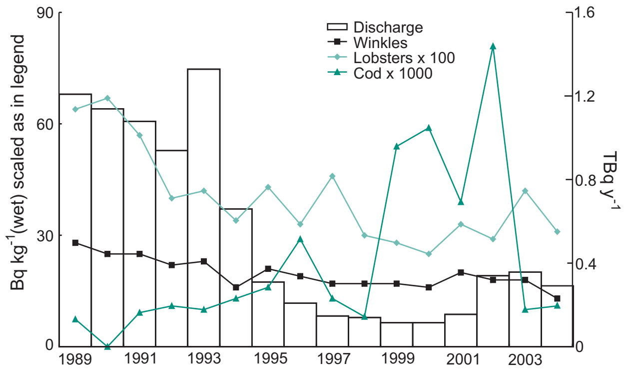


Figure 3.7 Plutonium-239/240 liquid discharge from Sellafield and concentrations in cod*, lobsters and winkles near Sellafield

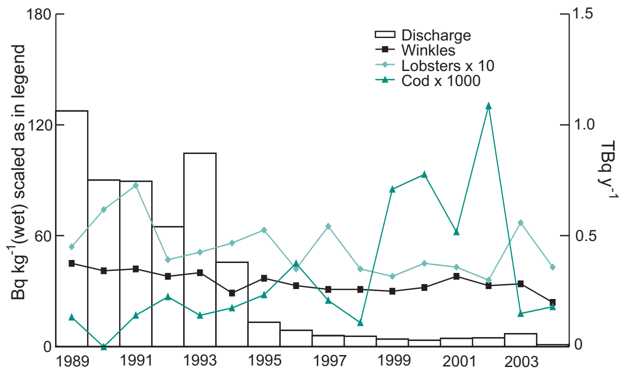


Figure 3.8 Americium-241 liquid discharge from Sellafield and concentrations in cod*, lobsters and winkles near Sellafield

* *Estimated in 2004 due to lack of availability of cod*

were found. However, there were increases in carbon-14 in shellfish and this continues the trend begun in 2000. Tritium levels in shellfish collected close to the site were also slightly higher when compared to 2003 levels. In contrast, technetium-99 levels were generally reduced following the success in reducing discharges. Increases in technetium-99 in cockles from the Dee Estuary are indicative of the movement of the radionuclide south along the Cumbrian and Lancastrian coats to the Welsh coast (Hunt *et al.*, 2002). Seaweeds are a sensitive indicator of technetium-99 and further information from samples collected throughout the UK is given later in this Section. There were also reductions of ruthenium-106 in shellfish following the reduction in discharge in 2004.

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 2004 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. Concentrations in fish and shellfish near Sellafield in 2004 were generally similar to those in 2003 (Figures 3.7 and 3.8). The long term trend has been for a slow reduction in concentrations though this may now have stopped. There is a significant variability from year to year. Levels of transuranics in samples from the north-eastern Irish Sea were the highest found in foodstuffs in the UK and their importance in determining critical group exposures, as shown later, remains.

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 2004 from radionuclides in fish and shellfish.

The dose to the local critical group of high-rate consumers from artificial radionuclides was 0.22 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 2004; changes were found in the mix of fish and shellfish species consumed but the overall consumption rates were similar to those in 2003. The new data are cited for reference in Appendix 4. There was a small increase in dose from 0.21 mSv in 2003 due to the change in consumption rates and small changes in concentrations. The effects of the increases of tritium and carbon-14 in seafood on doses were compensated by reductions in cobalt-60 and technetium-99. Most of the dose from the ingestion of seafood and external irradiation due to Sellafield was from historic discharges. The breakdown of the main contributions to dose is shown in Figure 3.9. Recent and current discharges of technetium-99 contributed about 12% of the dose to the Sellafield seafood consumers, a reduction from the value of 15% for 2003. The radionuclides giving the largest contribution to the food component of the dose in 2004 were plutonium isotopes and americium-241. This is consistent with data for the period from 2000.

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 2004 dose assessment was 2000-2004 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 2004 is provided in Table 3.6 for comparison with the same group using the five year average habit survey data.

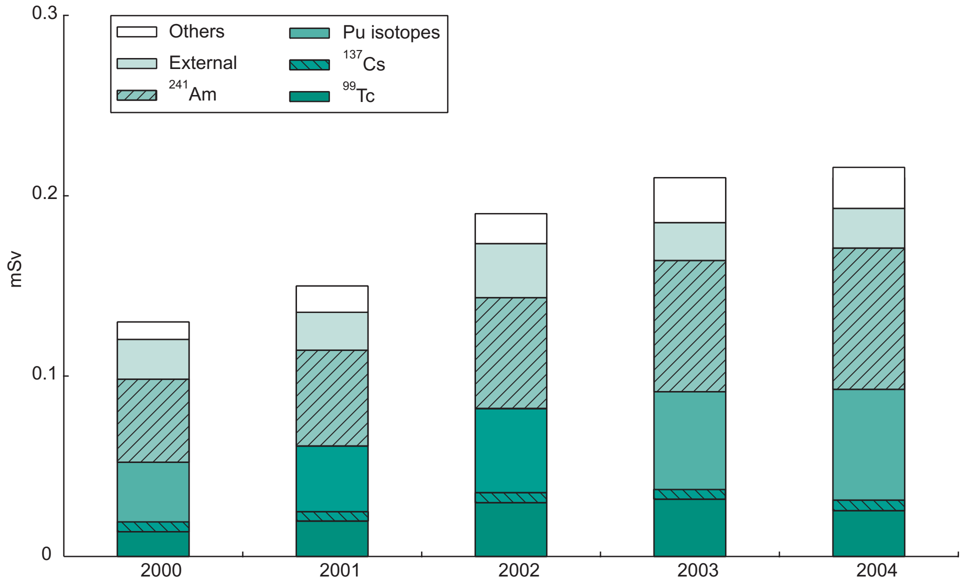


Figure 3.9 Contributions to dose to seafood consumers at Sellafield, 2000-2004

Data for natural radionuclides in fish and shellfish are discussed in Section 8. However, the effects on the Sellafield critical group from the legacy of 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 2004 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 0.22 mSv dose from artificial radionuclides from Sellafield this gives a total dose to the critical group of 0.63 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 (Watson *et al.*, 2005) 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 2003 (see following text table and Figure 3.10). The reduction in the dose for seafood landed at Whitehaven is due to a reduction in the observed concentrations of actinides. This is most likely to be due to the fishing vessels changing their catch area. Otherwise, whilst there have been changes in the concentrations of some radionuclides in seafood, their effect is relatively minor. All doses were well within the annual 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 2004. The exposure of potential consumers of trout from a tarn at a local farm was not assessed, as there was no evidence for consumption of trout from the lake in 2004.

Figure 3.10 Individual radiation exposures to seafood consumers from artificial radionuclides in the Irish Sea, 2000-2004

Doses from artificial radionuclides in the Irish Sea		
Group	Dose, mSv	
	2003	2004
Isle of Man	0.006	0.007
Northern Ireland	0.013	0.010
Dumfries and Galloway	0.036	0.038
Whitehaven	0.031	0.013
Sellafield	0.21	0.22
Morecambe Bay	0.075	0.068
Fleetwood	0.018	0.018
North Wales	0.012	0.012

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 Dumfries and Galloway, 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 3.11). Dose rates over intertidal areas throughout the Irish Sea in 2004 were generally similar to those data for the same locations in 2003. However, there were some reductions in the reported dose rates on the Scottish coastline which are thought to be most likely due to changes in instrument calibrations. The longer term reduction of gamma dose rates since the 1980s can be seen in Figure 3.12; 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, continued to show a significant excess above natural background downstream of the site. This is less likely to be due to monitoring equipment detecting direct radiation from Calder Hall as in previous years since power ceased to be produced in 2003. However, there are other sources of radiation on site, and 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 3.13 – 3.16. 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 is some evidence of a small increasing trend 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. This change in concentrations in sediment at Ravenglass is not marked and is not readily observed in fish and shellfish samples from Cumbria. Levels of cobalt-60 in mud are generally declining from the peak observed in 1999. Overall, concentrations in sediments in 2004 were similar to those in 2003.

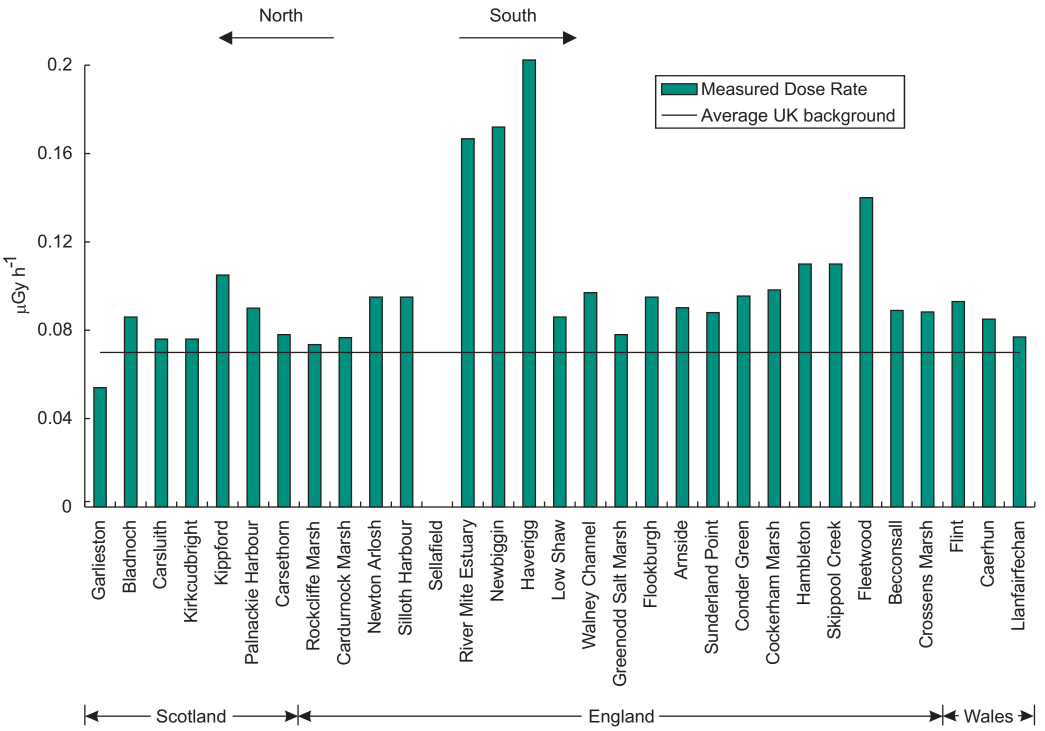


Figure 3.11 Gamma dose rate above mud and salt marsh with distance from Sellafield

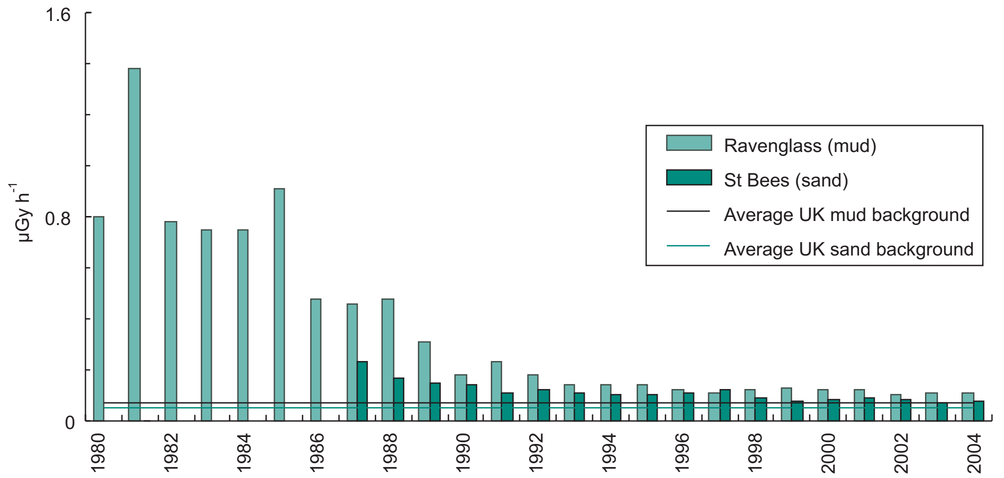


Figure 3.12 Gamma dose rate at Ravenglass and St Bees (data prior to 1988 are from BNFL surveys)

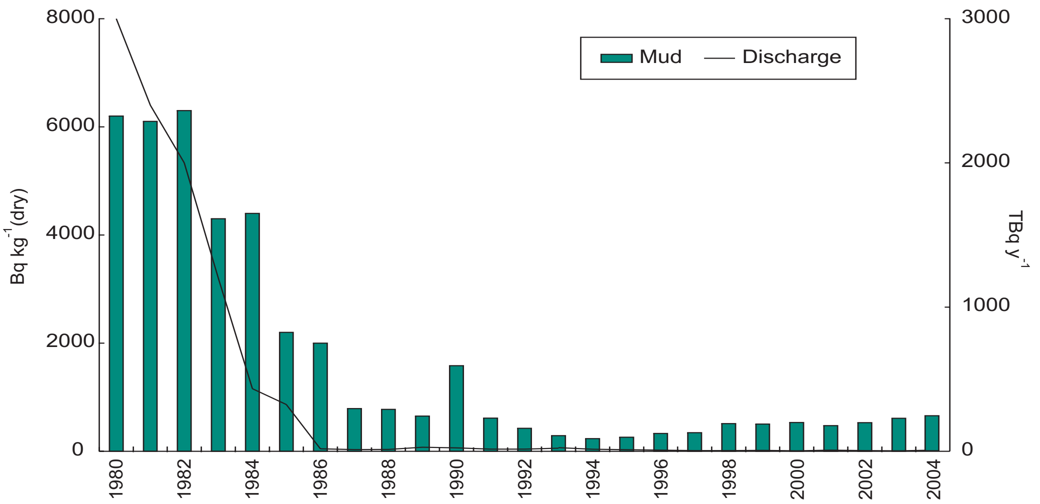


Figure 3.13 Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)

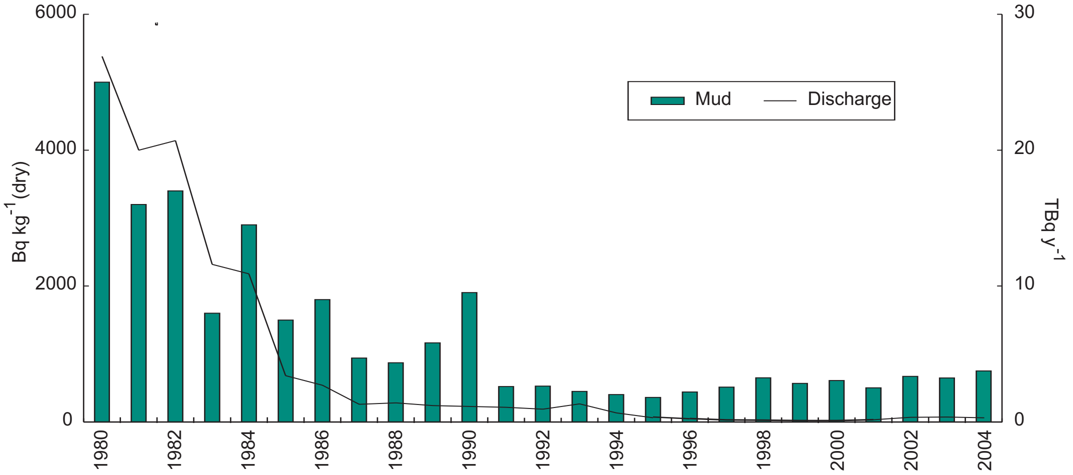


Figure 3.14 ***Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass** (data prior to 1988 are from BNFL surveys)*

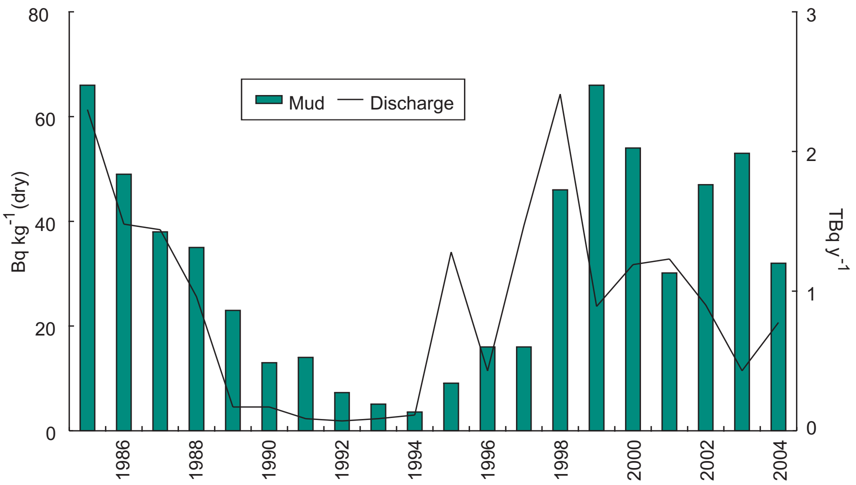


Figure 3.15 ***Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass** (data prior to 1988 are from BNFL surveys)*

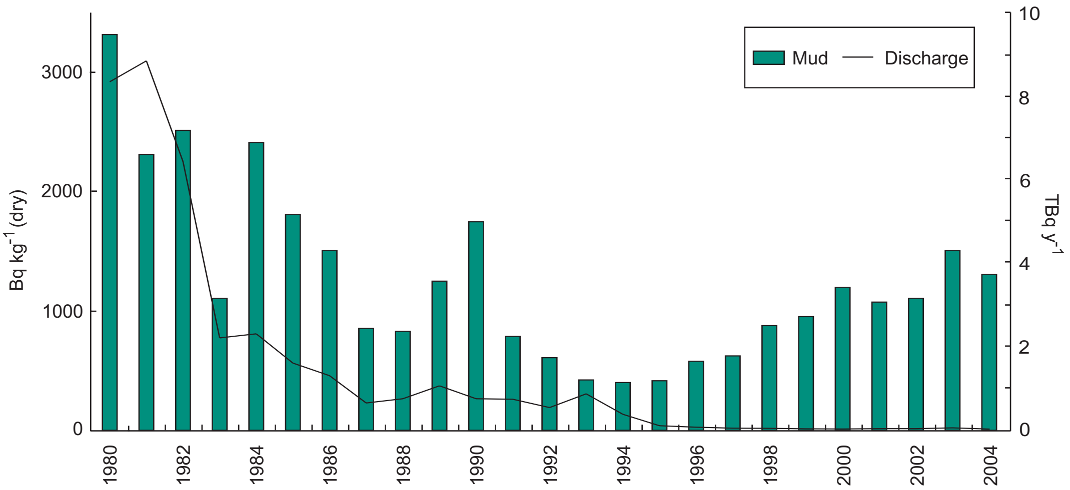


Figure 3.16 ***Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass** (data prior to 1988 are from BNFL surveys)*

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 2004, their dose was 0.058 mSv or about 6% of the dose limit for members of the public. This was less than the value of 0.079 mSv in 2003 due to a reduction in the estimated occupancies on the houseboats. 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 2004. The most important of these were found in the Ravenglass estuary where critical group exposures over salt marsh or mud were up to 0.039 mSv (represented by occupational exposure of a nature warden). Doses from recreational use were lower at 0.030 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.

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 2004 are presented in Table 3.9. Measured dose rates were generally similar to those for 2003. 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 2004, including a component due to natural radiation, was 0.080 mSv, which was less than 0.5% 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 2004 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 0.24 mSv in 2004 which was less than 1% of the skin dose limit.

In addition, more general beta/gamma monitoring of contamination on beaches continued in 2004. 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 2004 and no material was therefore removed.

BNGSL’s (BNFL in 2004) monitoring found two pieces of rubber gasket, contaminated with radioactivity, on the Sellafield and Seascale beaches in January and February 2004. Both were found to have come from the seaward end of one of the operational pipelines used by the company. Subsequent tests revealed that the radiation levels of both items were found to be low, thus presenting little potential hazard to the public. However, they were confirmed as being above the agreed reporting levels. The Environment Agency issued an enforcement notice because these finds indicated that BNGSL had failed to comply with a condition of their authorisation (see start of section 3.2)

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. The work on removal continued during 2004 without incident.

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 2004 were of the same order as those reported in 2003. 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 2004 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 decrease in technetium-99 in *Fucus vesiculosus* in 2004 and the highest concentrations which are found near Sellafield are now much less than those in the mid 1990s (Figure 3.17). 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 to the Welsh coast and into the English Channel also occurs (Hunt *et al*., 2002). Whilst the technetium-99 concentrations outside the eastern Irish Sea are measurable, their radiological significance is very low.

Seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a continuing research study in 2004. 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 2004, 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.

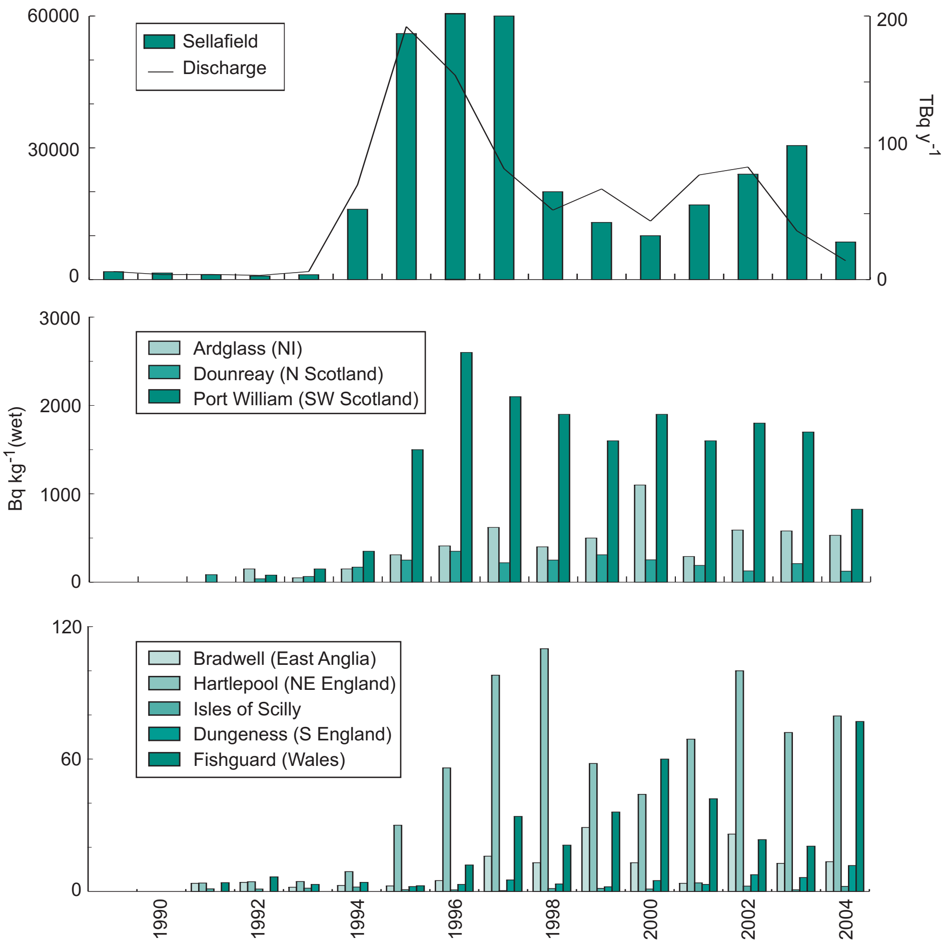


Figure 3.17 ***Technetium-99 liquid discharge from Sellafield and concentration in seaweed,*** **Fucus vesiculosus**

The technetium-99 concentrations in vegetables ranged from 2.6 to 58 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 0.015 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 the modelling approach in the report for 1997 (Ministry of Agriculture, Fisheries and 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 2004 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 2004 (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 2004; 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 2004 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 2004 are also presented in Table 3.12. The dose to the critical group of laverbread consumers in south Wales was 0.005 mSv, confirming the low radiological significance of this exposure pathway.

Monitoring for sea to land transfer at 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.

The results of measurements in 2004 are presented in Table 3.14. In general, the data are similar to those for 2003 and show lower concentrations than are found in the direct vicinity of Sellafield. The evidence for sea-to-land transfer is limited. Low levels of tritium were detected, particularly in sheep meat. A small amount of technetium-99 was detected in grass but the concentrations were very low. Concentrations of transuranic radionuclides were also very low but the observed isotopic ratios of $^{239+240}$Pu:^{238}Pu in some foodstuffs are not characteristic of fallout (40:1) and are therefore suggestive of a Sellafield influence.

The exposure due to consumption of terrestrial foods from Ravenglass in 2004 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 0.022 mSv, which was about 2% of the dose limit for members of the public of 1 mSv and is similar to 2003. Sea-to-land transfer for terrestrial foodstuffs is therefore not of radiological importance in the Ravenglass area.

3.2.2 The effects of gaseous discharges

Discharges of gaseous wastes from Sellafield are summarised in Appendix 1. There were significant reductions for some radionuclides when compared with 2003, 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 total beta discharges were similar to those for 2003.

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, strontium-90, technetium-99, iodine-129, radiocaesium, uranium and transuranic radionuclides. Analyses for sulphur-35 were stopped in 2004 because of the cessation in discharges from Calder Hall.

The results of routine monitoring in 2004 are presented in Table 3.15. The concentrations of all radionuclides were low and were generally similar to those in 2003.

Levels of activity in meat and offal from cattle and sheep continued to be analysed in 2004. Concentrations of radionuclides were low with limited evidence of the effects of Sellafield derived activity in data for tritium and carbon-14. Plutonium concentrations were much lower than those found in seafood.

A wide range of fruit and vegetables were sampled in 2004 including apples, blackberries, broccoli, cabbage, carrots, cauliflower, elderberries, onions, potatoes, runner beans, sprouts, swede and turnips. The results were similar to those found in previous years. In common with meat and offal samples, limited evidence for the effects of Sellafield discharges was found in data for tritium and carbon-14. 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 0.036 mSv (Adult: 0.020; 10y: 0.023). The most significant contributions to the 1-year-old's dose were from strontium-90 and ruthenium-106, but it is worth noting that the dose assessment used ruthenium-106 levels in foods at the LoD. Actual doses would probably be lower. 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 2004 (0.035 mSv) was similar to the corresponding dose in 2003 (0.031 mSv). Doses as a result of environmental non-food pathways were lower in 2004, due to the absence of discharges of argon-41 from Calder Hall.

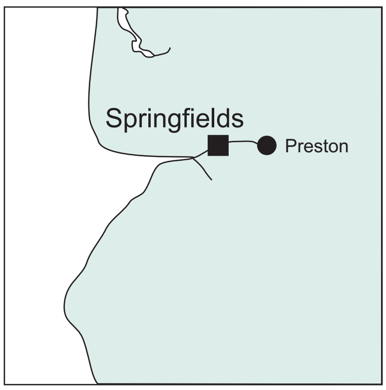
3.2.3 Other pathways

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. 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 2004 are shown in Table 3.16. Levels of caesium-137, plutonium isotopes and americium-241 were enhanced in the drains nearest the bird sanctuary, but are now more than a factor of ten 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. SFL, part of BNFL, now holds the authorisations to dispose of radioactive waste from the Springfields site.

Liquid discharges of beta-emitting radionuclides, which result in the greatest contribution to the radiological impact due to Springfields, increased from 97 TBq (2003) to 116 TBq (2004) (see Appendix 1). Discharges of gaseous effluents remained very low at a similar level to those for 2003. 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). Taking into account all responses, the Environment Agency has issued its decision (Environment Agency, 2004e) and new authorisations took effect from 1st November 2004.

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 (see Figure 3.18) where low-level solid wastes from Springfields used to be disposed of in landfill. Disposal ceased in 1983. Water and sediments were taken from Deepdale Brook, close to the main site. The local monitoring locations are shown in Figure 3.18.

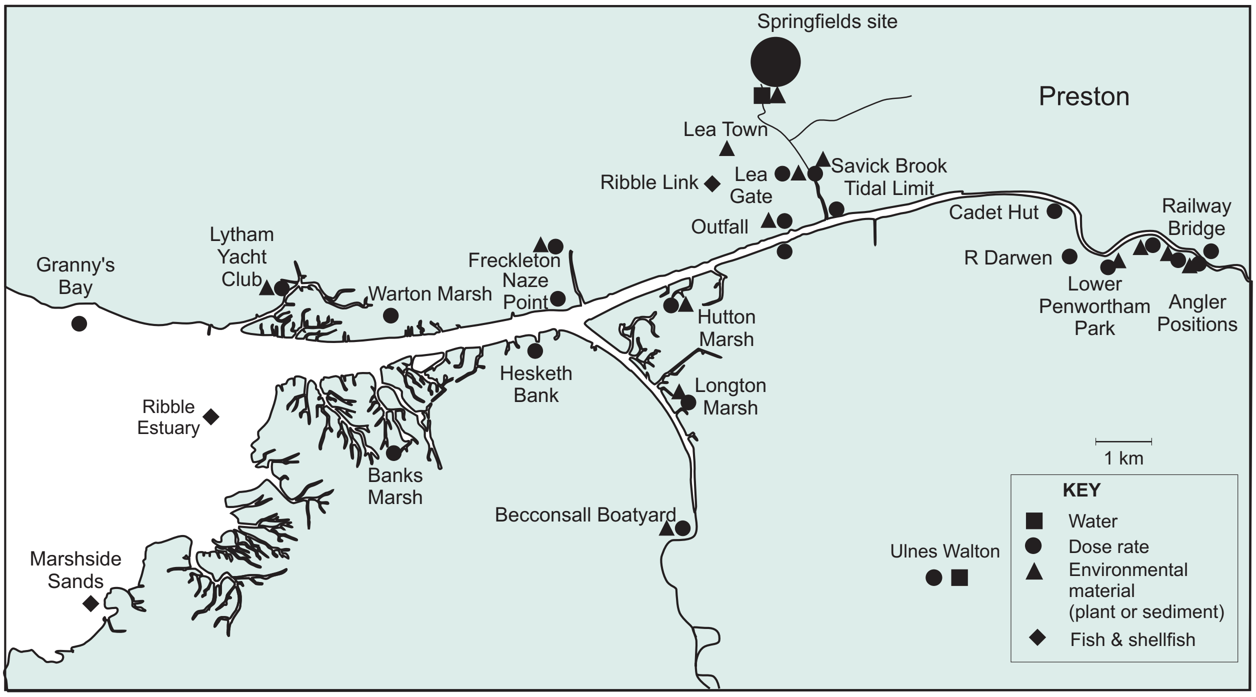


Figure 3.18 Monitoring locations at Springfields (excluding farms)

Results for 2004 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 3.19).

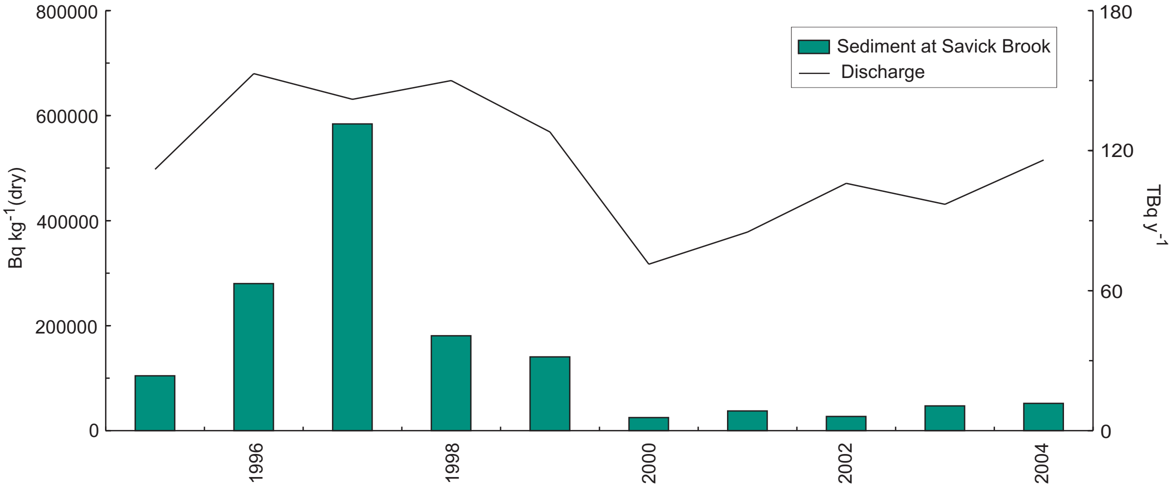


Figure 3.19 Total beta liquid discharge from Springfields and concentration in sediment at Savick Brook

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 effects of historic discharges from Sellafield. The results in 2004 were generally similar to those for 2003. 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 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 2004, the dose to houseboat dwellers was 0.058 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 2003 of 0.079 mSv, largely due to a reduction in the assumed occupancy (based on the use of five year averages).

The exposures of anglers and children playing were of lesser importance. In 2004, their doses were 0.011 mSv and less than 0.005 mSv, respectively, similar to the values for 2003.

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 0.32 mSv or less than 1% 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 2003. The dose for the seafood consumption group was 0.023 mSv or less than 3% 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 2004, 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 2003 were detected. Concentrations in fresh water in Deepdale Brook, a small stream that passes through the site, were also unchanged. However, those in sediments from the Brook increased by a factor of 10 to be roughly equivalent to the concentrations in soils found near the site. Freshwater from the vicinity of Ulnes Walton showed similar levels of uranium isotopes to those found in Deepdale Brook. It also contained a low, but detectable level of tritium. None of these observations suggest that public exposures due to Springfields as estimated earlier need to be reassessed.

Table 3.1(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{60}Co	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs	^{155}Eu	^{226}Ra	^{233}Pa	^{234}Th
Aquatic samples												
Flounder	Liverpool Bay	2	<25									
Flounder	Mersey Estuary	1	<25									
Dabs	Mersey Estuary	1	<25									
Shrimps	Wirral	2	<25	<0.06	3.7	<0.57	<0.15	2.0	<0.13			
Mussels	Liverpool Bay	2	<25									
Mussels	Mersey Estuary	2	<25									
Cockles	Dee Estuary	4		0.17	48	<0.58	0.35	1.9	<0.16			9.5
Elodea canadensis	Rivacre Brook	2		<0.11	10	<1.2	<0.27	0.18	<0.29		*	
Mud	Rivacre Brook	1		<0.56	180	<6.1	<1.5	7.1	<2.4	17	80	930
Mud and sand	Rivacre Brook	1		<0.27	130	<3.2	<0.82	4.7	<1.3	15	110	630
Sediment	Rivacre Brook	2[E]			290			4.9				150
Sediment	Rivacre Brook (1.6 km downstream)	2[E]			96			2.7				68
Sediment	Rivacre Brook (3.1 km downstream)	2[E]			39			1.8				<26
Sediment	Rossmore (4.3 km downstream)	2[E]			49			2.3				45
Freshwater	Rivacre Brook	1	<1.4	<0.12	0.028	<1.0	<0.29	<0.11	<0.25			
Freshwater	Rivacre Brook	2[E]	<4.7		<0.61							
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	<4.0		<0.56							
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<4.0		<0.55							
Freshwater	Rossmore (4.3 km downstream)	2[E]	<4.0		<0.70							
Freshwater	Dunkirk Lane Pond	2[E]	<4.0		<0.70							

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{234}U	^{235}U	^{238}U	^{237}Np	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Aquatic samples												
Cockles	Dee Estuary	4					0.16	0.92	2.4	0.0038		
Elodea canadensis	Rivacre Brook	2	9.3	0.35	5.2	0.17			<0.41			
Mud	Rivacre Brook	1	58	2.7	38	1.6			<2.6			
Mud and sand	Rivacre Brook	1	42	1.7	26	2.1			<1.5			
Sediment	Rivacre Brook	2[E]	120	4.6	71	<1.0					730	1300
Sediment	Rivacre Brook (1.6 km downstream)	2[E]	40	1.5	26	<1.0					260	550
Sediment	Rivacre Brook (3.1 km downstream)	2[E]	23	1.3	17	<1.0					160	700
Sediment	Rossmore (4.3 km downstream)	2[E]	28	<0.81	17	<1.0					120	570
Freshwater	Rivacre Brook	1	0.093	0.00063	0.0097				<0.13			
Freshwater	Rivacre Brook	2[E]	0.058	<0.0050	0.021	<0.10					0.080	0.32
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	0.030	<0.0050	0.017	<0.10					0.060	0.30
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	0.036	<0.0050	0.017	<0.10					0.050	0.27
Freshwater	Rossmore (4.3 km downstream)	2[E]	0.034	<0.0050	0.021	<0.10					<0.039	0.34
Freshwater	Dunkirk Lane Pond	2[E]	<0.012	<0.0065	<0.0075	<0.10					<0.20	5.9

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		6	<2.2	<0.0045				<0.0065
Milk	max		<2.3					
Gooseberries		1		<0.018				0.048
Potatoes		1		0.030				<0.031
Spinach		1		0.043	0.036	0.0015	0.041	0.20
Grass		8		<0.0075				<0.15
Grass	max			<0.0080				0.45
Grass/herbage	North of Ledsham	1[E]		<1.0	<0.55	<0.32	<0.45	
Grass/herbage	South of Capenhurst	1[E]		1.4	<0.15	<0.097	<0.18	
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		2.1	2.9	<0.84	2.3	
Grass/herbage	East of station	1[E]		<1.0	0.11	<0.070	<0.10	
Silage		4		<0.0075				0.55
Silage	max				0.045	0.0014	0.043	0.94
Soil		4						36
Soil	max				6.6	0.26	6.5	39
Soil	North of Ledsham	1[E]		<7.0	19	1.1	19	
Soil	South of Capenhurst	1[E]		8.7	17	<0.75	17	
Soil	Off lane from Capenhurst to Dunkirk	1[E]		17	18	1.2	19	
Soil	East of station	1[E]		5.4	24	0.73	24	

* *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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 3.1(b). Monitoring of radiation dose rates near Capenhurst, 2004

Location	Material or ground type	No. of sampling observa-tions	μGy h^{-1}
Gamma dose rates at 1m over intertidal areas			
Rivacre Brook Plant outlet	Concrete and grass	1	0.096
Rivacre Brook Plant outlet	Concrete and stones	1	0.091
Rivacre Brook 1.5 km downstream	Grass	2	0.079
Rivacre Brook 3.1 km downstream	Mud and sand	1	0.076
Rivacre Brook 3.1 km downstream	Leaves and mud	1	0.074
Rossmore Road West 4.3 km downstream	Grass	2	0.076

Table 3.2. Individual radiation exposures – Capenhurst and Springfields, 2004

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]	0.008	-	-	0.007	<0.005
Springfields	Seafood consumers	0.023	0.023	-	-	-
	Houseboat occupants	0.058	-	-	0.055	<0.005
	Fishermen handling nets or pots[c]	0.32	-	-	0.32	-
	Children playing at Savick Brook[d]	<0.005	-	-	<0.005	<0.005
	Anglers	0.011	-	-	0.011	-
	Consumers of locally grown food[e]	<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*
[e] *Includes a component due to natural sources of radionuclides*

Table 3.3. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2004

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb
Cumbria										
River Derwent	Sea trout	1				<0.07	<0.21		<0.29	<0.44
Parton	Cod	4				<0.10	<0.25		<0.29	<0.37
Whitehaven	Cod	4			88	<0.09	<0.24	0.030	<0.32	<0.48
Whitehaven	Plaice	4				<0.10	<0.25	0.093	<0.30	<0.36
Whitehaven	Skates / rays	4				<0.11	<0.31		<0.52	<0.88
River Ehen	Salmon	1				<0.09	<0.27		<0.35	<0.47
River Ehen	Sea trout	1				<0.10	<0.28		<0.32	<0.35
River Calder	Brown trout	1				<0.23	<0.76		<2.5	*
Calder Pond	Rainbow trout	1				<0.09	<0.25		<0.44	<0.92
Sellafield coastal area	Cod	5				<0.17	<0.26		<0.27	<0.31
Sellafield coastal area	Plaice	7	120	140		<0.11	<0.28		<0.47	<0.57
Sellafield coastal area	Bass	1				<0.10	<0.24		<0.35	<0.50
Sellafield coastal area	Mullet	1				<0.09	<0.34		<1.2	*
Sellafield offshore area	Plaice[a]	1			210	0.12	<0.10	0.14	<0.09	<0.07
Sellafield offshore area	Dab	1				0.22	<0.19		<0.17	<0.14
Sellafield offshore area	Red gurnard	1			86	<0.33	<0.86		<1.1	<1.4
Sellafield offshore area	Lesser spotted dogfish	1				<0.08	<0.17		<0.17	<0.13
Sellafield offshore area	Skates/rays	1				<0.16	<0.47		<0.63	<0.81
Ravenglass	Cod	3				<0.11	<0.26		<0.32	<0.45
Ravenglass	Plaice	4	180	270		<0.12	<0.25		<0.33	<0.46
Ravenglass	Pollack	1				<0.09	<0.22		<0.19	<0.16
Morecambe Bay (Flookburgh)	Flounder	4			110	<0.09	<0.24		<0.31	<0.42
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Plaice	4	<25	<25		<0.13	<0.36	0.027	<0.70	<1.4
Morecambe Bay (Morecambe)	Bass	2				<0.10	<0.31		<0.55	<1.1
Morecambe Bay (Sunderland Point)	Whitebait	1				0.11	<0.18	1.3	<0.23	<0.29
Fleetwood	Cod	2			94	<0.07	<0.20	0.052	<0.35	<0.71
Fleetwood	Plaice	3				<0.09	<0.26		<0.48	<1.0
Ribble Link	Brown trout	1				<0.03	<0.09		<0.13	<0.17
Ribble Estuary	Flounder	1				<0.13	<0.45		<1.3	*
Ribble Estuary	Salmon	1				<0.13	<0.36		<0.63	<1.1
Ribble Estuary	Sea trout	1				<0.14	<0.50		<1.4	*
Liverpool Bay	Flounder	2		<25						
Mersey Estuary	Flounder	1		<25						
Mersey Estuary	Dab	1		<25						
Scotland										
Shetland	Fish meal	4				<0.19	<0.50	0.019	<0.63	<0.91
Shetland	Fish oil	4				<0.11	<0.27		<0.55	<0.16
Minch	Herring	2				<0.09	<0.24		<0.32	<0.45
Minch	Mackerel	2			52	<0.07	<0.21	<0.037	<0.30	<0.40
West of Scotland	Mackerel	2				<0.11	<0.30		<0.43	<0.62
West of Scotland	Farmed salmon	1				<0.10	<0.32		<0.73	<1.6
Inner Solway	Plaice	3				<0.13	<0.39		<0.91	<1.3
Inner Solway	Flounder	4		<4.5	110	<0.12	<0.34	<0.10	<0.48	<0.72
Inner Solway	Lemon sole	1				<0.10	<0.21		<0.25	<0.26
Inner Solway	Salmon	1		5.5		<0.10	<0.16		<0.15	<0.14

Table 3.3. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Cumbria									
River Derwent	Sea trout	1		<0.61	<0.15	<0.07	3.5	<0.31	
Parton	Cod	4		<0.88	<0.25	<0.10	7.4	<0.49	
Whitehaven	Cod	4		<0.82	<0.21	<0.09	5.9	<0.44	
Whitehaven	Plaice	4		<0.85	<0.23	<0.09	4.6	<0.45	
Whitehaven	Skates / rays	4		<1.2	<0.30	<0.13	6.4	<0.68	
River Ehen	Salmon	1		<0.91	<0.22	<0.10	0.29	<0.57	
River Ehen	Sea trout	1		<1.0	<0.26	<1.1	1.7	<0.63	
River Calder	Brown trout	1		<3.1	<0.75	<0.27	50	<1.7	
Calder Pond	Rainbow trout	1		<1.9	<0.89	0.37	560	<1.1	
Sellafield coastal area	Cod	5		<0.86	<0.26	<0.18	9.0	<0.41	210
Sellafield coastal area	Plaice	7		<0.91	<0.25	<0.10	5.0	<0.54	180
Sellafield coastal area	Bass	1		<0.84	<0.25	0.10	17	<0.43	
Sellafield coastal area	Mullet	1		<1.1	<0.25	<0.10	5.1	<0.73	
Sellafield offshore area	Plaice[a]	1	22	<0.38	0.22	0.04	5.5	<0.19	
Sellafield offshore area	Dab	1		<0.71	<0.22	<0.08	8.9	<0.45	
Sellafield offshore area	Red gurnard	1	0.40	<3.7	<0.78	<0.38	5.2	<1.7	
Sellafield offshore area	Lesser spotted dogfish	1		<0.72	<0.23	0.19	13	<0.47	
Sellafield offshore area	Skates / rays	1		<1.8	<0.40	<0.17	4.6	<0.68	
Ravenglass	Cod	3		<0.84	<0.24	<0.11	7.9	<0.42	
Ravenglass	Plaice	4		<0.81	<0.24	<0.10	5.6	<0.42	
Ravenglass	Pollack	1		<0.86	<0.23	<0.10	8.2	<0.39	
Morecambe Bay (Flookburgh)	Flounder	4		<0.86	<0.25	<0.09	13	<0.47	
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Plaice	4	4.8	<1.4	<0.31	<0.14	4.0	<0.67	
Morecambe Bay (Morecambe)	Bass	2		<1.0	<0.27	<1.1	9.5	<0.60	
Morecambe Bay (Sunderland Point)	Whitebait	1		<0.61	<0.16	<0.07	5.5	<0.29	
Fleetwood	Cod	2	0.84	<0.64	<0.16	<0.07	4.0	<0.39	
Fleetwood	Plaice	3		<0.89	<0.23	<0.10	3.2	<0.54	
Ribble Link	Brown trout	1		<0.33	<0.08	<0.03	0.15	<0.21	
Ribble Estuary	Flounder	1		<1.3	<0.31	<0.13	5.2	<0.62	
Ribble Estuary	Salmon	1		<1.2	<0.28	<0.13	0.18	<0.61	
Ribble Estuary	Sea trout	1		<1.5	<0.32	<0.14	0.99	<0.79	
Scotland									
Shetland	Fish meal	4		<1.9	<0.48	<0.20	0.55	<1.1	
Shetland	Fish oil	4		<1.1	<0.31	<0.12	<0.11	<0.71	
Minch	Herring	2		<0.80	<0.20	<0.09	0.18	<0.45	
Minch	Mackerel	2		<0.78	<0.19	<0.08	<0.10	<0.45	
West of Scotland	Mackerel	2		<1.1	<0.25	<0.11	<0.10	<0.59	
West of Scotland	Farmed salmon	1		<1.1	<0.28	<0.12	0.32	<0.73	
Inner Solway	Plaice	3		<1.3	<0.31	<0.13	<0.21	<0.85	
Inner Solway	Flounder	4	2.7	<1.2	<0.33	<0.12	15	<0.73	
Inner Solway	Lemon sole	1		<0.72	<0.20	<0.10	0.55	<0.47	
Inner Solway	Salmon	1		<0.46	<0.13	<0.10	0.15	<0.34	

Table 3.3. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb
Isle of Man										
Isle of Man	Cod	3				<0.06	<0.15		<0.14	<0.12
Isle of Man	Herring	4				<0.10	<0.24		<0.29	<0.38
Wales										
North Anglesey	Skates / rays	4				<0.13	<0.39		<0.82	<1.9
North Anglesey	Plaice	2	<25	<25	53	<0.06	<0.18		<0.32	<0.71
Northern Ireland										
North coast	Cod	3				<0.06	<0.20		<0.33	<0.56
North coast	Saithe	1				<0.06	<0.20		<0.38	<0.75
North coast	Spurdog	4				<0.06	<0.22		<0.51	<0.48
Portrush	Spurdog	1				<0.08	<0.20		<0.19	<0.18
Portavogie	Haddock	4				<0.09	<0.31		<0.88	<0.91
Portavogie	Spurdog	3				<0.07	<0.23		<0.51	<0.48
Portavogie	Whiting	3				<0.05	<0.15		<0.29	<0.61
Ardglass	Herring	2				<0.09	<0.32		<0.96	<1.1
Kilkeel	Cod	4			50	<0.05	<0.16		<0.23	<0.36
Kilkeel	Haddock	1				<0.05	<0.17		<0.31	<0.57
Kilkeel	Whiting	3				<0.06	<0.16		<0.27	<0.53
Further afield										
Baltic Sea	Cod	4				<0.08	<0.29		<0.69	<0.35
Baltic Sea	Herring	4				<0.10	<0.36		<1.3	<0.44
Barents Sea	Cod	2				<0.06	<0.24		<0.56	<1.5
Norwegian Sea	Cod	1				<0.08	<0.30		<0.64	<1.7
Norwegian Sea	Herring	1				<0.12	<0.40		<1.0	<2.6
Norwegian Sea	Saithe	1				<0.06	<0.20		<0.52	<1.4
Norwegian Sea	Mackerel	1				<0.12	<0.35		<0.68	<1.3
Norwegian processed	Cod	2			28	<0.03	<0.09		<0.10	<0.11
Iceland area	Cod	2				<0.06	<0.20		<0.41	<0.06
Skagerrak	Cod	4				<0.06	<0.23		<0.84	*
Skagerrak	Herring	4				<0.08	<0.31		<1.1	<0.99
Northern North Sea	Cod	4				<0.06	<0.19	<0.024	<0.30	<0.51
Northern North Sea	Plaice	4				<0.07	<0.23		<0.47	<0.41
Northern North Sea	Haddock	4			19	<0.05	<0.15		<0.23	<0.34
Northern North Sea	Herring	2				<0.10	<0.29		<0.47	<0.75
Mid North Sea	Cod	4			29	<0.04	<0.12	<0.026	<0.15	<0.18
Mid North Sea	Plaice	4			28	<0.07	<0.17	<0.024	<0.20	<0.20
Gt Yarmouth (retail shop)	Cod	4				<0.05	<0.17		<0.28	<0.61
Gt Yarmouth (retail shop)	Plaice	4				<0.05	<0.15		<0.29	<0.61
Southern North Sea	Cod	2				<0.05	<0.13	<0.030	<0.17	<0.25
Southern North Sea	Sole	2				<0.11	<0.31	<0.025	<0.45	<0.64
Southern North Sea	Herring	2				<0.10	<0.30		<0.46	<0.80
English Channel-East	Cod	4				<0.07	<0.22		<0.46	<0.69
English Channel-East	Plaice	4				<0.06	<0.23		<0.52	<0.19
English Channel-West	Mackerel	4				<0.08	<0.24		<0.37	<0.65
English Channel-West	Plaice	4			18	<0.08	<0.22		<0.33	<0.51
English Channel-West	Whiting	4				<0.07	<0.22		<0.36	<0.37
Celtic Sea	Cod	4			35	<0.06	<0.19	<0.026	<0.24	<0.37
Celtic Sea	Haddock	1				<0.04	<0.14		<0.17	<0.24
Celtic Sea	Whiting	3				<0.06	<0.19		<0.39	<0.25

Table 3.3. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}				
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Isle of Man							
Isle of Man	Cod	3	<0.52	<0.14	<0.06	2.4	<0.30
Isle of Man	Herring	4	<0.86	<0.21	<0.10	0.85	<0.47
Wales							
North Anglesey	Skates / rays	4	<1.4	<0.30	<0.13	1.3	<0.66
North Anglesey	Plaice	2	<0.55	<0.13	<0.06	1.5	<0.27
Northern Ireland							
North coast	Cod	3	<0.61	<0.14	<0.07	2.2	<0.28
North coast	Saithe	1	<0.66	<0.17	<0.07	3.4	<0.45
North coast	Spurdog	4	<0.70	<0.16	<0.07	1.7	<0.40
Portrush	Spurdog	1	<0.67	<0.16	<0.08	1.2	<0.27
Portavogie	Haddock	4	<1.0	<0.23	<0.10	0.95	<0.61
Portavogie	Spurdog	3	<0.80	<0.19	<0.08	1.7	<0.49
Portavogie	Whiting	3	<0.49	<0.12	<0.05	1.4	<0.30
Ardglass	Herring	2	<1.1	<0.25	<0.10	0.86	<0.75
Kilkeel	Cod	4	<0.51	<0.12	<0.06	1.7	<0.25
Kilkeel	Haddock	1	<0.57	<0.14	<0.05	0.76	<0.39
Kilkeel	Whiting	3	<0.53	<0.13	<0.06	2.2	<0.30
Further afield							
Baltic Sea	Cod	4	<0.93	<0.24	<0.09	7.9	<0.57
Baltic Sea	Herring	4	<1.1	<0.27	<0.11	5.6	<0.70
Barents Sea	Cod	2	<0.74	<0.17	<0.08	0.24	<0.49
Norwegian Sea	Cod	1	<0.79	<0.16	<0.08	0.30	<0.35
Norwegian Sea	Herring	1	<1.2	<0.30	<0.14	0.16	<0.88
Norwegian Sea	Saithe	1	<0.65	<0.16	<0.06	0.35	<0.47
Norwegian Sea	Mackerel	1	<1.2	<0.25	<0.13	<0.12	<0.52
Norwegian processed	Cod	2	<0.30	<0.08	<0.03	0.27	<0.16
Iceland area	Cod	2	<0.57	<0.12	<0.06	0.18	<0.27
Skagerrak	Cod	4	<0.68	<0.14	<0.07	0.38	<0.44
Skagerrak	Herring	4	<1.0	<0.21	<0.09	0.47	<0.59
Northern North Sea	Cod	4	<0.60	<0.14	<0.06	0.19	<0.30
Northern North Sea	Plaice	4	<0.68	<0.14	<0.07	0.11	<0.31
Northern North Sea	Haddock	4	<0.54	<0.13	<0.06	0.15	<0.32
Northern North Sea	Herring	2	<0.98	<0.22	<0.10	<0.13	<0.47
Mid North Sea	Cod	4	<0.40	<0.10	<0.04	0.27	<0.26
Mid North Sea	Plaice	4	<0.67	<0.16	<0.07	0.15	<0.32
Gt Yarmouth (retail shop)	Cod	4	<0.55	<0.13	<0.06	0.25	<0.32
Gt Yarmouth (retail shop)	Plaice	4	<0.54	<0.13	<0.06	0.27	<0.32
Southern North Sea	Cod	2	<0.43	<0.11	<0.05	0.41	<0.25
Southern North Sea	Sole	2	<1.2	<0.25	<0.12	0.40	<0.54
Southern North Sea	Herring	2	<1.0	<0.24	<0.11	0.27	<0.58
English Channel-East	Cod	4	<0.66	<0.15	<0.07	0.19	<0.36
English Channel-East	Plaice	4	<0.68	<0.15	<0.07	0.11	<0.37
English Channel-West	Mackerel	4	<0.80	<0.20	<0.09	0.23	<0.48
English Channel-West	Plaice	4	<0.79	<0.18	<0.08	<0.11	<0.36
English Channel-West	Whiting	4	<0.69	<0.15	<0.07	0.26	<0.32
Celtic Sea	Cod	4	<0.60	<0.14	<0.07	0.53	<0.33
Celtic Sea	Haddock	1	<0.41	<0.09	<0.04	0.12	<0.19
Celtic Sea	Whiting	3	<0.59	<0.14	<0.06	0.30	<0.34

* *Not detected by the method used*

^{a} *The concentrations of ^{129}I and ^{147}Pm were <0.30 and 0.059 Bq kg^{-1} respectively*

Table 3.4. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2004

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	^{103}Ru
Cumbria													
Silloth	Mussels	4		<59		<0.08	0.86	<0.22		<0.29	<0.40		<0.32
Parton	Crabs	4				<0.13	0.97	<0.37		<1.0	<0.36		<0.26
Parton	Lobsters	4				<0.06	0.62	<0.17		<0.18	<0.21		<0.17
Parton	Winkles	4				<0.12	4.6	<0.30		<1.0	<0.30		<0.26
Whitehaven	*Nephrops*	4			120	<0.09	<0.10	<0.24	0.14	<0.25	<0.25	210	<0.21
Whitehaven	Whelks	1			82	<0.11	0.50	<0.37	0.063	<0.39	<0.48		<0.39
Saltom Bay	Winkles	4				<0.12	4.9	<0.30		<0.29	<0.29		<0.24
St Bees	Winkles[a]	4			240	<0.07	9.8	<0.23	1.9	<0.20	<0.24	190	<0.17
St Bees	Mussels	3				<0.09	4.4	<0.23		<0.33	<0.48		<0.38
St Bees	Limpets	4				<0.11	3.9	<0.29		<0.30	<0.34		<0.27
Nethertown	Winkles	12	<29	44	300	<0.14	14	<0.39	3.6	<0.42	<0.55	340	<0.39
Nethertown	Mussels	4	200	210	360	<0.10	8.4	<0.42		<0.38	<0.54	1200	<0.28
Sellafield coastal area	Crabs[b]	8			200	<0.11	3.1	<0.39	1.3	<0.56	<1.2	65	<0.75
Sellafield coastal area	Lobsters	8			400	<0.09	2.5	<0.52	0.35	<0.36	<0.63	2900	<0.41
Sellafield coastal area	*Nephrops*	1				<0.24	0.45	<0.66		<1.6	<4.0	550	<2.5
Sellafield coastal area[c]	Winkles	4			210	<0.15	8.7	<0.40	2.5	<0.49	<0.66	270	<0.47
Sellafield coastal area[c]	Mussels	5				<0.11	7.0	<0.37	1.2	<0.37	<0.49		<0.36
Sellafield coastal area[c]	Limpets	4			150	<0.11	3.2	<0.28	4.0	<0.33	<0.44	670	<0.37
Sellafield coastal area	Whelks	2			120	<0.12	2.0	<0.34	0.21	<0.48	<0.79	110	<0.52
Whitriggs	Shrimps	1				<0.23	0.38	<0.59		<0.57	<0.59		<0.46
Drigg	Winkles	4			320	<0.15	11	<0.37		<0.39	<0.50	230	<0.34
Ravenglass	Crabs	5				<0.10	1.6	<0.29	0.61	<0.45	<0.76	25	<0.53
Ravenglass	Lobsters	5				<0.15	1.0	<0.39	0.20	<1.5	<0.36	1300	<0.25
Ravenglass	Winkles	2				<0.11	5.3	<0.28		<0.27	<0.30		<0.23
Ravenglass	Cockles	4			360	<0.13	17	<0.33	1.6	<0.34	<0.35	48	<0.27
Ravenglass	Mussels	4		240		<0.10	7.0	<0.34		<0.28	<0.30	1800	<0.23
Tarn Bay	Winkles	2				<0.14	8.8	<0.36		<0.44	<0.63		<0.42
Haverigg	Cockles	2				<0.07	4.3	<0.18		<0.21	<0.20		<0.17
Millom	Mussels	2				<0.06	1.2	<0.16		<0.15	<0.16		<0.12
Barrow	Lobsters	2				<0.07	0.29	<0.20		<0.33	<0.60	820	<0.43
Morecambe Bay (Flookburgh)	Shrimps	4			130	<0.11	<0.10	<0.27		<0.49	<0.86	6.9	<0.68
Morecambe Bay (Flookburgh)	Cockles	4			120	<0.06	1.6	<0.14	0.52	<0.21	<0.29	29	<0.23
Lancashire and Merseyside													
Morecambe Bay (Morecambe)	Mussels	4	<56	<71	140	<0.06	0.62	<0.15		<0.19	<0.23	220	<0.19
Red Nab Point	Winkles	4				<0.09	0.73	<0.19		<0.28	<0.45		<0.34
Morecambe Bay (Middleton Sands)	Cockles	2				<0.06	1.3	<0.14		<0.23	<0.40		<0.31
Knott End	Cockles	1				<0.09	1.7	<0.24		<1.4	<0.55		<0.95
Fleetwood	Squid	1				<0.10	<0.07	<0.24		<0.57	<1.2		<0.82
Ribble Estuary	Shrimps	2			90	<0.06	<0.05	<0.14		<0.16	<0.18	1.5	<0.14
Ribble Estuary	Cockles	2				<0.10	0.50	<0.24		<0.40	<0.60		<0.45
Ribble Estuary	Mussels	1				<0.06	<0.06	<0.14		<0.18	<0.23		<0.19
Liverpool Bay	Mussels	2		<25									
Mersey Estuary	Mussels	2		<25									
Dee Estuary	Cockles	4				<0.05	0.17	<0.10		<0.12	<0.11	48	<0.10
Wirral	Shrimps	2		<25		<0.06	<0.06	<0.15		<0.20	<0.25	3.7	<0.20

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
Cumbria												
Silloth	Mussels	4	3.3	<0.16	0.98	<0.09	3.6	<0.43		<0.23	<0.19	
Parton	Crabs	4	<1.4	<0.40	<0.48	<0.12	1.8	<0.54		<0.34	<0.21	
Parton	Lobsters	4	<0.67	0.46	<0.33	<0.07	2.6	<0.33		<0.19	<0.15	
Parton	Winkles	4	13	<0.69	3.7	<0.11	8.7	<0.69		<0.27	<0.30	
Whitehaven	*Nephrops*	4	<0.92	<0.17	<0.27	<0.10	3.7	<0.48		<0.29	<0.23	260
Whitehaven	Whelks	1	<1.3	<0.24	<0.27	<0.11	0.52	<0.47		<0.40	<0.20	140
Saltom Bay	Winkles	4	16	0.98	6.9	<0.12	7.8	<0.58		<0.33	<0.27	
St Bees	Winkles[a]	4	25	3.0	5.5	<0.07	5.9	<0.42	1.4	<0.17	<0.13	
St Bees	Mussels	3	20	<0.18	4.3	<0.09	2.9	<0.80		<0.23	<0.27	
St Bees	Limpets	4	20	1.6	11	<0.12	9.8	<0.94		<0.32	<0.31	
Nethertown	Winkles	12	39	4.5	6.5	<0.15	10	<0.99	1.9	<0.36	<0.35	600
Nethertown	Mussels	4	43	<0.20	6.6	<0.10	3.5	1.4		<0.35	<0.29	870
Sellafield coastal area	Crabs[b]	8	<5.4	1.6	1.3	<0.10	2.3	<0.50	0.69	<0.28	<0.20	170
Sellafield coastal area	Lobsters	8	<1.9	3.8	0.95	<0.09	3.9	<0.50	0.59	<0.25	<0.19	2000
Sellafield coastal area	*Nephrops*	1	<2.3	<0.43	<0.47	<0.21	5.3	<0.80		<0.59	<0.28	
Sellafield coastal area[c]	Winkles	4	25	2.4	4.7	<0.16	4.4	<0.73	1.1	<0.36	<0.34	
Sellafield coastal area[c]	Mussels	5	28	<0.22	4.3	<0.12	3.0	<0.79		<0.28	<0.28	
Sellafield coastal area[c]	Limpets	4	18	1.8	12	<0.12	8.4	<0.79		<0.32	<0.33	
Sellafield coastal area	Whelks	2	5.5	0.90	1.1	<0.12	1.3	<0.57		<0.30	<0.26	
Whitriggs	Shrimps	1	<2.3	<0.44	<0.51	<0.24	3.9	<0.74		<0.69	<0.33	
Drigg	Winkles	4	35	4.0	5.1	<0.15	7.2	<0.88	2.1	<0.37	<0.30	450
Ravenglass	Crabs	5	<1.5	<0.77	<0.53	<0.10	1.7	<0.41		<0.26	<0.16	150
Ravenglass	Lobsters	5	<1.5	<1.4	<0.41	<0.13	2.5	<0.76		<0.35	<0.27	900
Ravenglass	Winkles	2	22	2.4	3.8	<0.12	5.3	<0.61		<0.32	<0.30	
Ravenglass	Cockles	4	23	<0.26	2.6	<0.14	6.3	<1.2		<0.51	<0.32	230
Ravenglass	Mussels	4	24	<0.19	4.1	<0.11	2.5	<0.60		<0.27	<0.24	
Tarn Bay	Winkles	2	23	1.7	3.8	<0.14	6.2	<0.67		<0.34	<0.28	
Haverigg	Cockles	2	7.0	<0.14	1.1	<0.08	3.9	<0.67		<0.25	<0.22	
Millom	Mussels	2	7.1	<0.11	1.2	<0.06	1.6	<0.32		<0.18	<0.11	
Barrow	Lobsters	2	<0.73	0.33	<0.17	<0.07	1.9	<0.30		<0.21	<0.12	560
Morecambe Bay (Flookburgh)	Shrimps	4	<1.1	<0.20	<0.32	<0.11	4.4	<0.60		<0.29	<0.26	
Morecambe Bay (Flookburgh)	Cockles	4	2.5	<0.11	0.68	<0.06	3.9	<0.29		<0.16	<0.13	
Lancashire and Merseyside												
Morecambe Bay (Morecambe)	Mussels	4	3.8	<0.11	0.97	<0.06	3.8	<0.30		<0.17	<0.14	
Red Nab Point	Winkles	4	3.1	<0.14	1.4	<0.08	4.9	<0.37		<0.20	<0.17	
Morecambe Bay (Middleton Sands)	Cockles	2	2.1	<0.10	0.66	<0.06	3.3	<0.32		<0.14	<0.15	
Knott End	Cockles	1	<1.0	<0.18	0.73	<0.09	3.3	<0.43		<0.20	<0.16	
Fleetwood	Squid	1	<0.82	<0.17	<0.19	<0.09	<0.08	<0.57		<0.24	<0.24	
Ribble Estuary	Shrimps	2	<0.53	<0.10	<0.14	<0.06	2.0	<0.29		<0.17	<0.14	
Ribble Estuary	Cockles	2	<1.2	<0.17	0.42	<0.09	2.7	<0.44		<0.24	<0.17	
Ribble Estuary	Mussels	1	<0.61	<0.10	0.28	<0.06	1.5	<0.37		<0.16	<0.18	
Dee Estuary	Cockles	4	<0.58	<0.08	0.35	<0.05	1.9	<0.27		<0.12	<0.16	
Wirral	Shrimps	2	<0.57	<0.11	<0.15	<0.06	2.0	<0.28		<0.17	<0.13	

Table 3.4. continued

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	^{103}Ru
Scotland													
Lewis	*Nephrops*	1				<0.10	<0.10	<0.14		<0.25	<0.43		
Skye	Lobster	1				<0.10	<0.10	<0.10		<0.17	<0.34		
Skye	Mussels	1				<0.10	<0.10	<0.10		<0.10	<0.10		
Islay	Crabs	1				<0.10	<0.10	<0.17		<0.20	<0.22		
Kirkcudbright	Scallops	6[F,S]				<0.06	<0.06	<0.13		<0.18	<0.26		<0.24
Kirkcudbright	Queens	8[F,S]				<0.07	<0.08	<0.10		<0.12	<0.14		<0.09
Southerness	Winkles	4		<8.7		<0.14	1.6	<0.31	0.47	<0.40	<0.62	180	
North Solway coast	Crabs	8[F,S]			130	<0.11	0.45	<0.24	0.34	<0.34	<0.39	14	<0.26
North Solway coast	Lobsters	8[F,S]			110	<0.10	<0.20	<0.21	0.15	<0.26	<0.32	560	<0.30
North Solway coast	Winkles	8[F,S]				<0.14	1.5	<0.36	0.25	<0.48	<0.55	260	<0.32
North Solway coast	Cockles	7[F,S]		<8.6	99	<0.07	1.6	<0.12	0.48	<0.19	<0.24	18	<0.24
North Solway coast	Mussels	8[F,S]		<9.8	91	<0.07	0.55	<0.15	0.60	<0.20	<0.26	240	<0.22
Inner Solway	Shrimps	4		<6.9		<0.11	<0.10	<0.23	0.10	<0.35	<0.53	1.2	
Isle of Man													
Isle of Man	Lobsters	4				<0.05	<0.05	<0.13		<0.17	<0.22	180	<0.18
Isle of Man	Scallops	4				<0.08	<0.07	<0.21		<0.42	<0.83		<0.56
Wales													
Conwy	Mussels	2			51	<0.05	<0.05	<0.12		<0.16	<0.20		<0.15
North Anglesey	Crabs	2				<0.05	<0.05	<0.12		<0.11	<0.10	1.8	<0.09
North Anglesey	Lobsters	2				<0.04	<0.04	<0.11		<0.21	<0.41	180	<0.32
Northern Ireland													
Ballycastle	Lobsters	4				<0.11	<0.10	<0.28		<0.56	<1.1	91	<0.82
County Down	Clams	4				<0.18	<0.18	<0.50		<0.77	<1.3		<0.91
Ards Peninsula	Winkles	4				<0.13	<0.14	<0.34		<0.45	<0.52		<0.41
Portavogie	*Nephrops*	4				<0.07	<0.07	<0.21		<0.31	<0.46	54	<0.34
Kilkeel	Crabs	3				<0.11	<0.09	<0.28		<0.68	<0.37		<0.68
Kilkeel	Lobsters	4				<0.13	<0.12	<0.34		<0.68	<1.4	160	<0.93
Kilkeel	*Nephrops*	4				<0.19	<0.17	<0.53		<1.4	<1.6		<0.99
Carlingford Lough	Mussels	2				<0.15	<0.13	<0.37		<0.80	<1.6	20	<1.1
Western Irish Sea	Scallops	2				<0.04	<0.04	<0.11		<0.15	<0.21		<0.16
Further afield													
Northern North Sea	*Nephrops*	4				<0.09	<0.08	<0.23		<0.39	<0.67	8.9	<0.47
Cromer	Crabs	1				<0.06	<0.06	<0.15		<0.16	<0.14		<0.11
The Wash	Mussels	2				<0.10	<0.09	<0.24		<0.34	<0.47		<0.36
Southern North Sea	Cockles	2				<0.05	<0.07	<0.14		<0.22	<0.39		<0.27
Southern North Sea	Mussels	4				<0.10	<0.10	<0.26		<0.48	<0.92	2.8	<0.62
Southern North Sea	Cockles[d]	2				<0.10	<0.14	<0.25		<0.30	<0.34	0.082	<0.27
Southern North Sea	Mussels[d]	2				<0.06	<0.05	<0.13		<0.41	<0.04		<0.77
English Channel-East	Scallops	4			31	<0.07	<0.08	<0.21		<0.36	<0.62		<0.45
English Channel-West	Crabs	4			31	<0.07	<0.07	<0.19		<0.37	<0.78		<0.50
English Channel-West	Lobsters	4				<0.07	<0.06	<0.16		<0.29	<0.24	0.50	<0.45
English Channel-West	Scallops	4			25	<0.05	<0.05	<0.14		<0.20	<0.31		<0.24

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
Scotland											
Lewis	*Nephrops*	1	<0.38	<0.10	<0.10	<0.10	0.19	<0.28	<0.10	<0.11	
Skye	Lobster	1	<0.25	<0.10	<0.10	<010	0.15	<0.17	<0.10	<0.10	
Skye	Mussels	1	<0.18	<0.10	<0.10	<0.10	<0.10	<0.13	<0.10	<0.10	
Islay	Crabs	1	<0.55	<0.10	<0.15	<0.10	0.21	<0.38	<0.10	<0.18	
Kirkcudbright	Scallops	6[F,S]	<0.43	<0.09	<0.11	<0.06	<0.16	<0.28	<0.12	<0.13	
Kirkcudbright	Queens	8[F,S]	<0.34	<0.08	<0.10	<0.07	<0.20	<0.22	<0.10	<0.11	
Southerness	Winkles	4	4.6	<0.30	2.0	<0.14	1.5	<0.75	<0.17	<0.29	
North Solway coast	Crabs	8[F,S]	<0.97	<0.16	<0.29	<0.11	1.2	<0.57	<0.19	<0.25	
North Solway coast	Lobsters	8[F,S]	<0.72	<0.15	<0.20	<0.10	1.8	<0.43	<0.19	<0.20	
North Solway coast	Winkles	8[F,S]	<3.6	<0.27	<1.5	<0.14	1.2	<0.77	<0.24	<0.33	
North Solway coast	Cockles	7[F,S]	<1.4	<0.10	<0.58	<0.08	3.6	<0.30	<0.13	<0.14	
North Solway coast	Mussels	8[F,S]	<1.6	<0.11	0.74	<0.08	2.3	<0.29	<0.13	<0.13	
Inner Solway	Shrimps	4	<0.77	<0.14	<0.22	<0.10	3.5	<0.52	<0.13	<0.21	
Isle of Man											
Isle of Man	Lobsters	4	<0.47	<0.09	<0.12	<0.05	0.40	<0.28	<0.15	<0.13	170
Isle of Man	Scallops	4	<0.70	<0.15	<0.16	<0.07	0.41	<0.34	<0.21	<0.13	
Wales											
Conwy	Mussels	2	<0.47	<0.09	<0.11	<0.05	0.23	<0.23	<0.13	<0.10	
North Anglesey	Crabs	2	<0.43	<0.09	<0.11	<0.05	0.44	<0.20	<0.16	<0.09	
North Anglesey	Lobsters	2	<0.39	<0.08	<0.10	<0.04	0.54	<0.24	<0.12	<0.10	200
Northern Ireland											
Ballycastle	Lobsters	4	<1.1	<0.20	<0.24	<0.10	0.18	<0.57	<0.29	<0.22	
County Down	Clams	4	<1.8	<0.32	<0.35	<0.17	0.45	<0.66	<0.52	<0.25	
Ards Peninsula	Winkles	4	<1.4	<0.24	<0.43	<0.14	0.38	<0.60	<0.40	<0.26	
Portavogie	*Nephrops*	4	<0.72	<0.14	<0.16	<0.08	0.92	<0.33	<0.22	<0.14	
Kilkeel	Crabs	3	<1.1	<0.21	<0.25	<0.10	0.27	<0.63	<0.26	<0.25	
Kilkeel	Lobsters	4	<1.3	<0.24	<0.27	<0.12	0.30	<0.59	<0.34	<0.25	
Kilkeel	*Nephrops*	4	<2.0	<0.36	<0.40	<0.18	0.74	<0.99	<0.48	<0.36	
Carlingford Lough	Mussels	2	<1.5	<0.28	<0.31	<0.14	0.78	<0.64	<0.35	<0.25	
Western Irish Sea	Scallops	2	<0.37	<0.08	<0.09	<0.04	0.28	<0.20	<0.12	<0.09	
Further afield											
Northern North Sea	*Nephrops*	4	<0.86	<0.16	<0.19	<0.08	<0.12	<0.44	<0.25	<0.19	
Cromer	Crabs	1	<0.58	<0.11	<0.15	<0.07	<0.06	<0.29	<0.19	<0.15	
The Wash	Mussels	2	<1.0	<0.17	<0.22	<0.09	0.27	<0.39	<0.26	<0.15	
Southern North Sea	Cockles	2	<0.47	<0.09	<0.11	<0.05	0.18	<0.29	<0.15	<0.13	
Southern North Sea	Mussels	4	<1.0	<0.19	<0.21	<0.10	<0.14	<0.44	<0.26	<0.17	
Southern North Sea	Cockles[d]	2	<0.99	<0.18	<0.24	<0.11	0.15	<0.41	<0.30	<0.18	
Southern North Sea	Mussels[d]	2	<0.52	<0.11	<0.12	<0.05	<0.04	<0.28	<0.14	<0.11	22
English Channel-East	Scallops	4	<0.67	<0.15	<0.16	<0.07	<0.07	<0.42	<0.22	<0.19	
English Channel-West	Crabs	4	<0.65	<0.13	<0.15	<0.07	<0.06	<0.37	<0.20	<0.16	
English Channel-West	Lobsters	4	<0.61	<0.12	<0.15	<0.06	<0.06	<0.36	<0.19	<0.15	
English Channel-West	Scallops	4	<0.49	<0.10	<0.12	<0.05	<0.05	<0.30	<0.16	<0.14	

[a] The concentration of ^{129}I was <0.47 Bq kg^{-1}
[b] The concentration of ^{129}I was <0.30 Bq kg^{-1}
[c] Samples collected by Consumer 971
[d] Landed in Holland or Denmark
[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, 2004

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
Cumbria									
Silloth	Mussels	1		0.82	4.4		7.8	*	0.012
River Derwent	Sea trout	1					<0.07		
Parton	Cod	4					<0.30		
Parton	Crabs	4					1.2		
Parton	Lobsters	4					1.5		
Parton	Winkles	1		1.6	8.0	74	14	*	0.014
Whitehaven	Cod	1		0.00045	0.0022		0.0047	*	0.000014
Whitehaven	Plaice	1		0.0017	0.0086		0.017	*	*
Whitehaven	Skates/rays	1		0.00099	0.0043		0.0066	*	0.000017
Whitehaven	*Nephrops*	1		0.024	0.12		0.43	*	*
Whitehaven	Whelks	1		0.053	0.27	2.6	0.31	*	0.00087
Saltom Bay	Winkles	4					14		
St Bees	Winkles	1	0.020	1.9	9.4	88	18	0.026	0.028
St Bees	Mussels	2		1.5	7.0	78	15	<0.012	0.033
St Bees	Limpets	1		3.0	15		27	0.059	0.044
Nethertown	Winkles	4	0.0084	2.7	13	130	24	<0.013	0.041
Nethertown	Mussels	4		2.3	11		21	<0.040	0.070
River Ehen	Salmon	1					<0.42		
River Ehen	Sea trout	1					<0.51		
River Calder	Brown trout	1					<0.52		
Calder Pond	Rainbow trout	1					<0.20		
Sellafield coastal area	Cod	2		0.00053	0.0022		0.0043	*	0.000016
Sellafield coastal area	Plaice	1		0.0059	0.029		0.052	0.000053	0.000045
Sellafield coastal area	Bass	1					<0.10		
Sellafield coastal area	Mullet	1					<0.40		
Sellafield coastal area	Crabs	2	0.0040	0.12	0.53	5.8	2.0	0.0043	0.0075
Sellafield coastal area	Lobsters	2	0.013	0.080	0.31	4.8	4.3	*	0.011
Sellafield coastal area	*Nephrops*	1		0.047	0.22		2.2	0.0035	0.0023
Sellafield coastal area[a]	Winkles	1	0.017	1.3	5.9	60	12	0.030	0.022
Sellafield coastal area[a]	Mussels	1		2.0	9.6	100	20	*	0.029
Sellafield coastal area[a]	Limpets	1		1.6	7.8	81	16	*	0.041
Sellafield coastal area	Whelks	1		0.48	2.3	23	4.9	0.011	0.0067
Whitriggs	Shrimps	1					<0.17		
Sellafield offshore area	Plaice	1	0.00027	0.0065	0.032		0.057	*	0.000075
Sellafield offshore area	Dab	1					<0.22		
Sellafield offshore area	Red gurnard	1					<1.2		
Sellafield offshore area	Lesser spotted dogfish	1					<0.23		
Sellafield offshore area	Skates/rays	1					<0.13		
Drigg	Winkles	1	0.021	2.7	13	130	26	0.031	0.047
Ravenglass	Cod	1		0.0015	0.0072		0.014	0.000018	0.000045
Ravenglass	Plaice	1		0.011	0.053		0.091	0.00011	0.00025
Ravenglass	Pollack	1					<0.26		
Ravenglass	Crabs	1		0.055	0.27	2.6	1.2	*	0.0024
Ravenglass	Lobsters	1		0.048	0.22	2.5	3.3	0.0060	0.0040
Ravenglass	Winkles	2					17		
Ravenglass	Cockles	1		2.7	12	120	32	0.040	0.052
Ravenglass	Mussels	1		1.5	7.1	76	15	*	0.037
Tarn Bay	Winkles	1		1.7	8.6	86	18	*	0.027
Haverigg	Cockles	1		1.1	5.9		18	*	0.023
Millom	Mussels	2					5.1		
Barrow	Lobsters	2					0.85		
Morecambe Bay (Flookburgh)	Flounder	1		0.00043	0.0028		0.0056	*	*
Morecambe Bay (Flookburgh)	Shrimps	1		0.0042	0.024	0.16	0.040	*	0.000050
Morecambe Bay (Flookburgh)	Cockles	1		0.40	2.2	18	5.9	*	0.011

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	$^{243}Cm+^{244}Cm$
Lancashire and Merseyside								
Morecambe Bay (Morecambe)	Plaice	4				<0.34		
Morecambe Bay (Morecambe)	Bass	2				<0.35		
Morecambe Bay (Morecambe)	Mussels	1	0.42	2.5		4.5	*	0.0060
Red Nab Point	Winkles	1	0.37	1.9		3.6	0.010	0.0075
Morecambe Bay (Middleton Sands)	Cockles	1	0.36	2.0		5.7	*	0.0070
Morecambe Bay (Sunderland Point)	Whitebait	1	0.090	0.54	6.5	0.81	0.0046	0.0020
Knott End	Cockles	1	0.41	2.2		6.4	*	0.0084
Fleetwood	Cod	1	0.00059	0.0027		0.0047	*	0.000011
Fleetwood	Plaice	1	0.00045	0.0024		0.0042	0.000013	*
Fleetwood	Squid	1				<0.36		
Ribble Link	Brown trout	1				<0.09		
Ribble Estuary	Flounder	1				<0.13		
Ribble Estuary	Salmon	1				<0.29		
Ribble Estuary	Sea trout	1				<0.37		
Ribble Estuary	Shrimps[b]	1	0.0038	0.019		0.036	0.000098	0.000074
Ribble Estuary	Cockles	1	0.28	1.5		4.4	*	0.0057
Ribble Estuary	Mussels	1				1.4		
Dee Estuary	Cockles	1	0.16	0.92		2.4	*	0.0038
Wirral	Shrimps	2				<0.12		
Scotland								
Shetland	Fish meal	1	0.000089	0.00078		0.00063	*	*
Shetland	Fish oil	4				<0.19		
Minch	Herring	2				<0.23		
Minch	Mackerel	1	<0.000022	0.000077		0.000031	*	*
West of Scotland	Mackerel	2				<0.31		
West of Scotland	Farmed salmon	1				<0.26		
Lewis	*Nephrops*	1				<0.10		
Skye	Lobster	1				<0.10		
Skye	Mussels	1				<0.10		
Islay	Crabs	1				<0.18		
Kirkcudbright	Scallops	2[F,S]	0.0024	0.014		0.032	*	*
Kirkcudbright	Queens	2[F,S]	0.016	0.090		0.015	<0.00014	<0.00016
Southerness	Winkles	1	0.18	1.0		2.1	<0.0020	<0.0020
North Solway coast	Crabs	2[F,S]	0.062	0.33	2.9	0.88	*	0.00069
North Solway coast	Lobsters	2[F,S]	0.017	0.085	0.83	0.79	*	0.0013
North Solway coast	Winkles	2[F,S]	0.19	1.0	9.1	2.7	0.0029	0.0037
North Solway coast	Cockles	5[F,S]	0.72	3.9	32	9.8	*	0.016
North Solway coast	Mussels	2[F,S]	0.62	3.2	26	5.4	*	0.0063
Inner Solway	Plaice	3				<0.14		
Inner Solway	Flounder	1	0.0052	0.021		0.037	<0.0013	<0.0013
Inner Solway	Lemon sole	1				<0.13		
Inner Solway	Salmon	1				<0.16		
Inner Solway	Shrimps	1	0.0033	0.020		0.039	<0.00057	<0.00057
Isle of Man								
Isle of Man	Cod	1	0.000053	0.00023		0.00061	*	*
Isle of Man	Herring	1	0.000045	0.00023		0.00036	*	*
Isle of Man	Lobsters	4				<0.14		
Isle of Man	Scallops	1	0.014	0.082		0.044	*	0.000061
Wales								
Conwy	Mussels	1	0.020	0.12		0.21	0.00024	0.00039
North Anglesey	Skates/rays	1	0.00026	0.0015		0.0017	*	*
North Anglesey	Plaice	2				<0.06		
North Anglesey	Crabs	1	0.0024	0.014		0.041	*	0.000095
North Anglesey	Lobsters	2				<0.08		

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}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Northern Ireland							
North coast	Cod	3			<0.07		
North coast	Saithe	1			<0.18		
North coast	Spurdog	4			<0.12		
Portrush	Spurdog	1			<0.07		
Ballycastle	Lobsters	4			<0.19		
County Down	Clams	4			<0.15		
Ards Peninsula	Winkles	1	0.035	0.19	0.21	*	0.00021
Portavogie	Haddock	4			<0.24		
Portavogie	Whiting	1	0.000059	0.00028	0.00043	*	*
Portavogie	Spurdog	3			<0.16		
Portavogie	*Nephrops*	1	0.0061	0.037	0.14	*	0.00023
Ardglass	Herring	2			<0.33		
Kilkeel	Cod	4			<0.10		
Kilkeel	Haddock	1			<0.15		
Kilkeel	Whiting	3			<0.12		
Kilkeel	Crabs	3			<0.26		
Kilkeel	Lobsters	4			<0.29		
Kilkeel	*Nephrops*	4			<0.40		
Carlingford Lough	Mussels	2			<0.21		
Western Irish Sea	Scallops	2			<0.12		
Further afield							
Baltic Sea	Cod	4			<0.30		
Baltic Sea	Herring	4			<0.30		
Barents Sea	Cod	2			<0.30		
Norwegian Sea	Cod	1			<0.08		
Norwegian Sea	Herring	1			<0.53		
Norwegian Sea	Saithe	1			<0.16		
Norwegian Sea	Mackerel	1			<0.11		
Norwegian processed	Cod	1	0.000012	0.00011	0.00020	*	*
Iceland area	Cod	2			<0.10		
Skagerrak	Cod	4			<0.21		
Skagerrak	Herring	4			<0.20		
Northern North Sea	Cod	1	0.0000079	0.000028	0.000059	*	*
Northern North Sea	Plaice	4			<0.09		
Northern North Sea	Haddock	1	0.000010	0.000091	0.00011	*	*
Northern North Sea	Herring	2			<0.18		
Northern North Sea	*Nephrops*	1	0.00022	0.0020	0.0026	*	0.000014
Mid North Sea	Cod	4			<0.16		
Mid North Sea	Plaice	4			<0.14		
The Wash	Mussels	2			<0.07		
Cromer	Crabs	1			<0.19		
Gt Yarmouth (retail shop)	Cod	4			<0.17		
Gt Yarmouth (retail shop)	Plaice	4			<0.18		
Southern North Sea	Cod	2			<0.14		
Southern North Sea	Sole	2			<0.28		
Southern North Sea	Herring	2			<0.31		
Southern North Sea	Cockles	1	0.00087	0.0055	0.0071	0.000077	0.00050
Southern North Sea	Mussels[c]	1	0.00042	0.0021	0.0031	*	*
Southern North Sea	Cockles[d]	1	0.00079	0.0064	0.0042	0.000021	0.00014
Southern North Sea	Mussels	1	0.0026	0.019	0.0069	*	*
English Channel-East	Cod	4			<0.18		
English Channel-East	Plaice	4			<0.13		
English Channel-East	Scallops	1	0.00058	0.0027	0.0010	*	0.000053
English Channel-West	Mackerel	4			<0.28		
English Channel-West	Plaice	4			<0.14		
English Channel-West	Whiting	4			<0.11		
English Channel-West	Crabs	1	0.000080	0.00098	0.00093	*	0.000087
English Channel-West	Lobsters	4			<0.13		
English Channel-West	Scallops	1	0.00017	0.0031	0.00069	*	*
Celtic Sea	Cod	4			<0.17		
Celtic Sea	Haddock	1			<0.05		
Celtic Sea	Whiting	3			<0.17		

* *Not detected by the method used*
[a] *Samples collected by consumer 971*
[b] *The concentration of ^{237}Np was 0.000057 Bq kg^{-1}*
[c] *Landed in Holland or Denmark*
[d] *Landed in Holland*
[F,S] *Samples collected on behalf of Food Standards Agency and SEPA*

Table 3.6. Individual radiation exposures, Sellafield, 2004

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 (2000-04)[d]	0.63[f]	0.19	0.41	-	0.022	-	-
Local seafood consumers (2004)[d]	0.83[e]	0.25	0.56	-	0.022	-	-
Whitehaven seafood consumers	0.013	0.013	-	-	-	-	-
Dumfries and Galloway seafood consumers	0.038	0.018	-	-	0.020	-	-
Morecambe Bay seafood consumers	0.068	0.048	-	-	0.020	-	-
Fleetwood seafood consumers	0.018	0.018	-	-	-	-	-
Isle of Man seafood consumers	0.007	0.007	-	-	-	-	-
Northern Ireland seafood consumers	0.010	0.008	-	-	<0.005	-	-
North wales seafood consumers	0.012	0.008	-	-	<0.005	-	-
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-
Other groups							
Ravenglass estuary, recreational use	0.030	-	-	-	0.026	<0.005	-
Ravenglass estuary, nature warden	0.039	-	-	-	0.034	<0.005	-
Fishermen handling nets or pots[c]	0.080	-	-	-	0.080	-	-
Bait diggers and shellfish[c] collectors	0.24	-	-	-	0.24	-	-
Ribble estuary houseboats	0.058	-	-	-	0.055	<0.005	-
Average beach occupancy in Cumbria	<0.005	-	-	-	<0.005	-	-
Local consumers at Ravenglass[b]	0.022	-	-	0.022	-	-	-
Local consumers of vegetables grown on land with seaweed added[b]	0.015	-	-	0.015	-	-	-
Consumers of laverbread in South Wales	<0.005	-	-	<0.005	-	-	-
Inhabitants and consumers of locally grown food[b]	0.036	-	-	0.035	-	-	<0.005
Average consumer of locally grown food	0.011	-	-	0.011	-	-	-

[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 2004 and a five year period, 2000 - 2004. Includes the effects of discharges from adjacent industrial site at Whitehaven*
[e] *The total dose due to nuclear industry discharges was 0.27 mSv*
[f] *The total dose due to nuclear industry discharges was 0.22 mSv*

Table 3.7. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2004

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, µGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Salt marsh	4[F]	0.071
Rockcliffe Marsh	Salt marsh and mud	1	0.076
Burgh Marsh	Grass and mud	1	0.073
Burgh Marsh	Grass and Salt marsh	1	0.071
Port Carlisle 1	Grass and mud	3	0.090
Port Carlisle 1	Grass and Salt marsh	1	0.087
Port Carlisle 2	Grass	3	0.10
Port Carlisle 2	Grass and mud	1	0.098
Greenend 1	Grass and mud	2	0.086
Greenend 1	Grass and Salt marsh	1	0.087
Greenend 1	Grass and sand	1	0.089
Greenend 2	Salt marsh	1	0.081
Greenend 2	Grass and mud	1	0.089
Greenend 2	Mud and pebbles	1	0.092
Greenend 2	Grass and Salt marsh	1	0.083
Greenend 3	Salt marsh	1	0.083
Greenend 3	Salt marsh and mud	1	0.090
Greenend 3	Grass and mud	1	0.086
Greenend 3	Grass and Salt marsh	1	0.082
Cardurnock Marsh	Salt marsh	1	0.076
Cardurnock Marsh	Grass	2	0.079
Cardurnock Marsh	Grass and Salt marsh	1	0.075
Newton Arlosh	Salt marsh	4[F]	0.10
Newton Arlosh	Grass and mud	3	0.090
Newton Arlosh	Grass	1	0.096
Silloth harbour	Mud and sand	3	0.095
Silloth silt pond	Grass	1	0.074
Silloth silt pond	Grass and sand	3	0.079
Allonby	Sand and stones	1	0.099
Allonby	Pebbles and sand	3	0.099
Maryport harbour	Sand	1	0.095
Maryport harbour	Pebbles and sand	1	0.097
Parton	Winkle bed	4[F]	0.082
Workington harbour	Pebbles and sand	2	0.099
Harrington harbour	Mud and sand	1	0.12
Harrington harbour	Sand and stones	1	0.10
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Mud and sand	12[F]	0.082
Whitehaven - outer harbour	Coal and sand	12[F]	0.12
Whitehaven - outer harbour	Sand	1	0.11
Whitehaven - outer harbour	Pebbles and sand	2	0.11
Whitehaven - outer harbour	NA	1	0.11
Whitehaven - yacht basin	Mud	1[F]	0.14
Saltom Bay	Winkle bed	4[F]	0.096
St Bees	Sand	4[F]	0.068
St Bees	Sand	4	0.084
Nethertown	Winkle bed	4[F]	0.089
Nethertown beach	Pebbles and rock	1	0.089
Nethertown beach	Rock and stones	1	0.083
Braystones	Pebbles and sand	1	0.10
Braystones	Pebbles and stones	1	0.11
Sellafield	Sand	4[F]	0.078
Sellafield beach	Sand	1	0.094
Sellafield beach	Pebbles and sand	1	0.093
Sellafield beach	Grass and sand	2	0.094
Pipeline on foreshore	Sand	1	0.12
Pipeline on foreshore	Pebbles and sand	1	0.10
Ehen Spit seashore	Sand	2	0.089
River Calder downstream of factory sewer	Pebbles and sand	1	0.13
River Calder downstream of factory sewer	Pebbles and stones	1	0.13
River Calder upstream of factory sewer	Grass	2	0.098
Seascale	Sand	4	0.080
Seascale	Grass	4	0.084
Drigg Barn Scar	Mussel bed	4[F]	0.083

Table 3.7. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, µGy h^{-1}
Cumbria, Ravenglass-Askam			
Ravenglass - Carleton Marsh	Salt marsh	4^F	0.17
Ravenglass - Carleton Marsh	Salt marsh	1	0.18
Ravenglass - Carleton Marsh	Grass and mud	2	0.16
Ravenglass - Carleton Marsh	Salt marsh and mud	1	0.13
Ravenglass - River Mite estuary	Salt marsh and mud	1	0.14
Ravenglass - River Mite estuary	Salt marsh	1	0.19
Ravenglass - River Mite estuary	Grass and mud	2	0.17
Ravenglass - Raven Villa	Mud	8^F	0.10
Ravenglass - Raven Villa	Mud and sand	4^F	0.11
Ravenglass - Raven Villa	Salt marsh	12^F	0.15
Ravenglass - Raven Villa	Salt marsh	3	0.16
Ravenglass - Raven Villa	Salt marsh and mud	1	0.16
Ravenglass - boat area	Mud and sand	2	0.10
Ravenglass - boat area	Mud and pebbles	2	0.10
Ravenglass - ford	Mud	2	0.12
Ravenglass - ford	Mud and sand	4^F	0.092
Ravenglass - ford	Mud and sand	2	0.11
Muncaster Bridge	Grass and mud	3	0.13
Muncaster Bridge	Grass	1	0.14
Ravenglass - salmon garth	Mud, sand and stones	4^F	0.10
Ravenglass - salmon garth	Sand and stones	4^F	0.086
Ravenglass - salmon garth	Mussel bed	4^F	0.082
Ravenglass - salmon garth	Mud and shingle	1	0.12
Ravenglass - salmon garth	Mud and pebbles	2	0.10
Ravenglass - salmon garth	Pebbles and stones	1	0.099
Ravenglass - Eskmeals Nature Reserve	Salt marsh	1	0.15
Ravenglass - Eskmeals Nature Reserve	Salt marsh and mud	1	0.16
Ravenglass - Eskmeals Nature Reserve	Grass and mud	2	0.16
Newbiggin/Eskmeals viaduct	Mud	1	0.13
Newbiggin/Eskmeals viaduct	Grass and mud	1	0.18
Newbiggin/Eskmeals viaduct	Salt marsh and mud	2	0.18
Newbiggin/Eskmeals small bridge	Salt marsh	3	0.18
Newbiggin/Eskmeals small bridge	Salt marsh and mud	1	0.19
Tarn Bay	Sand	2^F	0.061
Tarn Bay	Winkle bed	2^F	0.085
Tarn Bay	Pebbles and sand	1	0.099
Tarn Bay	Pebbles and stones	1	0.12
Silecroft	Pebbles and sand	1	0.12
Silecroft	Pebbles and stones	1	0.11
Haverigg	Mud	4^F	0.87
Haverigg	Sand	4^F	0.063
Haverigg	Sand	2	0.080
Millom	Mud and sand	4^F	0.086
Millom	Mud and sand	1	0.12
Millom	Grass and mud	1	0.099
Low Shaw	Grass and mud	2	0.086
Askam	Sand	2	0.081
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud and pebbles	2	0.097
Walney Channel, S of discharge point	Mud	2	0.093
Tummer Hill Marsh	Salt marsh	2	0.14
Roa Island	Pebbles and sand	1	0.099
Roa Island	Pebbles and stones	1	0.096
Greenodd	Salt marsh	2	0.078
Sand Gate Marsh	Salt marsh	4^F	0.085
Sand Gate Marsh	Salt marsh	3	0.091
Sand Gate Marsh	Salt marsh and mud	1	0.092
Flookburgh	Mud and sand	4^F	0.093
Flookburgh	Salt marsh	1	0.097
High Foulshaw	Salt marsh	4^F	0.079
High Foulshaw	Salt marsh	2	0.080
High Foulshaw	Grass and Salt marsh	2	0.081
Arnside	Salt marsh	4^F	0.087
Arnside 1	Mud	1	0.078
Arnside 1	Mud and sand	2	0.076
Arnside 1	Pebbles and sand	1	0.075
Arnside 2	Salt marsh	2	0.099
Arnside 2	Salt marsh and mud	1	0.10
Arnside 2	Grass and Salt marsh	1	0.098

Table 3.7. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, $\mu Gy\ h^{-1}$
Lancashire and Merseyside			
Morecambe Central Pier	Mussel bed	4^F	0.073
Morecambe Central Pier	Mud and sand	4^F	0.074
Morecambe Central Pier	Pebbles and sand	1	0.080
Morecambe Central Pier	Rock and sand	1	0.081
Half Moon Bay	Mud and sand	4^F	0.074
Half Moon Bay	Sand and stones	1	0.072
Half Moon Bay	Pebbles and sand	1	0.069
Middleton Sands	Sand	1	0.074
Middleton Sands	Pebbles and sand	1	0.067
Sunderland Point	Mud	3	0.088
Sunderland Point	Mud and sand	1	0.095
Sunderland	Mud	3	0.090
Sunderland	Mud and sand	1	0.094
Colloway Marsh	Salt marsh	4^F	0.13
Colloway Marsh	Salt marsh	2	0.089
Colloway Marsh	Grass and Salt marsh	2	0.10
Lancaster	Grass and mud	1	0.078
Lancaster	Grass	3	0.079
Aldcliffe Marsh	Salt marsh	4^F	0.093
Aldcliffe Marsh	Grass and Salt marsh	4	0.10
Conder Green	Mud and sand	4^F	0.091
Conder Green	Salt marsh	4^F	0.10
Conder Green	Grass and mud	4	0.091
Cockerham Marsh	Salt marsh	4^F	0.010
Cockerham Marsh	Salt marsh	3	0.098
Cockerham Marsh	Grass and Salt marsh	1	0.097
Knott End	Mud and sand	2^F	0.076
Heads - River Wyre	Salt marsh	2^F	0.098
Heads - River Wyre	Grass and mud	2	0.10
Heads - River Wyre	Grass and Salt marsh	2	0.10
Height o’ th’ hill - River Wyre	Salt marsh	4^F	0.10
Height o’ th’ hill - River Wyre	Grass and Salt marsh	4	0.11
Hambleton	Grass and mud	4	0.11
Skippool Creek 1	Grass and mud	4	0.12
Skippool Creek 2	Mud	2	0.11
Skippool Creek 2	Grass and mud	2	0.10
Skippool Creek 3	Wood	3	0.11
Skippool Creek boat 2 (boat cabin)	Wood	4	0.092
Skippool Creek boat 2 (mud)	Mud	1	0.10
Skippool Creek boat 2 (mud)	Grass and mud	3	0.10
Fleetwood shore 1	Sand	4	0.076
Fleetwood shore 2	Salt marsh	4	0.14
Blackpool	Sand	4	0.061
Crossens Marsh	Salt marsh	2	0.089
Crossens Marsh	Salt marsh and mud	1	0.088
Crossens Marsh	Salt marsh and sand	1	0.088
Ainsdale	Sand	4	0.063
Rock Ferry	Mud and sand	2	0.084
Rock Ferry	Sand	2	0.079
New Brighton	Mud and sand	1	0.075
New Brighton	Sand	3	0.062
West Kirby	Mud	3	0.069
West Kirby	Sand	1	0.067
Little Neston Marsh 1	Salt marsh and mud	1	0.12
Little Neston Marsh 2	Salt marsh	2	0.089
Flint 1	Mud	2	0.095
Flint 2	Salt marsh	2	0.091
Scotland			
Piltanton Burn	Salt marsh	4	<0.054
Garlieston	Mud	4	<0.054
Innerwell	Mud	4^F	0.078
Innerwell	Mud	4	0.077
Bladnoch	Mud	4	0.086
Creetown	Salt marsh	4	0.076
Carsluith	Mud	4	0.076
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.079
Cumstoun	Salt marsh	4	0.069
Kirkcudbright	Salt marsh	4	0.076
Cutters Pool	Winkle bed	4^F	0.086
Cutters Pool	Winkle bed	4	0.091
Rascarrel Bay	Winkle bed	4^F	0.11
Rascarrel Bay	Winkle bed	4	0.12

Table 3.7. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, $\mu Gy\ h^{-1}$
Scotland (cont.)			
Gardenburn	Salt marsh	4	0.094
Palnackie Harbour	Mud	4	0.090
Kippford - Slipway	Mud	4	0.10
Kippford - Merse	Salt marsh	4	0.11
Southerness	Winkle bed	4	0.073
Carsethorn	Mud	4	0.078
Glencaple Harbour	Mud and sand	4	0.086
Isle of Man			
Ramsey	Pebbles and seaweed	1	0.087
Wales			
Prestatyn	Sand	2	0.058
Rhyl	Mud	2	0.076
Llandudno	Pebbles and sand	2	0.089
Caerhun	Salt marsh	1	0.090
Caerhun	Salt marsh and mud	1	0.080
Llanfairfechan	Salt marsh and sand	1	0.082
Llanfairfechan	Grass and mud	1	0.072
Northern Ireland			
Lishally	Mud	1	0.079
Eglington	Shingle	1	0.066
Bellerena	Mud	2	0.065
Carrichue House	Mud	1	0.061
Benone	Sand	2	0.071
Castlerock	Sand	2	0.067
Portstewart	Sand	2	0.064
Blue Pool	Sand	1	0.073
White Rocks	Sand	1	0.073
Port-Ballintrae	Sand	1	0.066
Giant's Causeway	Sand	1	0.066
Ballycastle	Sand	1	0.065
Cushendun	Sand	1	0.066
Cushendall	Sand and stones	1	0.071
Red Bay	Sand	1	0.069
Carnlough	Sand	1	0.067
Glenarm	Sand	1	0.062
Half Way House	Sand	1	0.064
Ballygally	Sand	1	0.065
Drains Bay	Sand	1	0.062
Larne	Sand	1	0.066
Whitehead	Sand	1	0.067
Carrickfergus	Sand	1	0.063
Belfast Lough	Sand	1	0.064
Helen's Bay	Sand	1	0.075
Groomsport	Sand	1	0.075
Millisle	Sand	1	0.077
Ballywalter	Sand	1	0.077
Ballyhalbert	Sand	1	0.074
Cloughy	Sand	1	0.083
Portaferry	Shingle and stones	1	0.10
Kircubbin	Sand	1	0.095
Greyabbey	Sand	1	0.082
Ards Maltings	Mud	1	0.086
Island Hill	Mud	1	0.086
Nicky's Point	Mud	1	0.089
Strangford	Shingle and stones	1	0.11
Kilclief	Sand	1	0.077
Ardglass	Mud	1	0.098
Killough	Mud	1	0.10
Rocky Beach	Sand	1	0.090
Tyrella	Sand	1	0.087
Dundrum	Mud	1	0.097
Newcastle	Sand	1	0.096
Annalong	Sand	1	0.12
Cranfield Bay	Sand	1	0.085
Greencastle	Sand	1	0.089
Mill Bay	Mud	1	0.10
Rostrevor	Sand	1	0.13
Narrow Water	Mud	1	0.093

NA Not available

[F] Measurements labelled "F" are those in which the Food Standards Agency has also participated for quality control purposes, all other measurements are made on behalf of the Environment Agency

Table 3.8. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2004

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{54}Mn	^{58}Co	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Cumbria												
Newton Arlosh	Turf	4[F]	<0.80	<1.3	<2.0		<2.8	<3.4	<10	<4.0	<0.93	450
Newton Arlosh	Sediment	4			<2.0		<2.2	<1.2	<7.5	<9.0	<0.82	270
Maryport Outer Harbour	Sediment	2			<0.85	<1.1	<1.6	<0.80	<4.6	<4.8	<0.56	79
Workington Harbour	Sediment	2			3.6		<2.9	<1.7	<7.6	<8.1	<1.2	120
Harrington Harbour	Sediment	2			<3.0		<2.1	<1.1	<6.6	<7.4	<0.91	230
Whitehaven Outer Harbour	Sediment	4			<1.2	<1.8	<2.1	<1.2	<6.3	6.8	<0.80	140
Whitehaven yacht basin	Mud	1[F]	<1.8	<4.2	7.7		<11	<21	<23	33	<1.9	850
St Bees	Sand	4[F]	<0.52	<0.92	4.4		<2.0	<3.1	<5.7	<1.8	<0.56	70
St Bees	Sediment	4			4.1		<1.7	<0.88	<5.2	<5.0	<0.67	75
Sellafield	Sand	4[F]	<0.53	<0.96	4.0		<2.1	<3.0	<6.0	<2.6	<0.55	82
Ehen Spit	Sediment	2			2.8		<2.1	<1.3	<5.6	<5.6	<0.76	81
River Calder - downstream	Sediment	2			<0.99		<2.3	<1.1	<6.1	<6.3	<0.93	120
River Calder - upstream	Sediment	2			<1.0		<2.3	<1.3	<6.1	<5.9	<1.0	61
Seascale beach	Sediment	4			3.0		<1.7	<0.83	<5.2	<4.9	<0.67	48
Ravenglass - Carleton Marsh	Mud	4[F]	<1.2	<2.2	34		<4.9	<7.3	200	32	<1.4	380
Ravenglass - Carleton Marsh	Sediment	4			33		<4.1	<2.0	130	28	<1.7	570
River Mite Estuary	Sediment	4			<11	<46	<4.3	<1.8	<32	<19	<1.7	1100
Ravenglass - Raven Villa	Mud and sand	4[F]	<1.1	<2.0	27		<4.4	<6.8	88	28	<1.2	220
Ravenglass - Raven Villa	Sediment	4			27		<3.3	<1.5	<100	31	<1.5	520
Newbiggin (Eskmeals)	Sediment	4			32	84	<3.7	<1.8	100	30	<1.6	650
Haverigg	Sediment	2			<0.60		<1.3	<0.71	<3.8	<3.5	<0.51	24
Millom	Mud and sand	4[F]	<0.80	<1.4	6.0		<3.2	<4.8	27	7.6	<0.88	140
Millom	Sediment	2			11		<2.7	<1.3	37	12	<0.97	140
Low Shaw	Sediment	2			<1.4		<2.1	<1.0	<6.7	<6.8	<0.76	120
Walney Channel - west	Sediment	2			5.8		<2.3	<1.4	<23	10	<0.96	120
Walney Channel - east	Sediment	2			4.9		<1.9	<1.2	<17	9.1	<0.83	110
Sand Gate Marsh	Turf	4[F]	<0.77	<1.5	<1.4		<3.4	<5.3	<8.2	<2.8	<0.87	180
Sand Gate Marsh	Sediment	4			<1.3		<2.4	<1.1	<7.0	<6.6	<0.84	130
Flookburgh	Mud and sand	4[F]	<0.64	<1.2	<0.53		<2.6	<3.7	<7.3	<2.7	<0.74	250
Flookburgh	Sediment	1			<0.59		<1.3	<0.69	<4.8	<6.5	<0.51	360
Lancashire												
Morecambe	Mud and sand	4[F]	<0.87	<1.3	3.2		<2.7	<3.8	<16	7.3	<1.0	180
Morecambe	Sediment	2			<2.2							130
Half Moon Bay	Mud and sand	4[F]	<0.80	<1.3	3.4		<3.0	<4.2	<14	8.7	<0.95	140
Half Moon Bay	Sediment	2			<0.95							33
Heysham pipelines	Sediment	2			<0.96							23
Potts Corner	Sediment	2			<0.74							37
Sunderland Point	Sediment	4			1.8		<2.1	<1.1	<5.7	5.9	<0.76	91
Conder Green	Turf	4[F]	<0.96	<1.8	3.8		<3.8	<5.7	<11	5.2	<1.2	290
Conder Green	Sediment	4			<1.3		<2.2	<1.2	<6.1	<6.2	<0.71	160
Hambleton	Sediment	4			<3.9		<3.8	<1.9	<13	<13	<1.5	400
Skippool Creek	Sediment	4			4.9		<5.1	<2.5	<15	<14	<1.8	480
Fleetwood	Sediment	4			<0.76		<1.8	<1.1	<4.5	<4.0	<0.66	17
Blackpool	Sediment	4			<0.67		<1.5	<0.85	<4.2	<3.3	<0.56	4.5
Crossens Marsh	Sediment	4			<1.6		<4.0	<1.8	<11	<12	<1.7	170
Ainsdale	Sediment	4			<0.72		<1.5	<0.81	<4.5	<3.8	<0.61	8.3
Rock Ferry	Sediment	4			<1.0		<2.3	<1.3	<6.6	<6.5	<0.94	86
New Brighton	Sediment	4			<0.69		<1.5	<0.83	<4.2	<3.6	<0.58	4.9
Scotland												
Campbeltown	Sediment	1	<0.10	<0.16	<0.10		<0.30	<0.38	<0.75	<0.22	<0.10	9.0
Garlieston	Sediment	4	<0.10	<0.15	0.54		<0.40	<0.35	<0.70	1.7	<0.09	36
Innerwell	Mud	2[F]	<0.95	<1.8	3.0		<3.3	<5.0	<10	<3.2	<1.1	100
Innerwell	Sediment	4	<0.10	<0.20	2.3		<0.61	<0.45	3.9	3.0	<0.12	100
Bladnoch	Sediment	4	<0.14	<0.39	4.8		<0.87	<1.2	12	5.1	<0.20	370
Carsluith	Sediment	4	<0.12	<0.14	3.3		<0.38	<0.52	<7.8	<3.9	<0.18	170
Palnackie Harbour	Sediment	4	<0.10	<0.20	3.8		<0.51	<0.56	6.8	3.8	<0.11	180
Kippford Slipway	Sediment	4	<0.11	<0.22	4.1		<0.52	<0.75	11	5.1	<0.16	<120
Kippford Merse	Turf	4	<0.11	<0.23	5.6		<0.41	<0.91	<3.9	3.7	<0.18	300
Carsethorn[a]	Sediment	2	<0.17	<0.42	3.2		<0.79	<1.3	<9.5	5.3	<0.24	190
Kirkconnel Merse	Sediment	4	<0.10	<0.27	3.9		<0.97	<1.2	<1.6	2.3	<0.15	620
Dornoch Brow	Sediment	4	<0.11	<0.23	2.5		<0.78	<0.83	7.2	4.9	<0.14	170

Table 3.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}										
			^{144}Ce	^{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]	<5.8	<2.6	<2.7				230				
Newton Arlosh	Sediment	4	<4.1	<4.3	<2.2				190			540	890
Maryport Outer Harbour	Sediment	2	<2.6	<3.0	<1.5	11	54	480	76			440	700
Workington Harbour	Sediment	2	<4.0	<4.8	<2.2				120			1000	1400
Harrington Harbour	Sediment	2	<3.6	<3.8	<2.1				150			860	1200
Whitehaven Outer Harbour	Sediment	4	<3.2	<3.9	<1.8	8.7	46	420	45			400	1100
Whitehaven yacht basin	Mud	1[F]	<10	19	<4.2				1200				
St Bees	Sand	4[F]	<3.6	<1.6	<1.6				160				
St Bees	Sediment	4	<2.5	<3.5	<1.4				190			410	640
Sellafield	Sand	4[F]	<3.4	<1.7	<1.5				170				
Ehen Spit	Sediment	2	<2.7	<3.5	<1.5				130			450	610
River Calder - downstream	Sediment	2	<3.3	<4.1	<1.9				19			590	1400
River Calder - upstream	Sediment	2	<3.3	<4.5	<1.8							420	1500
Seascale beach	Sediment	4	<2.5	<3.7	<1.5				170			390	500
Ravenglass - Carleton Marsh	Mud	4[F]	33	9.2	<5.3				980				
Ravenglass - Carleton Marsh	Sediment	4	<18	11	<3.9				1600			3000	2200
River Mite Estuary	Sediment	4	<7.5	<11	<4.1	130	660	6500	1400			2700	2000
Ravenglass - Raven Villa	Mud and sand	4[F]	<15	<4.9	<3.9				630				
Ravenglass - Raven Villa	Sediment	4	<16	8.8	<4.0				1300			2800	1700
Newbiggin (Eskmeals)	Sediment	4	<14	11	<4.8	150	750	7300	1300			3300	2200
Haverigg	Sediment	2	<2.0	<3.0	<1.1				21			110	450
Millom	Mud and sand	4[F]	<5.8	<2.2	<2.7				240				
Millom	Sediment	2	<6.1	<4.4	<2.0				360			810	910
Low Shaw	Sediment	2	<3.2	<4.2	<1.8				160			460	610
Walney Channel - west	Sediment	2	<3.5	<4.3	<2.0				230			760	840
Walney Channel - east	Sediment	2	<3.6	<3.2	<2.0				220			620	810
Sand Gate Marsh	Turf	4[F]	<5.7	<2.0	<2.6				93				
Sand Gate Marsh	Sediment	4	<3.5	<4.4	<2.0				99			440	820
Flookburgh	Mud and sand	4[F]	<5.3	<1.8	<2.4				72				
Flookburgh	Sediment	1	<2.7	<2.7	<1.4				190			710	1100
Lancashire													
Morecambe	Mud and sand	4[F]	<5.9	<2.3	<2.9				130				
Morecambe	Sediment	2							110				
Half Moon Bay	Mud and sand	4[F]	<4.7	<2.1	<2.2	11	63		120	*	*		
Half Moon Bay	Sediment	2							29				
Heysham pipelines	Sediment	2							21				
Potts Corner	Sediment	2							12				
Sunderland Point	Sediment	4	<2.9	<3.5	<1.6				80			480	730
Conder Green	Turf	4[F]	<6.8	<2.8	<3.2				190				
Conder Green	Sediment	4	<3.2	<3.9	<1.7				120			580	800
Hambleton	Sediment	4	<6.1	<6.7	<3.4				310			1000	1300
Skippool Creek	Sediment	4	<7.1	<7.7	<3.8				370			1100	1400
Fleetwood	Sediment	4	<2.3	<3.2	<1.3				18			<120	520
Blackpool	Sediment	4	<2.1	<3.0	<1.2				4.4			<100	270
Crossens Marsh	Sediment	4	<5.6	<7.1	<3.3				110			650	1100
Ainsdale	Sediment	4	<2.2	<3.2	<1.2				4.1			<120	300
Rock Ferry	Sediment	4	<3.3	<4.5	<1.9				44			<400	970
New Brighton	Sediment	4	<2.1	<3.1	<1.2				3.2			<100	380
Scotland													
Campbeltown	Sediment	1	<0.70	<0.16	<0.26				0.99				
Garlieston	Sediment	4	<0.66	<0.26	<0.38	5.9	32		55	<0.056		0.14	
Innerwell	Mud	2[F]	<5.6	<2.6	<2.7				140				
Innerwell	Sediment	4	<1.1	<0.78	0.99				120				
Bladnoch	Sediment	4	<1.8	2.6	<1.7				370				
Carsluith	Sediment	4	<0.69	<1.2	1.1	30	150		130			300	770
Palnackie Harbour	Sediment	4	<1.0	1.1	<1.1	23	140		210				
Kippford Slipway	Sediment	4	<1.1	1.4	<1.1	25	130		250				
Kippford Merse	Turf	4	<1.3	2.3	<1.4	57	290		530				
Carsethorn[a]	Sediment	2	<1.3	<1.3	1.1				160				
Kirkconnel Merse	Sediment	4	<1.7	<1.9	<1.3	55	310		540				
Dornoch Brow	Sediment	4	<1.2	<0.71	1.2	7.4	38		84	<0.067		<0.067	

Table 3.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{54}Mn	^{58}Co	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Isle of Man												
Ramsey	Sediment	1			<0.82		<1.4	<0.66	<4.9	<4.2	<0.69	6.6
Wales												
Rhyl	Sediment	2			<0.95		<2.3	<1.1	<6.1	<6.4	<0.81	75
Llandudno	Sediment	2			<0.66		<1.6	<0.95	<4.0	<3.5	<0.70	3.9
Caerhun	Sediment	2			<1.4		<3.9	<1.9	<11	<11	<1.3	190
Llanfairfechan	Sediment	2			<1.6		<4.6	<2.6	<12	<11	<1.4	85
Northern Ireland												
Carrichue House	Mud and sand	1^F	<0.35	<0.55	<0.28		<1.3	<1.6	<3.5	<0.91	<0.41	1.8
Carrichue House	Mud, sand and stones	1^F	<0.24	<0.48	<0.19		<0.94	<1.4	<2.2	<0.55	<0.24	1.5
Portrush	Sand	2^F	<0.60	<1.6	<0.46		<3.1	<7.6	<5.4	<1.2	<0.57	<0.60
Oldmill Bay	Mud	2^F	<0.61	<0.81	<0.62		<1.8	<1.9	<5.3	<1.7	<0.74	24
Ballymacormick	Mud	2^F	<0.58	<0.90	<0.51		<1.8	<2.0	<5.5	<1.6	<0.66	26
Strangford Lough - Nickey's Point	Mud	2^F	<0.65	<1.0	<0.63		<1.9	<2.4	<6.1	<1.8	<0.77	33
Dundrum Bay	Mud	2^F	<0.75	<1.7	<0.65		<3.9	<6.8	<6.6	<1.7	<0.84	7.6
Carlingford Lough	Mud	2^F	<0.89	<1.4	<0.79		<2.7	<3.5	<8.1	<2.4	<1.1	67

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), 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
Isle of Man												
Ramsey	Sediment	1	<2.2	<3.8	<1.3						370	820
Wales												
Rhyl	Sediment	2	<3.2	<4.4	<1.9			39			550	920
Llandudno	Sediment	2	<2.2	<3.0	<1.3						<100	440
Caerhun	Sediment	2	<5.1	<6.6	<2.8			45			450	910
Llanfairfechan	Sediment	2	<5.7	<7.4	<3.2			47			650	1000
Northern Ireland												
Carrichue House	Mud and sand	1^F	<2.7	<0.86	<1.2	0.025	0.19	0.26	*	*		
Carrichue House	Mud, sand and stones	1^F	<1.7	<0.53	<0.75			<0.88				
Portrush	Sand	2^F	<3.0	<1.4	<1.3			<1.9				
Oldmill Bay	Mud	2^F	<3.6	<1.8	<2.6	1.9	11	18	*	0.020		
Ballymacormick	Mud	2^F	<3.6	<1.6	<1.8	1.8	12	18	0.02	0.02		
Strangford Lough - Nickey's Point	Mud	2^F	<3.9	<1.9	<2.0	1.6	9.5	10	0.02	0.01		
Dundrum Bay	Mud	2^F	<4.6	<2.0	<2.2			<3.7				
Carlingford Lough	Mud	2^F	<5.0	<2.4	<2.4	2.1	13	9.1	0.01	0.015		

* *Not detected by the method used*

^{a} *The concentration of ^{3}H was <3.0 Bq kg^{-1}*

^{F} *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 3.9. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2004

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, µSv h^{-1}
M	Nets	4	0.13
	Ropes	4	0.059
S	Nets	2	0.084
	Pots	3	0.17
T	Gill nets	3	0.11
	Pots	3	0.23
W	Gill nets	1	0.070
	Pots	2	0.081
X	Gill nets	4	0.090
	Pots	4	0.11
Z	Nets	4	0.12

Table 3.10. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2004

Location	Ground type	No. of sampling observ-ations	µSv h^{-1}
Whitehaven - outer harbour	Mud and sand	2	0.24
St Bees	Sand	2	0.14
Nethertown	Winkle bed	2	0.44
Sellafield pipeline	Sand	2	0.20
Drigg Barn Scar	Mussel bed	2	0.22
Ravenglass - Raven Villa	Salt marsh	2	0.67
Ravenglass - salmon garth	Mussel bed	2	0.32
Tarn Bay	Sand	2	0.10

Table 3.11. Concentrations of radionuclides in surface waters from West Cumbria, 2004

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
Ehen Spit issue	4	430	<0.44	<0.068	<0.42	<0.64	<0.014	<0.0078	<2.5	11
Seaburn sewer outfall	4	11	<0.48	<0.038	<0.45	<0.42	<0.011	<0.0058	<0.030	1.0
River Calder (downstream)	4	<4.0	<0.48	<0.030	<0.43	<0.40	<0.0098	<0.0060	<0.075	<0.36
River Calder (upstream)	4	<4.0	<0.49	<0.027	<0.45	<0.40	<0.0085	<0.0053	<0.085	<0.32
Wast Water	1	<4.0	<0.51			<0.40			<0.020	<0.10
Ennerdale Water	1	<4.0	<0.51			<0.41			<0.020	<0.10
Devoke Water	1	<4.0	<0.48			<0.41			<0.020	<0.10
Thirlmere	1	<4.0	<0.48			<0.40			<0.020	<0.10

Table 3.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2004

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Cumbria									
Silloth	Seaweed	2		<1.8			<2.8	<1.4	3600
Harrington Harbour	Seaweed	2		<2.5			<3.2	<1.7	2900
St Bees	*Fucus vesiculosus*[a]	4[F]	<0.05	4.3	<0.16	2.6	<0.15	<0.18	3900
St Bees	*Porphyra*[b]	4[F]	<0.08	0.70	<0.22	0.16	<0.25	<0.32	4.5
St Bees	Seaweed	2		16			<3.5	<1.8	4800
Braystones South	*Porphyra*	4[F]	<0.07	1.2	<0.21		<0.24	<0.30	
Sellafield	*Fucus vesiculosus*	4[F]	<0.11	12	<0.30	4.9	<0.32	<0.36	7100
Sellafield	Seaweed	2		15			<3.4	<1.7	10000
Seascale	*Porphyra*[c]	51[F]	<0.29	<1.5	<0.67		<0.49	<0.29	
Rabbit Cat How	Samphire	1[F]	<0.05	0.11	<0.12		<0.20	<0.31	0.70
Ravenglass	Seaweed	2		<12			<3.5	<1.8	1600
Lancashire									
Half Moon Bay	*Fucus vesiculosus*	4[F]	<0.09	0.46	<0.23		<0.30	<0.41	1400
Half Moon Bay	Seaweed	2		<3.4			<7.1	<4.5	3100
Cockerham Marsh	Samphire	1[F]	<0.07	<0.07	<0.18		<0.42	<0.96	
Scotland									
Wick	*Fucus vesiculosus*	1[F]	<0.05	<0.05	<0.14		<0.11	<0.09	
Cape Wrath	*Ascophyllum nodosum*	1[F]	<0.06	<0.06	<0.16		<0.14	<0.11	350
Lewis	Seaweed	1	<0.10	<0.10	<0.21		<0.18	<0.17	210
Islay	Seaweed	1	<0.10	<0.10	<0.10		<0.10	<0.10	
Campbeltown	Seaweed	1	<0.10	<0.10	<0.22		<0.23	<0.27	
Knock Bay	*Porphyra*	4[F]	<0.06	<0.06	<0.19		<0.28	<0.49	
Knock Bay	*Porphyra*	4	<0.10	<0.10	<0.11		<0.11	<0.14	<12
Port William	*Fucus vesiculosus*	4[F]	<0.08	<0.13	<0.21		<0.29	<0.39	820
Port William	Seaweed	4	<0.10	0.24	<0.13		<0.12	<0.13	830
Garlieston	*Fucus vesiculosus*	4[F]	<0.07	0.52	<0.21		<0.26	<0.35	1000
Garlieston	Seaweed	4	<0.10	<0.62	<0.15		<0.14	<0.13	1400
Auchencairn	*Fucus vesiculosus*	4[F]	<0.10	0.66	<0.27		<0.34	<0.44	1400
Auchencairn	Seaweed	4	<0.10	0.91	<0.14		<0.13	<0.13	1600
Isle of Man	*Fucus vesiculosus*	4[F]	<0.07	<0.10	<0.19		<0.22	<0.28	840
Wales									
Cemaes Bay	*Fucus vesiculosus*	2[F]	<0.05	<0.05	<0.14		<0.13	<0.12	280
Cemaes Bay	Seaweed	2		<1.6			<2.7	<1.3	760
Porthmadog	*Fucus vesiculosus*	1[F]	<0.10	<0.09	<0.27		<0.31	<0.39	84
Porthmadog	Seaweed	2		<2.3			<4.0	<2.0	21
Lavernock Point	*Fucus serratus*	2[F]	<0.05	<0.05	<0.15		<0.13	<0.12	0.66
Fishguard	*Fucus vesiculosus*	1[F]	<0.08	<0.08	<0.22		<0.20	<0.18	99
Fishguard	Seaweed	2		<0.97			<1.6	<0.73	55
South Wales, manufacturer A	Laverbread	4[F]	<0.10	<0.09	<0.25		<0.52	<1.1	
South Wales, manufacturer C	Laverbread	4[F]	<0.10	<0.10	<0.28		<0.48	<0.94	
South Wales, manufacturer D	Laverbread	4[F]	<0.10	<0.09	<0.26		<0.58	<0.59	
South Wales, manufacturer E	Laverbread	1[F]	<0.09	<0.09	<0.23		<0.27	<0.32	
Northern Ireland									
Portrush	*Fucus spp.*	4	<0.07	<0.07	<0.19		<0.21	<0.26	
Strangford Lough	*Rhodymenia spp.*	3	<0.16	<0.15	<0.42		<0.65	<1.2	28
Ardglass	*Ascophyllum nodosum*	3	<0.08	<0.09	<0.23		<0.29	<0.37	
Ardglass	*Fucus vesiculosus*	2	<0.24	<0.25	<0.60		<0.79	<1.0	530
Carlingford Lough	*Ascophyllum nodosum*	1	<0.12	<0.13	<0.33		<0.39	<0.40	
Carlingford Lough	*Fucus spp.*	3	<0.20	<0.20	<0.53		<0.63	<0.69	630
Isles of Scilly	*Ascophyllum nodosum*	1[F]	<0.04	<0.05	<0.12		<0.10	<0.08	2.3

Table 3.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{106}Ru	^{110m}Ag	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu
Cumbria										
Silloth	Seaweed	2	<10	<1.8	<8.4	<2.1	<1.4	6.3	<4.4	
Harrington Harbour	Seaweed	2	<12	<1.9	<9.7	<2.4	<1.6	5.4	<4.9	
St Bees	*Fucus vesiculosus*[a]	4[F]	2.6	<0.30	4.7	*	<0.05	4.5	<0.22	<0.14
St Bees	*Porphyra*[b]	4[F]	8.7	<0.15	1.8	<0.32	<0.08	1.9	<0.39	<0.26
St Bees	Seaweed	2	<14	<2.3	<11	<2.4	<1.8	7.8	<5.1	
Braystones South	*Porphyra*	4[F]	24	<0.15	1.9	*	<0.07	1.7	<0.35	<0.23
Sellafield	*Fucus vesiculosus*	4[F]	5.9	0.86	6.3	*	<0.15	6.9	<0.51	<0.29
Sellafield	Seaweed	2	<13	<2.3	9.8	<2.2	<1.8	20	<5.3	
Seascale	*Porphyra*[c]	51[F]	26	<0.53	<5.3	<0.42	<0.31	1.7	<1.4	<0.89
Rabbit Cat How	Samphire	1[F]	<0.51	<0.09	<0.12	*	<0.05	0.59	<0.27	<0.13
Ravenglass	Seaweed	2	<33	<2.2	<15	<2.8	<1.8	100	<6.2	
Lancashire										
Half Moon Bay	*Fucus vesiculosus*	4[F]	<0.78	<0.16	1.4	*	<0.09	4.4	<0.47	<0.26
Half Moon Bay	Seaweed	2	<20	<3.4	<16	<47	<2.7	14	<8.9	
Cockerham Marsh	Samphire	1[F]	<0.75	<0.13	<0.17	*	<0.07	1.8	<0.40	<0.18
Scotland										
Wick	*Fucus vesiculosus*	1[F]	<0.43	<0.09	<0.10	<1.1	<0.05	0.07	<0.18	<0.17
Cape Wrath	*Ascophyllum nodosum*	1[F]	<0.52	<0.11	<0.15	*	<0.06	0.32	<0.33	<0.19
Lewis	Seaweed	1	<0.58	<0.10	<0.15		<0.10	<0.10	<0.41	<0.10
Islay	Seaweed	1	<0.23	<0.10	<0.10		<0.10	0.33	<0.16	<0.10
Campbeltown	Seaweed	1	<0.55	<0.10	0.23		<0.10	0.80	<0.39	<0.10
Knock Bay	*Porphyra*	4[F]	<0.63	<0.12	<0.12	*	<0.06	0.20	<0.24	<0.20
Knock Bay	*Porphyra*	4	<0.87	<0.10	<0.10		<0.10	0.20	<0.16	<0.10
Port William	*Fucus vesiculosus*	4[F]	<0.71	<0.14	0.53	<0.26	<0.08	1.2	<0.46	<0.23
Port William	Seaweed	4	<0.33	<0.10	0.66		<0.10	1.2	<0.24	<0.10
Garlieston	*Fucus vesiculosus*	4[F]	<0.67	<0.14	0.82	<0.20	<0.08	2.6	<0.39	<0.24
Garlieston	Seaweed	4	<0.39	<0.10	1.2		<0.10	4.2	<0.27	<0.11
Auchencairn	*Fucus vesiculosus*	4[F]	<0.86	<0.17	1.2	<0.28	<0.10	3.7	<0.45	<0.31
Auchencairn	Seaweed	4	<0.39	<0.10	1.6		<0.10	3.1	<0.26	<0.10
Isle of Man	*Fucus vesiculosus*	4[F]	<0.58	<0.12	<0.29	<0.43	<0.07	0.88	<0.32	<0.23
Wales										
Cemaes Bay	*Fucus vesiculosus*	2[F]	<0.47	<0.09	<0.13	<0.23	<0.06	0.86	<0.26	<0.18
Cemaes Bay	Seaweed	2	<10	<1.6	<7.6	<1.9	<1.4	<1.2	<4.0	
Porthmadog	*Fucus vesiculosus*	1[F]	<0.82	<0.17	<0.20	*	<0.10	0.47	<0.51	<0.30
Porthmadog	Seaweed	2	<15	<2.7	<12	<2.6	<2.0	<4.1	<6.0	
Lavernock Point	*Fucus serratus*	2[F]	<0.45	<0.10	<0.11	<0.43	<0.06	0.35	<0.25	<0.19
Fishguard	*Fucus vesiculosus*	1[F]	<0.64	<0.15	<0.15	*	<0.08	0.44	<0.28	<0.29
Fishguard	Seaweed	2	<5.7	<1.0	<4.6	<0.81	<0.81	<0.75	<2.4	
South Wales, manufacturer A	Laverbread	4[F]	<1.1	<0.18	<0.21	*	<0.10	<0.08	<0.48	<0.27
South Wales, manufacturer C	Laverbread	4[F]	<1.0	<0.19	<0.20	*	<0.09	<0.15	<0.36	<0.29
South Wales, manufacturer D	Laverbread	4[F]	<0.93	<0.18	<0.20	<0.19	<0.09	<0.08	<0.44	<0.27
South Wales, manufacturer E	Laverbread	1[F]	<0.86	<0.14	<0.18	*	<0.09	<0.07	<0.31	<0.27
Northern Ireland										
Portrush	*Fucus spp.*	4	<0.58	<0.12	<0.14	<0.06	<0.07	<0.10	<0.31	<0.24
Strangford Lough	*Rhodymenia spp.*	3	<1.6	<0.28	<0.34	<1.5	<0.16	0.90	<0.72	<0.47
Ardglass	*Ascophyllum nodosum*	3	<0.75	<0.15	<0.24	*	<0.09	0.49	<0.40	<0.27
Ardglass	*Fucus vesiculosus*	2	<2.3	<0.42	<0.56	<2.4	<0.25	0.89	<0.99	<0.72
Carlingford Lough	*Ascophyllum nodosum*	1	<1.0	<0.22	<0.26	*	<0.13	0.88	<0.51	<0.42
Carlingford Lough	*Fucus spp.*	3	<1.9	<0.34	<0.41	*	<0.22	0.79	<0.65	<0.61
Isles of Scilly	*Ascophyllum nodosum*	1[F]	<0.41	<0.08	<0.11	<0.66	<0.05	0.05	<0.21	<0.16

Table 3.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total beta
Cumbria										
Silloth	Seaweed	2					<2.0			
Harrington Harbour	Seaweed	2					<5.2			
St Bees	*Fucus vesiculosus*[a]	4[F]	<0.11	1.9	8.3		3.6	*	0.0086	
St Bees	*Porphyra*[b]	4[F]	<0.19	0.54	2.9	26	4.7	*	0.011	150
St Bees	Seaweed	2					17			
Braystones South	*Porphyra*	4[F]	<0.16	0.57	2.8	27	4.9	*	0.0082	
Sellafield	*Fucus vesiculosus*	4[F]	<0.28	3.9	16		7.7	0.0074	0.019	
Sellafield	Seaweed	2					20			
Seascale	*Porphyra*[c]	51[F]	<0.68				4.7			
Rabbit Cat How	Samphire	1[F]	<0.12				1.7			
Ravenglass	Seaweed	2					350			
Lancashire										
Half Moon Bay	*Fucus vesiculosus*	4[F]	<0.23				0.87			
Half Moon Bay	Seaweed	2					<3.5			
Cockerham Marsh	Samphire	1[F]	<0.17				1.2			310
Scotland										
Wick	*Fucus vesiculosus*	1[F]	<0.09				<0.06			180
Cape Wrath	*Ascophyllum nodosum*	1[F]	<0.17				<0.18			430
Lewis	Seaweed	1	<0.21				<0.19			
Islay	Seaweed	1	<0.10				<0.10			
Campbeltown	Seaweed	1	<0.19				0.15			
Knock Bay	*Porphyra*	4[F]	<0.10				0.15			
Knock Bay	*Porphyra*	4	<0.10				0.24			
Port William	*Fucus vesiculosus*	4[F]	<0.22				<0.51			
Port William	Seaweed	4	<0.15				<0.80			
Garlieston	*Fucus vesiculosus*	4[F]	<0.20				1.9			
Garlieston	Seaweed	4	<0.15				<5.2			
Auchencairn	*Fucus vesiculosus*	4[F]	<0.22				1.8			
Auchencairn	Seaweed	4	<0.14				3.5			
Isle of Man	*Fucus vesiculosus*	4[F]	<0.16				<0.24			840
Wales										
Cemaes Bay	*Fucus vesiculosus*	2[F]	<0.13				<0.18			
Cemaes Bay	Seaweed	2					<1.6			
Porthmadog	*Fucus vesiculosus*	1[F]	<0.27				<0.40			
Porthmadog	Seaweed	2					<2.4			
Lavernock Point	*Fucus serratus*	2[F]	<0.14				<0.19			210
Fishguard	*Fucus vesiculosus*	1[F]	<0.14				<0.09			
Fishguard	Seaweed	2					<1.1			
South Wales, manufacturer A	Laverbread	4[F]	<0.19				<0.23			
South Wales, manufacturer C	Laverbread	4[F]	<0.14				<0.10			
South Wales, manufacturer D	Laverbread	4[F]	<0.17				<0.16			76
South Wales, manufacturer E	Laverbread	1[F]	<0.14				<0.16			
Northern Ireland										
Portrush	*Fucus spp.*	4	<0.15				<0.14			
Strangford Lough	*Rhodymenia spp.*	3	<0.32	0.087	0.46		0.67	*	0.0012	
Ardglass	*Ascophyllum nodosum*	3	<0.19				<0.21			
Ardglass	*Fucus vesiculosus*	2	<0.46				<0.50			
Carlingford Lough	*Ascophyllum nodosum*	1	<0.25				<0.31			
Carlingford Lough	*Fucus spp.*	3	<0.29				<0.15			
Isles of Scilly	*Ascophyllum nodosum*	1[F]	<0.10				<0.06			

* *Not detected by the method used*

[a] *The concentration of* ^{129}I *was 11 Bq* kg^{-1}

[b] *The concentration of* ^{14}C *was 75 Bq* kg^{-1}

[c] *Counted wet*

[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 3.13. Concentrations of radionuclides in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2004

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	^{154}Eu	^{155}Eu	^{241}Am
Newton Arlosh	Grass	1				1.1								
Newton Arlosh	Washed grass	1				0.50								
Newton Arlosh	Soil	1				3.4								
Sellafield 14[b]	Beetroot	1	<0.07	<0.23	<0.28	34	<0.67	<0.13	<0.07	<0.06	<0.24	<0.24	<0.10	<0.05
Sellafield 14[b]	Onions	1	<0.05	<0.25	<0.41	3.5	<0.56	<0.11	<0.05	<0.05	<0.21	<0.16	<0.09	<0.10
Sellafield 14[b]	Potatoes	1	<0.04	<0.10	<0.10	18	<0.29	<0.07	<0.03	0.27	<0.14	<0.12	<0.06	<0.04
Sellafield 14[b]	Runner Beans	1	<0.04	<0.15	<0.18	58	<0.43	<0.08	<0.04	0.10	<0.15	<0.14	<0.06	<0.03
Sellafield 14[b]	Soil	1	9.4	<3.1	<3.8	3600	<9.9	<2.8	<0.94	40	<5.5	<2.3	<2.6	26
Sellafield 1674[b]	Beetroot	1	<0.09	<0.29	<0.39	30	<0.78	<0.15	<0.08	<0.07	<0.25	<0.26	<0.10	<0.06
Sellafield 1674[b]	Onions	1	<0.02	<0.08	<0.12	2.6	<0.19	<0.05	<0.02	0.05	<0.11	<0.06	<0.05	<0.05
Sellafield 1674[b]	Potatoes	1	<0.06	<0.25	<0.36	7.4	<0.51	<0.12	<0.06	0.38	<0.26	<0.19	<0.12	<0.15
Sellafield 1674[b]	Soil	1	<0.74	<3.2	<5.7	780	<6.2	<1.7	<0.81	52	<3.8	<1.9	<1.6	3.1
Sellafield 1676[b]	Cabbage	1	<0.05	<0.31	<0.66	44	<0.49	<0.09	<0.05	0.08	<0.19	<0.15	<0.07	<0.03
Sellafield 1676[b]	Potatoes	1	<0.05	<0.16	<0.17	23	<0.49	<0.12	<0.05	0.27	<0.30	<0.18	<0.15	<0.23
Sellafield 1676[b]	Soil	1	4.0	<2.4	<3.2	1300	<7.1	<2.0	<0.74	67	<4.9	<1.7	<2.2	39
Sellafield 1710[b]	Onions	1	<0.10	<0.26	<0.29	2.9	<0.89	<0.19	<0.09	<0.08	<0.34	<0.28	<0.15	<0.18
Sellafield 1710[b]	Potatoes	1	<0.03	<0.05	<0.04	12	<0.23	<0.06	<0.03	0.12	<0.11	<0.09	<0.05	<0.03
Sellafield 1710[b]	Soil	1	<0.74	<2.3	<3.4	560	<6.1	<1.7	<0.75	56	<4.8	<1.5	<2.2	1.9
Hutton Marsh	Grass	1				2.5								
Hutton Marsh	Washed grass	1				1.3								
Hutton Marsh	Soil	1				36								

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

Table 3.14. Concentrations of radionuclides in terrestrial food and the environment near Ravenglass, 2004

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[d]		3	<4.8	16	<0.34	0.053	<0.58	<0.43	<0.0048	<2.3	<0.66	<0.016
Milk	max		<5.3	17	<0.35	0.069	<0.61	<0.44	<0.0053	<2.6	<0.68	<0.018
Apples		1	5.0	15	<0.50	0.16	<0.70	<0.30	<0.029	<3.0	<0.90	<0.023
Barley		1	<6.0	80	<0.50	0.33	<0.70	<0.40		<2.8	<0.90	<0.034
Beetroot		1							<0.039			
Blackberries		1	<4.0	8.0	<0.20	0.55	<0.40	<0.30	<0.026	<1.9	<0.60	<0.031
Bovine kidney		1	<7.0	29	<0.30	0.36	<0.40	<0.30	<0.027	<2.2	<0.60	
Bovine liver		1	<6.0	35	<0.20	0.044	<0.30	<0.30	<0.037	<1.1	<0.60	<0.048
Bovine muscle		1	<5.0	56	<0.40	<0.012	<0.50	<0.30	<0.016	<1.5	<0.60	<0.030
Cabbage		1	5.0	<2.0	<0.20	1.2	<0.80	<0.50	<0.036	<3.4	<0.70	<0.038
Carrots		1	<4.0	<3.0	<0.40	0.20	<0.40	<0.50	<0.035	<3.3	<0.60	<0.035
Honey		1	<7.0	67	<0.10	0.032	<0.40	<0.40	<0.024	<1.8	<0.60	<0.011
Lettuce[e]		1							<0.027			
Ovine muscle		2	11	28	<0.25	<0.012	<0.40	<0.35	<0.016	<2.4	<0.55	<0.034
Ovine muscle	max		16	33	<0.30	<0.015	<0.50	<0.40		<2.9	<0.60	<0.035
Ovine offal		2	23	25	<0.30	<0.077	<0.35	<0.30	<0.017	<2.1	<0.70	<0.033
Ovine offal	max		36	31		0.14	<0.40		<0.018	<2.2	<0.80	<0.044
Potatoes		1	9.0	8.0	<0.60	0.084	<0.50	<0.40	<0.028	<3.0	<0.60	<0.040
Runner beans		1	<4.0	<2.0	<0.50	0.11	<0.60	<0.50	<0.025	<3.5	<1.1	<0.041
Grass		2							0.079			
Grass	max								0.13			

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}							
			Total Cs	^{144}Ce	^{155}Eu	Total U	^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Pu	^{241}Am
Milk[d]		3	0.16	<1.2	<0.51		<0.00019	<0.00019	<0.038	<0.00013
Milk	max		0.22	<1.3	<0.57		<0.00020	<0.00020	<0.043	<0.00018
Apples		1	0.11	<1.3	<0.60		<0.00040	0.00050	<0.048	0.0017
Barley		1	0.14	<1.6	<0.70		0.0013	0.015	0.12	0.021
Beetroot		1				<0.031				
Blackberries		1	0.10	<1.0	<0.40		0.00030	0.0027	<0.044	0.0043
Bovine kidney		1	0.40	<1.4	<1.1		0.00050	0.00010	<0.11	0.00060
Bovine liver		1	0.32	<1.8	<1.0		<0.00060	0.00030	<0.12	0.00080
Bovine muscle		1	0.25	<0.90	<0.40		<0.00030	<0.00040	<0.12	<0.00020
Cabbage		1	0.081	<1.2	<0.60		0.00060	0.0033	<0.069	0.0076
Carrots		1	0.16	<1.5	<0.60		<0.00070	<0.00050	<0.092	0.0026
Honey		1	0.25	<1.9	<1.1		<0.00020	0.00050	<0.065	0.0012
Lettuce[e]		1				0.12				
Ovine muscle		2	0.65	<1.2	<0.55		<0.00030	<0.00030	<0.055	<0.00035
Ovine muscle	max		0.80		<0.60		<0.00050	<0.00040	<0.064	0.00040
Ovine offal		2	0.69	<2.0	<1.3		0.00070	0.0028	<0.11	0.0038
Ovine offal	max		0.75				0.00080	0.0031	0.12	0.0040
Potatoes		1	0.12	<1.5	<0.60		<0.00040	<0.00030	0.066	<0.00020
Runner beans		1	0.19	<0.20	<0.70	<0.031	0.00050	0.0028	0.081	0.0069
Soil		2				50				
Soil[f]	max					52				

[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 concentrations of ^{134}Cs and ^{137}Cs were <0.29 (max <0.30) and <0.35 (max <0.36) Bq l^{-1}*
[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.059, 0.0013 and 0.065 Bq kg^{-1} respectively*
[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 13, 0.56 and 12 Bq kg^{-1} respectively*

Table 3.15. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2004

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[d]		16	<3.9	<5.1	17	<0.31	0.091	<0.0035	<2.2	<0.64	<0.016
Milk[d]	max		<4.8	<6.5	22	<0.34	0.25		<2.4	<0.71	<0.033
Apples		2	<9.5	<8.5	17	<0.30	0.23	0.026	<2.2	<0.60	<0.019
Apples	max		<13	13	19		0.41		<2.7	<0.70	
Barley		1		<6.0	110	<0.30	1.3		<2.3	<0.80	<0.047
Blackberries		3	<4.3	<8.7	16	<0.33	1.4		<2.4	<0.70	<0.036
Blackberries	max		<6.0	16	17	<0.40	3.5		<2.8	<0.90	<0.054
Bovine kidney		1	<8.0	8.0	31	<0.30	0.38	<0.025	<1.8	<0.90	
Bovine liver		1	9.0	16	38	<0.30	0.015	<0.030	<2.3	<0.60	<0.055
Bovine muscle		1	<7.0	6.0	32	<0.40	0.013	<0.027	<2.2	<0.60	<0.035
Broccoli		1	<4.0	<4.0	<3.0	<0.30	0.19		<2.2	<0.60	<0.024
Cabbage		1	<4.0	<4.0	<3.0	<0.30	0.22		<1.8	<0.60	<0.021
Carrots		1	<4.0	<4.0	10	<0.40	0.21	<0.017	<2.4	<0.70	<0.019
Cauliflower[e]		1	<4.0	<4.0	8.0	<0.30	0.12		<2.0	<0.60	<0.019
Eggs		1	<4.0	<4.0	34	<0.20	0.049		<2.3	<0.90	<0.020
Elderberries		1	<9.0	9.0	20	<0.20	0.52		<1.6	<0.70	0.12
Honey		1		<6.0	94	<0.20	0.059		<1.8	<0.60	0.014
Mushrooms		1	2.0	6.0	<4.0	<0.40	0.71		<1.4	<0.40	<0.024
Onions		1	<6.0	<4.0	10	<0.30	0.24		<2.5	<0.60	<0.015
Ovine kidney		1	5.0	13	<9.0	<0.20	1.4	<0.055	<2.3	<0.90	
Ovine liver		1	<12	10	15	<0.30	0.34	<0.032	<2.1	<0.60	<0.030
Ovine muscle		3	<6.3	8.3	35	<0.37	0.056	<0.021	<2.1	<0.53	<0.046
Ovine muscle	max		<9.0	9.0	36	<0.40	0.077	<0.034	<2.6	<0.60	<0.081
Ovine offal		2	<6.5	<6.0	28	<0.25	0.32	0.034	<2.2	<0.85	<0.043
	max		<7.0		36	<0.30	0.36	0.041	<2.3	<0.90	<0.048
Pheasants		1	<6.0	<5.0	25	<0.30	<0.012	<0.016	<1.8	<0.70	<0.027
Potatoes		1	1.0	5.0	18	<0.30	<0.010		<2.3	<0.70	<0.026
Rabbit		1	1.0	7.0	21	<0.30	0.026	<0.016	<1.9	<0.90	<0.017
Runner beans		1	<8.0	7.0	11	<0.50	0.25		<3.4	<0.90	<0.037
Sprouts		1	<4.0	4.0	20	<0.30	0.20		<2.3	<0.80	<0.024
Swede		1	<5.0	<4.0	8.0	<0.20	0.73		<2.1	<0.50	<0.021
Turnips		1	<4.0	<4.0	9.0	<0.50	0.57		<2.9	<0.50	<0.017
Wheat		1		<7.0	70	<0.40	0.77		<1.2	<0.70	0.037
Grass		5				<0.40		<0.018	<1.8	<1.6	
Grass	max							<0.024	<2.4	3.4	
Soil		3				<0.43			<1.4	<0.73	
Soil[f]	max					0.80			<1.5	<0.80	

Table 3.15. continued

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{154}Eu	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[d]		16	<0.28	<0.38	0.24	<1.2	<0.36		<0.00018	<0.00021	<0.040	<0.00013
Milk[d]	max		<0.30	<0.81	0.82	<1.3	<0.39		<0.00020	<0.00025	<0.050	<0.00018
Apples		2			0.43	<1.2	<0.30		0.00025	<0.0013	<0.055	<0.0016
Apples	max				0.65				0.00030	0.0021	<0.056	0.0027
Barley		1			0.22	<1.1	<0.30		<0.00040	0.0047	<0.12	0.0084
Blackberries		3			1.0	<1.1	<0.37		<0.00053	0.0028	<0.054	0.0068
Blackberries	max				2.3	<1.2	<0.40		0.00090	0.0037	<0.059	0.0088
Bovine kidney		1			2.2	<1.8	<0.50		0.00050	0.00060	<0.095	0.00070
Bovine liver		1			1.3	<1.2	<0.30		<0.0012	0.0041	0.32	0.0018
Bovine muscle		1			2.2	<1.3	<0.40		<0.00020	<0.00020	<0.060	<0.00020
Broccoli		1			0.07	<1.3	<0.40		<0.00020	<0.00030	<0.043	<0.00020
Cabbage		1			0.09	<1.3	<0.40		<0.00030	<0.00030	<0.049	<0.00030
Carrots		1			0.19	<1.5	<0.40		<0.00030	0.00030	0.29	0.0014
Cauliflower[e]		1			0.085	<1.4	<0.40	<0.030	<0.00020	<0.00030	<0.041	0.00030
Eggs		1			0.10	<1.8	<0.60		<0.00020	<0.00020	<0.039	<0.00030
Elderberries		1			0.68	<1.3	<0.30		0.0028	0.016	<0.050	0.021
Honey		1			0.13	<1.7	<0.40		0.00020	<0.00050	<0.092	0.00060
Mushrooms		1			0.51	<1.0	<0.30		0.0013	0.0095	0.18	0.027
Onions		1			0.036	<1.0	<0.40		0.00050	<0.00040	<0.058	0.00050
Ovine kidney		1			0.76	<1.9	<0.60		0.00070	0.00070		0.0017
Ovine liver		1			0.53	<0.80	<0.30		0.00040	0.0030	0.13	0.0022
Ovine muscle		3			1.2	<1.2	<0.37		<0.00027	<0.00037	<0.069	<0.00043
Ovine muscle	max				2.5	<1.4	<0.40		<0.00040	0.00060	0.098	0.00080
Ovine offal		2			1.0	<2.2	<0.55		<0.0055	0.026	<0.31	0.033
	max				1.6		<0.60		0.011	0.052	0.55	0.065
Pheasants		1			1.4	<2.1	<0.50		<0.00090	0.00060	<0.083	0.00050
Potatoes		1			0.18	<1.4	<0.40		0.00030	0.00020	<0.062	<0.00020
Rabbit		1			0.92	<1.5	<0.50		<0.00080	0.00040	<0.083	0.00020
Runner beans		1			0.26	<1.4	<0.40		0.0014	0.0061	<0.060	0.015
Sprouts		1			0.14	<1.5	<0.40		0.00030	0.00030	0.065	0.00090
Swede		1			0.89	<1.0	<0.40		0.00010	0.0020	<0.075	0.0011
Turnips		1			0.04	<1.4	<0.40	<0.029	<0.00030	<0.00040	<0.044	0.00020
Wheat		1			0.44	<1.3	<0.40		0.00040	0.0029	<0.045	0.0052
Grass		5	<0.27	3.7		<1.1	<0.37					
Grass	max		<0.30	6.6		<1.6	<0.40					
Soil		3	<0.20	52		<1.1	<0.33	60				4.9
Soil[f]	max			73		<1.3	<0.40	64				8.5

[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 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 ^{131}I was <0.015 Bq l^{-1} and the maximum was <0.018 Bq l^{-1}

[e] The concentrations of ^{234}U, ^{235}U and ^{238}U were <0.00080, <0.00080 and <0.00090 Bq kg^{-1} respectively

[f] The concentrations of ^{234}U, ^{235}U and ^{238}U were 16, 0.64 and 15 Bq kg^{-1} respectively

Table 3.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2004

Material	Location	No. of sampling observ-ations	Radioactivity concentration (dry), Bq kg^{-1}						
			^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Gullypot sediment	Seascale SS 204	1	<1.2	12	<1.5	840	7.1	55	59
Gullypot sediment	Seascale SS 233	1	<1.3	<1.0	<1.2	250	2.2	16	24
Gullypot sediment	Seascale SS 209	1	<0.95	<1.0	<0.84	22	1.4	7.2	14
Gullypot sediment	Seascale SS 232	1	<0.92	<1.3	<0.81	57	1.1	7.4	14
Gullypot sediment	Seascale SS 231	1	<1.0	<1.0	<1.0	7.7	1.3	7.1	9.4
Gullypot sediment	Whitehaven SS 201	1	<2.3	<1.0	<2.2	39	<0.44	1.9	2.9

Table 3.17(a). Concentrations of radionuclides in food and the environment near Springfields, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			^{60}Co	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}Th
Marine samples											
Flounder	Ribble Estuary	1	<0.13		<1.3	<0.31	5.2				*
Salmon	Ribble Estuary	1	<0.13		<1.2	<0.28	0.18				*
Sea trout	Ribble Estuary	1	<0.14		<1.5	<0.32	0.99				*
Brown trout	Ribble Link	1	<0.03		<0.33	<0.08	0.15	0.080	0.024	0.033	*
Shrimps[d]	Ribble Estuary	2	<0.05	1.5	<0.53	<0.14	2.0	0.014	0.025	0.0063	<4.9
Cockles	Ribble Estuary	2	0.50		<1.2	0.42	2.7	0.58	0.51	0.22	35
Mussels	Ribble Estuary	1	<0.06		<0.61	0.28	1.5	0.25	0.43	0.15	40
Samphire	Marshside Sands	1	<0.02		<0.20	<0.05	0.80				
Grass (washed)	Hutton Marsh	1		1.3							
Grass (unwashed)	Hutton Marsh	1		2.5							
Soil	Hutton Marsh	1		36							
Sediment	River Ribble outfall	4[E]	<3.8		<55		230	24	200	21	150000
Sediment	Savick Brook (tidal limit)	1[E]	3.5		<20		310	24	740	30	74000
Sediment	Lea Gate	1[E]	2.9		<14		310	29	360	40	4100
Sediment	Lower Penwortham	4[E]	<2.2		<12		270	26	270	31	3100
Sediment	Penwortham rail bridge	4[E]	<1.6		<9.2		110	24	140	21	14000
Sediment	Penwortham rail bridge - West bank	1[E]	<2.2		<16		410	37	250	31	1700
Sediment	Penwortham position 1	4[E]	<1.4		<8.5		95	25	140	23	860
Sediment	Penwortham position 2	1[E]	<0.95		<6.8		52	15	44	13	590
Sediment	Lytham	1[E]	<2.2		<18		330	45	140	32	17000
Sediment	Becconsall	4[E]	<1.6		<12		230	30	150	29	9500
Sediment	Freckleton	1[E]	<1.2		<10		150	29	120	26	6200
Sediment	Hutton Marsh	1[E]	3.0		<14		240	24	100	21	22000
Sediment	Longton Marsh	1[E]	<1.0		<6.6		64	18	29	25	200

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						<0.13				
Salmon	Ribble Estuary	1						<0.29				
Sea trout	Ribble Estuary	1						<0.37				
Brown trout	Ribble Link	1	0.048	0.0013	0.038			<0.09				
Shrimps[d]	Ribble Estuary	2				0.0038	0.019	0.036	0.000098	0.000074		
Cockles	Ribble Estuary	2				0.28	1.5	4.4	*	0.0057		
Mussels	Ribble Estuary	1						1.4				
Samphire	Marshside Sands	1						0.40				
Sediment	River Ribble outfall	4[E]	38	<1.6	29			140			1600	110000
Sediment	Savick Brook (tidal limit)	1[E]	60	1.8	44			150			3000	52000
Sediment	Lea Gate	1[E]	41	1.6	36			180			1400	7200
Sediment	Lower Penwortham	4[E]	37	1.4	32			160			1600	3000
Sediment	Penwortham rail bridge	4[E]	26	<1.0	23			58			1000	13000
Sediment	Penwortham rail bridge - West bank	1[E]	41	1.3	37			210			1400	2600
Sediment	Penwortham position 1	4[E]	19	<0.75	16			54			840	1600
Sediment	Penwortham position 2	1[E]	16	<0.70	15			31			480	1400
Sediment	Lytham	1[E]	28	1.0	30			200			1000	9900
Sediment	Becconsall	4[E]	26	0.96	26			140			920	5100
Sediment	Freckleton	1[E]	25	1.0	23			100			1000	5200
Sediment	Hutton Marsh	1[E]	25	0.71	19			130			1000	11000
Sediment	Longton Marsh	1[E]	17	0.73	19			27			300	680

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	^{106}Ru	^{129}I	^{137}Cs	Total Cs
Terrestrial samples										
Apples		1	<4.0	10	<0.40	0.075	<2.8	<0.020		0.050
Beetroot		1	<4.0	10	<0.40	0.24	<2.6	<0.028		<0.021
Cabbage		1	<4.0	15	<0.40	0.20	<2.3	<0.030		<0.028
Duck		1	<5.0	47	<0.30	<0.0090	<2.2			1.4
Eggs		1	<5.0	45	<0.30	<0.0090	<1.9	<0.027		0.055
Elderberries		1	<3.0	14	<0.30	0.29	<2.5	<0.035		0.069
Potatoes		1	<4.0	18	<0.50	0.050	<2.7	<0.033		0.042
Runner beans		1	7.0	16	<0.20	0.075	<1.1	<0.026		0.068
Sediment	Deepdale Brook	2[E]			<1.0		<5.9		<1.6	
Grass		1			<0.40		<2.2		5.3	
Freshwater[e]	Ulnes Walton	1[E]	23		<0.49				<0.40	

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}						
			^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples									
Milk		6							<0.0067
Milk	max								<0.0077
Apples		1	0.0013	0.00050					<0.028
Beetroot		1	0.014	0.012		0.048	0.0031	0.045	0.075
Cabbage		1	0.0029	<0.00080					<0.031
Duck		1	0.0045	<0.0019					
Eggs		1	0.00070	<0.00060					
Elderberries		1	0.0068	<0.0011					<0.031
Potatoes		1	0.0013	<0.00080					<0.031
Runner beans		1	0.0019	<0.00090					<0.030
Sediment	Deepdale Brook	2[E]			590	210	8.6	200	
Grass		1							0.68
Grass	Site fence	1[E]				2.9	0.14	2.9	
Grass	Opposite site entrance	1[E]				1.2	<0.14	0.75	
Grass	Opposite windmill	1[E]				1.8	<0.12	1.7	
Grass	Deepdale Brook	1[E]				0.93	0.090	0.73	
Grass	Lea Town	1[E]				0.82	<0.090	0.71	
Grass	N of Lea Town	1[E]				0.66	<0.12	0.49	
Silage		1				0.51	0.030	0.28	1.2
Soil		1				24	1.1	23	58
Soil	Site fence	1[E]				190	9.7	180	
Soil	Opposite site entrance	1[E]				140	6.5	130	
Soil	Opposite windmill	1[E]				140	5.4	130	
Soil	Deepdale Brook	1[E]				82	2.9	82	
Soil	Lea Town	1[E]				40	1.3	40	
Soil	N of Lea Town	1[E]				80	3.7	67	
Freshwater	Deepdale Brook	4[E]				1.1	0.045	1.1	
Freshwater[e]	Ulnes Walton	1[E]	<0.0050	<0.0050		0.37	0.016	0.36	

Table 3.17(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Total alpha	Total beta
Terrestrial samples								
Apples		1	0.00030	0.00090	<0.053	0.0025		
Beetroot		1	<0.00010	<0.00030	<0.055	0.00050		
Cabbage		1	<0.00040	0.00050	<0.059	<0.00050		
Duck		1	<0.00050	<0.00080	0.36	0.0040		
Eggs		1	<0.00050	<0.00030	0.14	<0.00030		
Elderberries		1	0.00070	0.0060	0.13	0.013		
Potatoes		1	<0.00030	0.00010	<0.058	<0.00020		
Runner beans		1	0.00040	0.00070	0.050	0.00050		
Sediment	Deepdale Brook	2[E]				<1.7	710	1600
Grass		1				2.9		
Freshwater	Deepdale Brook	4[E]					1.5	0.73
Freshwater[e]	Ulnes Walton	1[E]					0.49	0.79

* *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 concentrations of ^{14}C and ^{237}Np were 90 and 0.000057 Bq kg^{-1} respectively*

[e] *The concentration of ^{228}Th was <0.0050 Bq l^{-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, 2004

Location	Material or ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Lytham Yacht Club	Mud	1	0.10
Warton Marsh	Mud	4[F]	0.12
Warton Marsh	Mud[a]	4[F]	0.12
Warton Marsh	Salt marsh	4[F]	0.11
Warton Mud Marsh	Mud	2	0.10
Warton Salt Marsh	Salt marsh	2	0.11
Naze Point	Salt marsh	1	0.11
Naze Point	Grass and salt marsh	1	0.12
Banks Marsh	Mud	4[F]	0.12
Banks Marsh	Mud[a]	4[F]	0.12
Banks Marsh	Salt marsh	4[F]	0.13
Banks Marsh	Salt marsh	2	0.11
Hesketh Bank	Salt marsh	1	0.12
Hesketh Bank	Grass and salt marsh	1	0.11
Freckleton	Mud	1	0.11
Becconsall	Mud	3	0.093
Becconsall	Grass and mud	1	0.085
Becconsall (houseboat)	Grass and mud	2	0.091
Longton Marsh	Grass and salt marsh	1	0.14
Hutton Marsh	Mud	1	0.14
River Ribble outfall	Mud	3	0.14
River Ribble outfall	Grass and mud	1	0.11
Savick Brook, tidal limit	Grass and mud	1	0.12
Savick Brook, confluence with Ribble	Mud	1	0.20
Savick Brook, confluence with Ribble	Grass and mud	1	0.088
Savick Brook, Lea Gate	Grass and mud	1	0.11
South bank opposite outfall	Mud	1	0.11
Penworthham Bridge cadet hut	Leaves and mud	1	0.074
Lower Penwortham Park	Grass and mud	2	0.077
Lower Penwortham Park	Grass	2	0.086
Lower Penwortham Railway Bridge	Mud	2	0.082
Lower Penwortham Railway Bridge	Mud and sand	1	0.089
Lower Penwortham Railway Bridge	Grass and mud	1	0.078
River Darwen	Grass and mud	3	0.075
River Darwen	Grass	1	0.085
Riverbank Angler location 1	Grass and mud	4	0.073
Riverbank Angler location 2	Grass	1	0.079
Ulnes Walton, BNFL area survey	Grass and mud	3	0.081
Mean beta dose rates			
Lytham - Granny's Bay	Mud and sand	1[F]	2.1
Ribble Estuary	Gill net	2[F]	0.45
Ribble Estuary	Shrimp net	2[F]	0.28
Banks Marsh	Mud	4[F]	4.3
Banks Marsh	Salt marsh	4[F]	0.90
Warton Marsh	Mud	4[F]	4.4
Warton Marsh	Salt marsh	4[F]	0.81

[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 RWE NUKEM Limited 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) adjacent to the Dounreay site, and GE Healthcare at Harwell. Windscale is adjacent to the British Nuclear Group (BNG) 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.

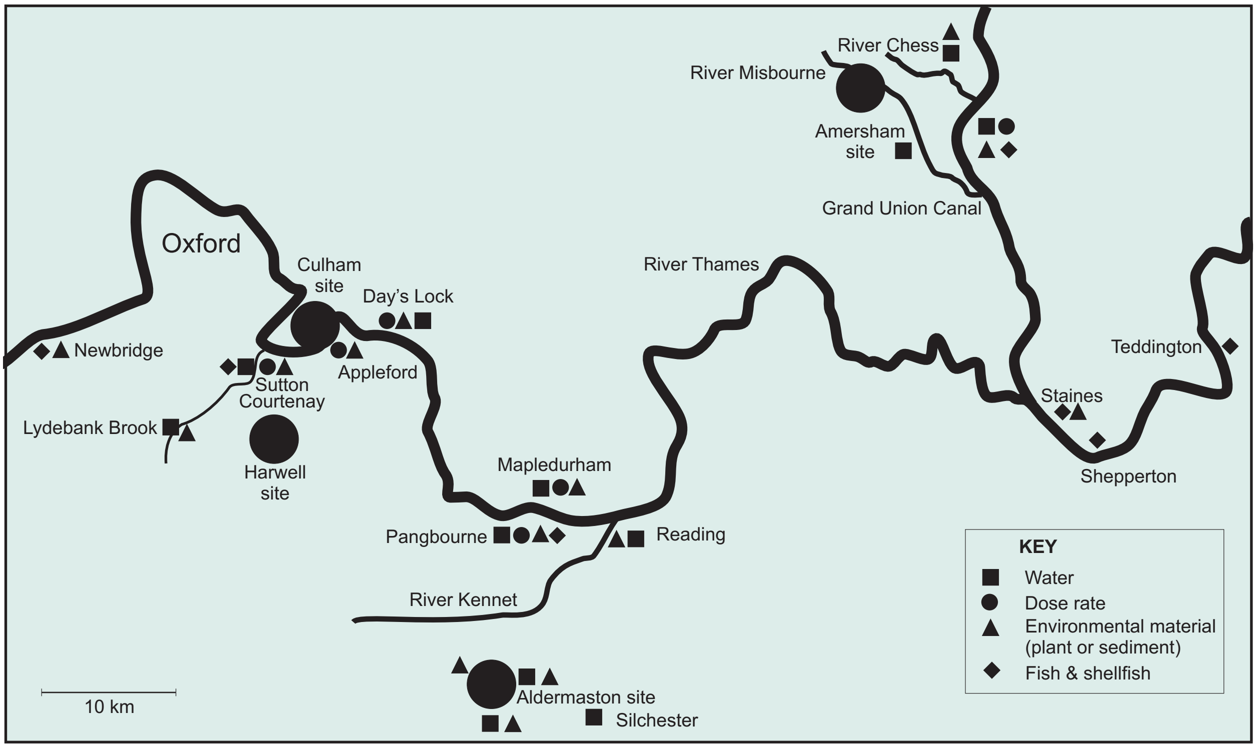
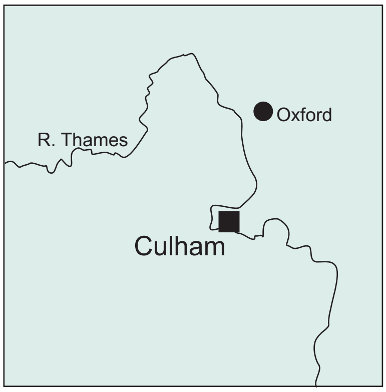


Figure 4.1 Monitoring locations at Thames sites (excluding farms)

Research sites

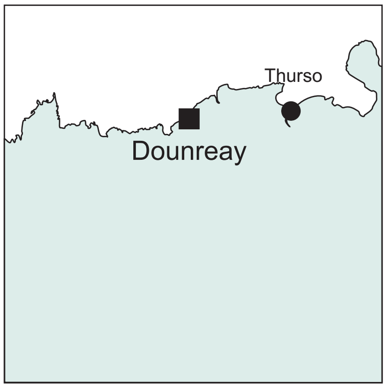
4.1 Culham, Oxfordshire



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 2004. Locations and data are shown in Figure 4.1 and Table 4.1 respectively. The main effect of the site's operation was increased tritium found in grass collected near the site perimeter. Although the value found in 2004 was relatively high (97 Bq kg^{-1}), the concentration would be likely to have been transient due to the nature of the discharges. The Environment Agency will continue to monitor the situation in 2005. In the extreme, if all terrestrial foods were contaminated at the same concentration, the exposure of high-rate consumers would still have been less than 0.005 mSv.

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 2004 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 the Scottish Environment Protection Agency. The quantities discharged in 2004 were generally similar to those in 2003 (Appendix 1). 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 Defence Procurement Agency.

In 2004, the Scottish Environment Protection Agency issued a variation to the authorisation for the discharge of liquid effluents, which introduced new discharge limits. The variation took effect on the 4th October 2004. This previous discharge limits were appropriate to the reprocessing activities that used to be undertaken at Dounreay. The new discharge limits are more appropriate to the main activity taking place at Dounreay now, namely decommissioning. Two sets of discharge limits now apply: one covers the Prototype Fast Reactor (PFR) liquid metal disposal plant, the other all facilities other than this. The new limits and the discharges contained in the new authorisation are given in Appendix 1. The new limits represent a substantial reduction in the discharges allowed compared with the previous authorisation. They also extend the control to include sodium-22, an important component of decommissioning waste that Dounreay has a need to dispose of. The Scottish Environment Protection Agency intend to issue a completely new authorisation reflecting Dounreay's decommissioning focus by the end of 2006.

The sodium disposal plant, which opened in 2002, was in full operation in 2004 and is progressing well with the treatment of 1500 tons of sodium that was used as a coolant in the PFR. It was noted last year that UKAEA was given regulatory consent to begin transferring radioactive liquor from its D1208 storage facility to the Dounreay Cementation Plant. The liquors are being mixed with cement to produce a solid waste that can be stored until a disposal option is available. This treatment is progressing and is resulting in the removal of one of the major hazards on site.

In September 2004, an inspection team from the EC visited UKAEA Dounreay to verify that Article 35 of the Euratom treaty was being adequately implemented. The purpose of such visits is to ensure that radioactive discharges to the environment are being adequately monitored. The resulting verification report concludes that: the Commission found that the facilities necessary to carry out continuous monitoring of levels of radioactivity in the air, water and soil around the Dounreay site were adequate, and that the Commission could verify the operation and efficacy of these facilities.

Monitoring conducted in 2004, 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 on the seabed near Dounreay, by UKAEA, and prohibits the harvesting of seafoods within a 2 km radius of the discharge pipeline. The results of the Scottish Environment Protection Agency's monitoring are presented in Tables 4.3(a) and (b).

During 2004, UKAEA continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by the Scottish Environment Protection Agency. It should be noted that the agreement for vehicular access to a privately owned, publicly accessible beach ceased at the end of April 2004, and consequently, no further monitoring of this beach was undertaken in 2004.

In 2004, five fragments were recovered from Sandside Bay and nine from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 14 kBq and 97 kBq. Surveys undertaken by divers during 2004 identified 73 fragments on the offshore seabed, all of which were recovered.

In 2004, UKAEA trialed a remotely operated survey vehicle to assist with demarcation of the extent of contamination of the marine environment. In 2005 further monitoring will occur to provide more information on the extent of the contamination of the environment.

In 2005, in accordance with the authorisation issued by the Scottish Environment Protection Agency, UKAEA monitored the beach at Dunnet for the presence of radioactive particles. During this survey UKAEA detected and recovered a piece of contaminated plastic and a single radioactive fragment with activities of 20 kBq and 8.9.kBq caesium-137, respectively.

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 the Scottish Environment Protection Agency's website (Dounreay Particles Advisory Group, 2003).

The Scottish Environment Protection Agency has commissioned the National Radiological Protection Board (NRPB) (now the Radiation Protection Division of HPA) to undertake a re-assessment of potential health effects of particles. The scientific work assessing the probability of encountering a particle and the potential hazard was completed in summer 2005 and is available on the Scottish Environment Protection Agency's website.

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.

** DPAG was set up in 2000 to provide independent advice to Scottish Envionment Protection Agency and UKAEA on issues relating to the Dounreay fragments.*

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 2004 were generally similar to those for 2003. 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).

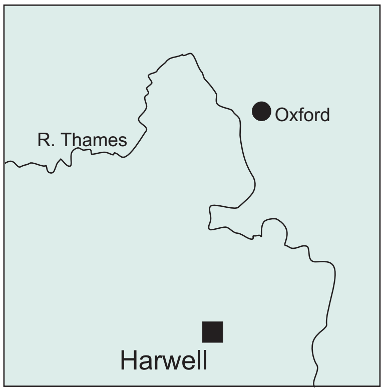
The second potential pathway relates to external exposure over local beaches. Gamma dose rates measured over intertidal areas were close to or less than those measured in previous years. The radiation dose due to occupancy in such areas was 0.007 mSv, which was less than 1% of the annual dose limit for 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 2003. 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. The measurements in 2004 gave results at the LoD, indicating 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 strontium-90, caesium-137, europium-155, uranium, plutonium and americium-241 were reported in samples. The dose to the critical group of local terrestrial consumers, including a contribution due to weapon test fallout, was estimated to be 0.008 mSv, which was less than 1% of the annual dose limit for members of the public of 1 mSv. A similar value was reported for 2003 (0.006 mSv). 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 2004 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.

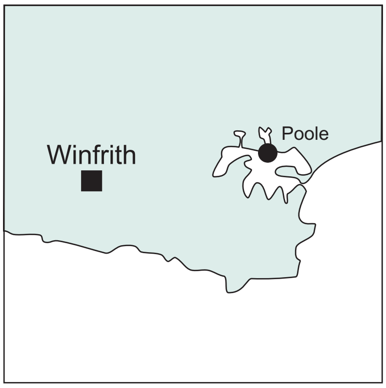
The results of measurements of radioactivity concentrations and dose rates are shown in Tables 4.4(a) and (b).

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 concentrations of most radionuclides in local pike were below the LoD; only caesium-137 was positively detected. The concentration of caesium-137 in pike was lower than for 2003 and there seems to be a continuing decline in levels (1999: 7.4 Bq kg^{-1}; 2000: 3.0 Bq kg^{-1}; 2001: 1.7 Bq kg^{-1}, 2002 and 2003: 0.53 Bq kg^{-1} and 2004: 0.21 Bq kg^{-1}). Concentrations of caesium-137 and plutonium-239/240 in Lydebank Brook were similar to those in 2003.

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 2004 was 0.013 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv (Table 4.2). 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 close to or 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. The Environment Agency consulted on an application by NNC Ltd. to vary its authorisation for radioactive waste disposal from the Winfrith site. NNC required the variation because they relocated to a new building on the site. A new authorisation was issued in 2004. (Environment Agency, 2004f).

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.

Data are presented in Tables 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 total 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 anomalous level of technetium-99 in seaweed from Lulworth Cove in 2003, 200 Bq kg^{-1} was not found in 2004 (2.9 Bq kg^{-1}). 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 2004 at less than 0.005 mSv which was less than 0.5% 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 2004 due to operation of these sites.

4.5.1 Imperial College Reactor Centre, Ascot, Berkshire

The Environment Agency issued a revised authorisation which took effect on 1st December 2004 (Environment Agency, 2004g). This followed public consultation on an application received from the Imperial College of Science, Technology and Medicine principally to reduce the aqueous and gaseous discharge limits (Environment Agency, 2004h). The reductions as implemented now minimise the headroom between limits and actual discharges from the site.

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 2004 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 2004 were less than the limits of detection. The Food Standards Agency will undertake no further terrestrial sampling at this site.

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 the Scottish Environment Protection Agency 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. The Scottish Environment Protection Agency has received applications to amend the operational authorisations in line with current work.

Research sites

Table 4.1. Concentrations of radionuclides in the environment near Culham, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha	Total beta
Freshwater	River Thames (upstream)	2	<4.0				<0.40	<0.037	0.25
Freshwater	River Thames (downstream)	2	<4.0				<0.40	<0.040	0.23
Grass	1 km west of site perimeter	1	97	<25	2.6	<2.0	<1.5		470
Sediment	River Thames (upstream)	2					12		
Sediment	River Thames (downstream)	2					24		
Soil	1 km west of site perimeter	1	<25	<25	5.2	<2.0	6.4		480

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

Table 4.2. Individual radiation exposures – research sites, 2004

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	0.007	-	-	0.007	-
	Geo occupants	<0.005	-	-	<0.005	-
	Consumers of locally grown food	0.008	-	0.008	-	-
Harwell	Anglers	0.013	<0.005	-	0.013	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Winfrith	Seafood consumers	<0.005	<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, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples															
Crabs[b]	Pipeline	1	<0.11	<0.51	<0.10	<0.29	<0.10	<1.1	<4.4	1.6	<0.85	<0.11	<0.20	<0.10	<0.10
Crabs	Pipeline inner zone	2	<0.10	<0.29	<0.10	<0.18		<0.64	<2.3		<0.56	<0.10	<0.15	<0.10	<0.14
Crabs	Strathy	4	<0.15	<0.27	<0.13	<0.38		<0.53	<0.71		<1.3	<0.15	<0.34	<0.14	<0.14
Crabs	Kinlochbervie	4	<0.14	<0.28	<0.13	<0.32		<0.54	<0.97	0.88	<1.0	<0.14	<0.27	<0.13	<0.11
Crabs	Melvich Bay	4	<0.11	<0.17	<0.11	<0.27		<0.31	<0.33	1.7	<0.91	<0.11	<0.24	<0.11	<0.11
Winkles	Brims Ness	4	<0.13	<0.21	<0.13	<0.32	<0.10	<0.39	<0.72		<1.1	<0.13	<0.31	<0.13	<0.12
Winkles	Sandside Bay	4	<0.12	<0.23	<0.11	<0.28	<0.10	<0.45	<0.90	18	<0.98	<0.12	<0.25	<0.11	<0.11
Mussels	Echnaloch Bay	4	<0.13	<0.26	<0.11	<0.31		<0.51	<0.81	13	<1.1	<0.47	<0.28	<0.11	<0.11
Seaweed	Sandside Bay	4	<0.10	<0.12	<0.12	<0.16		<0.16	<0.19	220	<0.40	<0.10	<0.13	<0.10	0.32
Seaweed	Brims Ness	4	<0.10	<0.12	<0.10	<0.17		<0.19	<0.26		<0.46	<0.10	<0.13	<0.10	<0.14
Seaweed[c]	Kinlochbervie	4	<0.29	<0.16	<0.10	<0.21		<0.27	<0.50	110	<0.55	<0.11	<0.15	<0.10	<0.23
Seaweed	Burwick Pier	4	<0.10	<0.10	<0.10	<0.17		<0.13	<0.10	46	<0.45	<0.10	<0.54	<0.10	<0.16
Sediment	Oigins Geo	2	<0.11	<0.31	<0.11	<0.37		<0.66	<7.8		<0.83	<0.13	<0.25	<0.12	5.3
Sediment	Sandside Bay	4	<0.10	<0.11	<0.10	<0.20		<0.20	<0.20		<0.49	<0.11	<0.15	<0.10	2.6
Sediment	Rennibister	4	<0.10	<0.29	<0.11	<0.35		<0.30	<0.33		<0.84	<0.15	<0.25	<0.12	13
Seawater[d]	Sandside Bay	4	<0.10	<0.10	<0.10	<0.10		<0.14	<0.21		<0.25	<0.10	<0.10	<0.10	<0.10
Spume	Oigins Geo	2	<0.20	<0.45	0.56	<0.80		<0.89	<1.7		<2.9	<0.45	<0.90	<0.36	16

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	1	<0.60	<0.11	<0.19	0.0066	0.031	0.030				
Crabs	Pipeline inner zone	2	<0.40	<0.10	<0.14			<0.10				
Crabs	Strathy	4	<0.77	<0.17	<0.32	0.0037	0.022	0.0098	<0.00063	<0.00063		
Crabs	Kinlochbervie	4	<0.65	<0.14	<0.24	0.0054	0.012	0.0053				
Crabs	Melvich Bay	4	<0.56	<0.13	<0.23	0.0027	0.011	0.011				
Winkles	Brims Ness	4	<0.71	<0.16	<0.30	0.017	0.07	0.22				
Winkles	Sandside Bay	4	<0.63	<0.14	<0.25	0.026	0.12	0.11		<0.0050		
Mussels	Echnaloch Bay	4	<0.68	<0.14	<0.27	0.014	0.08	0.037				
Seaweed	Sandside Bay	4	<0.28	<0.10	<0.15			0.50			<5.9	350
Seaweed	Brims Ness	4	<0.32	<0.10	<0.17			<0.16				
Seaweed[c]	Kinlochbervie	4	<0.39	<0.11	<0.18			<0.17				
Seaweed	Burwick Pier	4	<0.32	<0.10	<0.17			<0.16				
Sediment	Oigins Geo	2	<0.89	<0.18	1.0	2.3	9.8	5.0				
Sediment	Sandside Bay	4	<0.45	<0.35	<0.37	2.8	12	11	0.05	0.11		
Sediment	Rennibister	4	<0.78	<0.18	0.76			<0.40				
Seawater[d]	Sandside Bay	4	<0.18	<0.10	<0.10			<0.10				
Spume	Oigins Geo	2	<2.3	<1.1	<0.86	4.9	25	19				

Table 4.3(a). continued

Material	Location or Selection[e]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{129}I	^{134}Cs	^{137}Cs
Terrestrial samples												
Barley		1	<5.0	<0.06	<0.10	<0.49	<1.1	<0.69	<0.09	<0.020	<0.07	<0.06
Bovine muscle		1	<5.0	<0.05	<0.10	<0.13	<0.13	<0.36	<0.05	<0.020	<0.05	0.09
Bovine offal		1	<5.0	<0.05	<0.10	<0.12	<0.13	<0.34	<0.05	<0.030	<0.05	<0.05
Ovine muscle		1	<5.0	<0.05	<0.10	<0.11	<0.07	<0.31	<0.05	<0.020	<0.05	0.21
Potatoes		1	<5.0	<0.05	<0.10	<0.12	<0.10	<0.39	<0.05		<0.05	<0.05
Rosehips		1	<5.0	<0.05	0.86	<0.21	<0.29	<0.46	<0.08	<0.010	<0.05	1.5
Turnips		2	<5.0	<0.05	0.41	<0.12	<0.11	<0.41	<0.05	<0.0080	<0.05	0.19
Turnips	max				0.45	<0.13	<0.12	<0.43	<0.06			0.27
Grass		6	<5.0	<0.05	<0.39	<0.22	<0.35	<0.40	<0.05	<0.081	<0.05	<0.17
Grass	max				0.92	<0.27	<0.49	<0.46	<0.06	<0.16		0.36
Soil		6	<5.0	<0.07	<1.1	<0.21	<0.21	<0.58	<0.09	<0.12	<0.08	22
Soil	max			<0.09	1.5	<0.24	<0.32	<0.80	<0.13	<0.15	<0.11	29

Material	Location or Selection[e]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{144}Ce	^{155}Eu	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Terrestrial samples										
Barley		1	<0.52					<0.050	<0.050	0.025
Bovine muscle		1	<0.25		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Bovine offal		1	<0.26		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Ovine muscle		1	<0.21		<0.00078	<0.00078	<0.00078	<0.050	<0.050	<0.050
Potatoes		1	<0.29							<0.13
Rosehips		1	<0.33		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Turnips		2	<0.28					<0.050	<0.050	<0.050
Grass		6	<0.29		<0.094	<0.043	<0.087	<0.041	<0.041	<0.057
Grass	max		<0.34		0.19	<0.050	0.20	<0.050	<0.050	0.094
Soil		6	<0.55	1.1	31	1.9	29	<0.064	0.50	<0.19
Soil	max		<0.77	2.0	55	3.6	49	0.099	0.71	0.29

[a] *Except for seawater where units are Bq l^{-1}, and for soil and sediment where dry concentrations apply*
[b] *The concentration of ^{14}C was 40 Bq kg^{-1}*
[c] *The concentration of ^{210}Po was 4.3 Bq kg^{-1}*
[d] *The concentration of ^{3}H was <1.0 Bq l^{-1}*
[e] *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*

Table 4.3(b). Monitoring of radiation dose rates near Dounreay, 2004

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	0.056
Sandside Bay	Winkle bed	4	0.12
Oigin's Geo	Spume/sludge	4	0.16
Melvich	Salt Marsh	1	0.075
Melvich	Sand	1	0.061
Strathy	Sand	1	0.049
Thurso	Riverbank	1	0.099
Achreregan Hill	Soil	1	<0.047
Strathy Park	NA	1	0.082
Archvarasdal	NA	1	0.082
Thurso Park	Soil	1	0.085
Borrowston Mains	Soil	1	0.085
East of Dounreay	Soil	1	0.081
Castletown Harbour	NA	1	0.080
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, 2004

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Shebster	11	<0.011	<0.0055	0.089
Reay	12	<0.010	<0.0058	0.095
Balmore	12	<0.013	<0.0074	0.12

Table 4.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{57}Co	^{60}Co	^{134}Cs	^{137}Cs	^{155}Eu
Freshwater samples									
Pike	Outfall (Sutton Courtenay)	1		<25	<0.03	<0.04	<0.04	0.21	<0.11
Pike	Newbridge	1		<25	<0.03	<0.05	<0.06	<0.05	<0.11
Pike	Staines	1	<25	<25	<0.03	<0.04	<0.04	0.12	<0.10
Pike	Shepperton	1	<25	<25	<0.04	<0.06	<0.05	0.16	<0.11
Pike	Teddington	1	<25	<25	<0.04	<0.06	<0.06	0.11	<0.12
Flounder	Beckton	1		<25	<0.03	<0.06	<0.06	0.25	<0.10
Nuphar lutea	Newbridge	1		<25	<0.05	<0.06	<0.07	<0.05	<0.14
Nuphar lutea	Staines	1		<25	<0.02	<0.04	<0.04	<0.04	<0.06
Mud	Position 'E' [b]	2			<0.60	3.6	<0.92	700	<2.1
Sediment	Appleford	4[E]				<0.66		12	
Sediment	Outfall (Sutton Courtenay)	4[E]				<0.54		7.3	
Sediment	Day's Lock	4[E]				<0.64		5.4	
Sediment	Lydebank Brook	4[E]				<1.4		8.7	
Freshwater	Day's Lock	4[E]		<4.0		<0.44		<0.35	
Freshwater	Lydebank Brook	4[E]		<4.3		<0.43		<0.37	
Freshwater	R Thames (above discharge point)	4[E]		<4.0		<0.47		<0.39	
Freshwater	R Thames (below discharge point)	4[E]		<4.0		<0.49		<0.39	

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
Freshwater samples									
Pike	Outfall (Sutton Courtenay)	1			<0.11				
Pike	Newbridge	1	0.000063	0.00022	0.00041	*	*		
Pike	Staines	1			<0.10				
Pike	Shepperton	1			<0.14				
Pike	Teddington	1			<0.15				
Flounder	Beckton	1			<0.06				
Nuphar lutea	Newbridge	1			<0.12				
Nuphar lutea	Staines	1			<0.03				
Mud	Position 'E' [b]	2			4.1				
Sediment	Appleford	4[E]	<0.51	<0.23	0.62			<210	330
Sediment	Outfall (Sutton Courtenay)	4[E]	<0.49	<0.24	<0.40			250	430
Sediment	Day's Lock	4[E]	<0.33	<0.30	0.45			200	370
Sediment	Lydebank Brook	4[E]	<0.50	0.47	0.59			190	460
Freshwater	Day's Lock	4[E]						<0.037	0.22
Freshwater	Lydebank Brook	4[E]						<0.040	0.16
Freshwater	R Thames (above discharge point)	4[E]						<0.055	0.24
Freshwater	R Thames (below discharge point)	4[E]						<0.076	0.24

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	<4.4	<4.4	<0.35	<0.29	<0.31
Milk	max		<5.0	<5.0	<0.38	<0.30	<0.33
Apples		1	<4.0	<4.0	<0.30	<0.40	<0.40
Beetroot		1	2.0	6.0	<0.50	<0.40	<0.40
Blackberries		1	<4.0	<4.0	<0.30	<0.30	<0.30
Honey		1		<6.0	<0.20	<0.20	<0.20
Potatoes		1	<5.0	5.0	<0.20	<0.30	<0.40
Spinach		1	<4.0	<4.0	<0.40	<0.30	<0.40

[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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 4.4(b). Monitoring of radiation dose rates near Harwell, 2004

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Appleford	Mud	1	0.069
Appleford	Grass and mud	1	0.073
Sutton Courtenay	Grass and soil	1	0.080
Sutton Courtenay	Grass and pebbles	1	0.078
Position "E"[a]	Soil	2[F]	0.084
Day's Lock	Mud	2	0.069

[a] *Near the outfall*

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 4.5(a). Concentrations of radionuclides in food and the environment near Winfrith, 2004

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									
Plaice	Weymouth Bay	2		<0.06	<0.17		0.11		
Bass	Weymouth Bay	2		<0.05	<0.13		0.32		
Crabs	Chapman's Pool	1		0.23	<0.17		<0.06	0.000083	0.00045
Crabs	Lulworth Banks	1	35	0.17	<0.20		<0.06	0.00024	0.0010
Pacific Oysters	Poole	1		<0.13	<0.36		<0.11		
Cockles	Poole	1		0.32	<0.07		0.04		
Whelks	Poole	1		0.14	<0.13		<0.04	0.00041	0.0022
Scallops	Lulworth Ledges	1		<0.04	<0.13		<0.04	0.00032	0.0023
Clams	Portland Harbour	1		0.36	<0.35		<0.10		
Fucus serratus	Kimmeridge	2		0.61	<0.29	0.72	<0.09		
Fucus serratus	Bognor Rock	2		0.34	<0.13	1.4	<0.04		
Seaweed	Lulworth Cove	2[E]		<2.0		2.9	<1.5		
Seawater	Arish Mell	2[E]		<0.38			<0.31		

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							
Plaice	Weymouth Bay	2	<0.26				
Bass	Weymouth Bay	2	<0.10				
Crabs	Chapman's Pool	1	0.0011	*	0.000041		
Crabs	Lulworth Banks	1	0.0016	*	0.000022		
Pacific Oysters	Poole	1	<0.47				
Cockles	Poole	1	<0.09				
Whelks	Poole	1	0.0024	*	0.000059		
Scallops	Lulworth Ledges	1	0.00039	*	0.000012		
Clams	Portland Harbour	1	<0.23				
Fucus serratus	Kimmeridge	2	<0.36				
Fucus serratus	Bognor Rock	2	<0.05				
Seaweed	Lulworth Cove	2[E]	<1.9				
Seawater	Arish Mell	2[E]	<0.41			<3.3	12

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	<4.0	<4.0	18	<0.29	<0.29		
Milk	max				19	<0.33	<0.30		
Apples		1	<6.0	<4.0	8.0	<0.20	<0.40		
Cabbage		1	<6.0	<4.0	11	<0.40	<0.40		
Carrots		1	<4.0	<4.0	5.0	<0.20	<0.40		
Honey		1		<7.0	110	<0.20	<0.20		
Potatoes		1	<5.0	<4.0	16	<0.30	<0.30		
Raspberries		1	<6.0	<4.0	16	<0.30	<0.30		
Grass		2	<4.5	<5.0	26	<0.30	2.5		
Grass	max		<5.0		29		3.9		
Sediment	North of site	2[E]				<0.53	7.2	<120	<110
Sediment	R Frome (upstream)	2[E]				<0.59	<1.1	<100	<180
Sediment	R Frome (downstream)	2[E]				<0.92	5.7	170	220
Sediment	R Win, East of site	2[E]				<1.2	<3.9	<390	<320
Freshwater	North of site	2[E]		15		<0.43	<0.34	<0.24	0.55
Freshwater	R Frome (upstream)	2[E]		<4.0		<0.48	<0.40	<0.031	<0.12
Freshwater	R Frome (downstream)	2[E]		<6.8		<0.50	<0.40	<0.037	<0.15
Freshwater	R Win, East of site	2[E]		<6.5		<0.51	<0.40	<0.028	0.17

** 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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency

Table 4.5(b). Monitoring of radiation dose rates near Winfrith, 2004

Location	Material or ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m			
Weymouth Bay	Pebbles and sand	1	0.055
Red Cliffe Point to Black Head	Pebbles	1	0.053
Osmington Mills	Rock and stones	1	0.060
Ringstead Bay	Pebbles and sand	1	0.052
Durdle Door	Pebbles and shingle	1	0.053
Lulworth Cove	Pebbles	1	0.064
Kimmeridge Bay	Pebbles and stones	1	0.071
Swanage Bay 1	Sand	1	0.054
Swanage Bay 2	Sand	1	0.056
Swanage Bay 3	Sand	1	0.057
Poole Harbour	Pebbles and sand	1	0.051

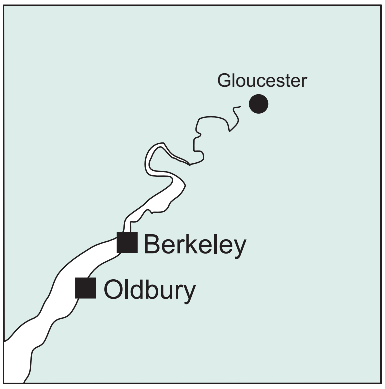
5. NUCLEAR POWER STATIONS

This section considers the effects of discharges from 13 locations where nuclear power stations were operating or undergoing defuelling or decommissioning during 2004. 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 BNG, one of the BNFL companies). British Energy Generation Ltd. and British Energy Generation (UK) Ltd. operate a fleet of 7 advanced gas-cooled reactor (AGR) power stations and 1 PWR power station. Magnox Electric operates a fleet of 10 older Magnox power stations, 6 of which are now decommissioning.

Estimates of dose discussed in this section (and summarised in Table 5.1) do not include a component from direct radiation from the site. The sites are grouped in the section according to whether they are in England, Scotland or Wales.

ENGLAND

5.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire



Berkeley and Oldbury are both Magnox power stations. 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 the GE (Healthcare) 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 advisory level for gaseous discharge of carbon-14 in May 2004. The Food Standards Agency organised early collection and analysis of local milk samples to establish whether further action was needed. The highest concentration of carbon-14 detected in milk was 32 Bq l^{-1}, which dropped down to 9 Bq l^{-1} three weeks later, with an average over the 4 weeks sampled of 22 Bq l^{-1}. The average from all farms for the year was 17 Bq l^{-1} and the observed increase at the time of sampling would have had a minor effect on the annual radiation dose.

Data for 2004 are presented in Tables 5.2(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

** British Nuclear Group run the Magnox stations under contract to NDA as of 1st April 2005*

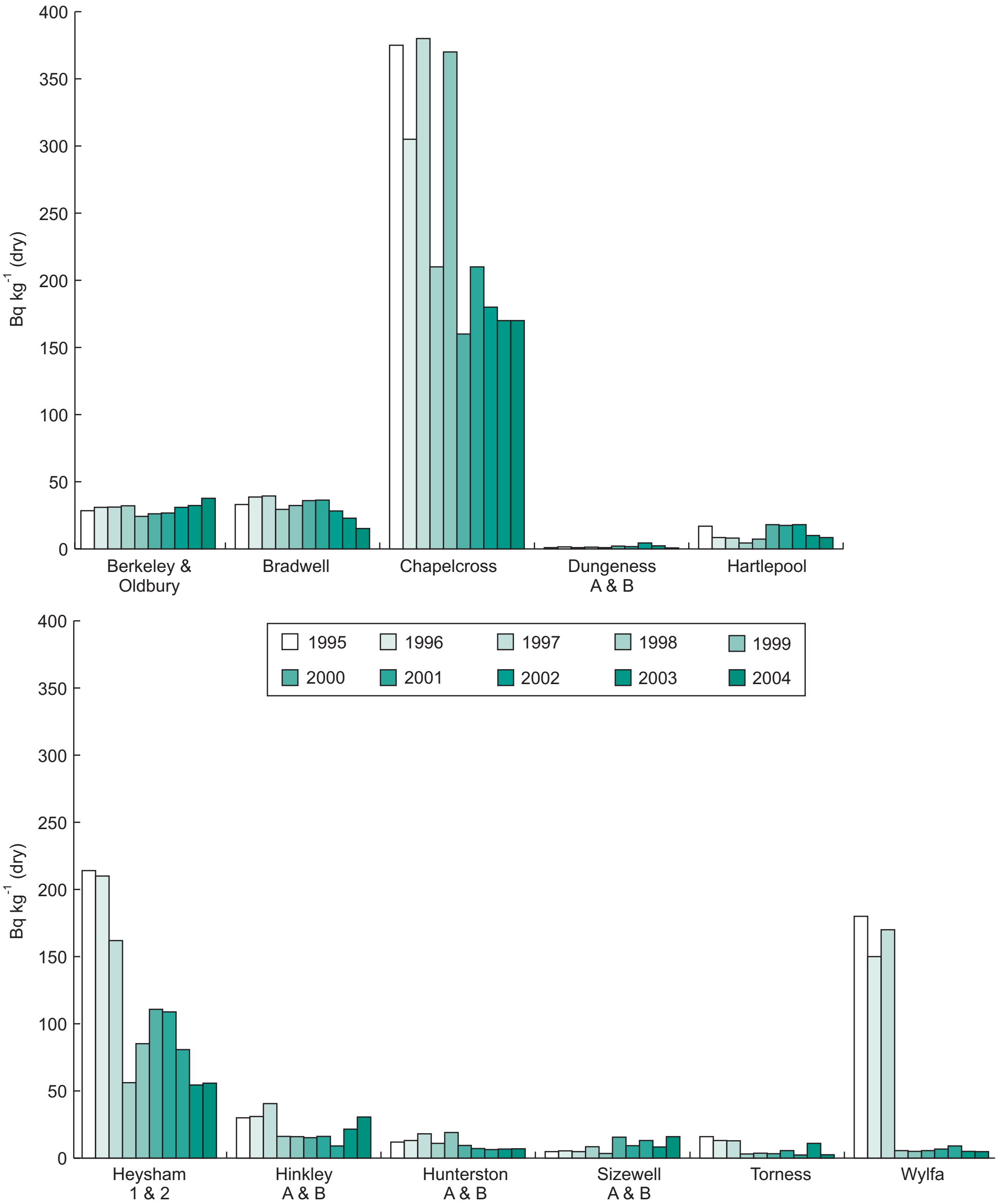
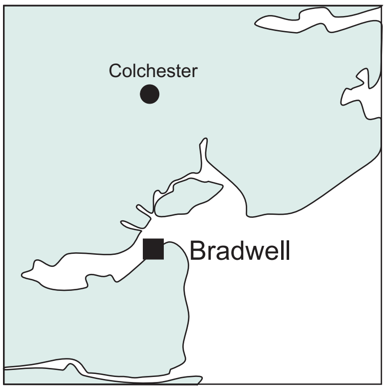


Figure 5.1 Caesium-137 concentration in sediments near nuclear power stations

discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. Caesium-137 concentrations in sediment have remained the same for the last decade (Figure 5.1). Relatively high concentrations of tritium were detected in fish and shellfish and these were mainly due to discharges from GE (Healthcare) 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 0.006 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 5.1). This includes external radiation and a component due to the tritium originating from GE (Healthcare) 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 total 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 0.005 mSv, which was 0.5% of the dose limit.

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, fruit and crop samples for tritium, carbon-14 and sulphur-35. Samples of water are also taken from a coastal ditch and public supplies. 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 2004 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 generally similar to those for 2003, however, there is evidence for a decline in caesium-137 concentrations in sediments (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}. Tritium concentrations in the ditch increased in 2004 but were substantially below the EU reference level for tritium of 100 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 0.007 mSv, mostly due to the effects of external exposure, which was less than 1% 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 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.

In April 2004, during defuelling airborne contamination was inadvertently released onto the pilecap in Reactor 2. The release into the reactor building was estimated to involve 160 MBq of cobalt-60, although none was released to the environment. Milk samples from a nearby farm were analysed for cobalt-60. No activity was detected.

5.3 Dungeness, Kent

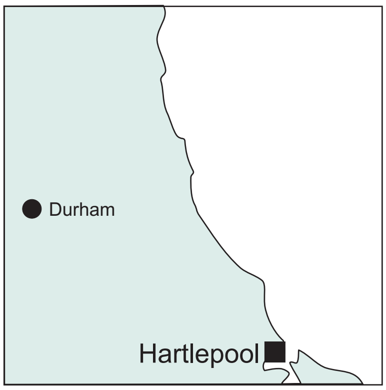
There are two separate ‘A’ and ‘B’ nuclear power stations on this site; the ‘A’ station is powered by Magnox reactors and the ‘B’ station by AGRs. Discharges are made via separate but adjacent outfalls and stacks, and for the purposes of environmental monitoring these are considered together.

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 four occasions in 2004 Dungeness ‘A’ operators notified the Environment Agency that weekly advisory levels for gaseous discharge of carbon-14 had been or were likely to be exceeded. In each case, milk sampling from the nearest dairy farms was considered and on three occasions samples were collected and analysed for carbon-14 in advance of the normal programme. Analyses for tritium and sulphur-35 were also undertaken. No change in the normal levels expected near the site was observed.

The results of monitoring for 2004 are given in Tables 5.4(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 sediment were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood. Gamma dose rates were difficult to distinguish from the natural background; beta dose rates were not detected. The critical group was represented by local bait diggers who also eat fish and shellfish. Their radiation dose was low at 0.013 mSv, which was less than 2% 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 total beta activity in freshwater were within WHO screening levels for drinking water. 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 2004 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.

5.4 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. This year the analytical schedule was extended to include determinations of lead-210 and polonium-210, to consider the possibility of local enhancement of natural radionuclides from waste slag historically disposed of from the local iron or steel industry along parts of the River Tees. A selection of terrestrial foods, including milk, was sampled in surveillance of gaseous disposals.

In June 2004, an incident occurred at the power station in which approximately two cubic metres of tritiated water was spilled within the effluent treatment plant (Environment Agency, 2004i). This resulted in enhanced discharges of tritium to atmosphere via the engineered ventilation systems for a period of time following the event. The increase in tritium discharges to atmosphere as a result of the event was approximately 25% of the annual limit over a period of about three months, but the impact of the event on public health and the environment was small. The Quarterly Notification Level (QNL) for tritium discharges to atmosphere was exceeded as a result of the event, but discharges of tritium to atmosphere remained well within the authorised annual limits. Milk samples were taken from a nearby farm shortly after the event. No increase above normal levels were found in these samples.

Results of the routine monitoring programme carried out in 2004 are shown in Tables 5.5(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 for drinking water. The critical group dose in 2004 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 2004. 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 a combination of waste slag from local iron or steel industry, used in sea defences, or and the build up of natural gamma-ray-emitting radionuclides in sediments at this location as the result of degradation of the sea defence materials over time. The critical occupancy group does not spend time at Paddy's Hole. The radiation dose to local fish and shellfish consumers, including external radiation but excluding natural radionuclides in seafood, 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.

The concentrations of lead-210 and polonium-210 found in winkles from Paddy's Hole are above those expected due to natural sources (see Appendix 6). They are based on a single sample. If the expected background concentrations are subtracted, and the consumption rate of molluscs for the critical group for the Hartlepool power station is used, the estimated dose to seafood consumers from the enhancement is 0.18 mSv. It is premature to regard the estimate as reliable because (i) Paddy's Hole is unlikely to sustain a high rate consumption of molluscs as it is a very localized area which contains oil and other wastes, (ii) the most recent habits survey undertaken did not identify any consumption of molluscs from Paddy's Hole and (iii) earlier results found no significant local enhancement (Rollo et. al., 1992). Nevertheless this level of exposure deserves further investigation and work is underway to extend the sampling and analysis for lead-210, polonium-210 and other natural radionuclides in seafood and sediments near Hartlepool. Results will be reported in the RIFE report for 2005.

5.5 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 2004 are given in Tables 5.6(a) and (b). In general, similar levels to those for 2003 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 but they are in decline (Figure 5.1). The radiation dose in 2004 to the critical group of fishermen, including a component due to external radiation, was 0.068 mSv, which is well within the dose limit for members of the public of 1 mSv (Table 5.2) and a small decrease compared with 0.075 mSv in 2003.

The effects of gaseous disposals were also difficult to detect in 2004. Small enhancements of concentrations of carbon-14 were apparent in some samples. The critical group dose was estimated to be 0.005 mSv which was 0.5% of the dose limit for members of the public of 1 mSv.

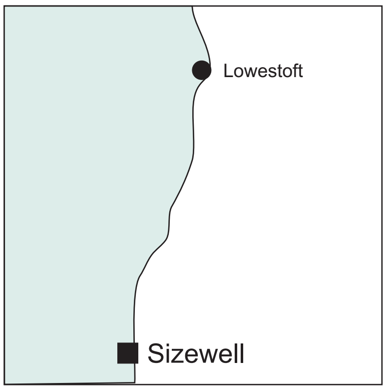
5.6 Hinkley Point, Somerset

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. Defuelling was complete 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 GE Healthcare plant at Cardiff.

The environmental results for 2004 are presented in Tables 5.7 (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 2003 (see also Figure 5.1), however, tritium in cod and shrimps reduced to roughly half their levels in 2003. 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 tests 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 GE Healthcare, 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 2003. The critical group of local fishermen was estimated to receive a dose of 0.017 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 2004 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). Freshwater contained alpha and beta activities less than WHO screening levels for drinking water. 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.

5.7 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 2004 are shown in Tables 5.8 (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 2004, 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 2004. 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 2004 was 0.040 mSv or 4% of the dose limit for members of the public of 1 mSv.

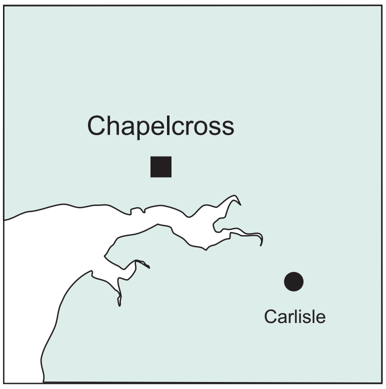
In March 2004, Sizewell ‘A’ exceeded its QNL for discharges of gaseous carbon-14. Milk samples were taken and analysed in advance of the normal scheduled programme and the results showed concentrations of carbon-14 up to 29 Bq l^{-1} (the average for the year was 20 Bq l^{-1}). There was a minor effect on the annual radiation dose and no further action was necessary.

Deficiencies were found in the liquid waste filtration system at Sizewell B in 2004. Small amounts of particulate material were detected in the liquid waste stream. Monitoring by the Environment Agency and the operators showed that there was no detectable hazard to the public or the environment (Environment Agency, 2004j). The Environment Agency issued an Enforcement Notice to the company to ensure compliance with the need to operate and maintain equipment to the highest standard.

In October 2004, the Environment Agency was notified of a failure in the equipment for monitoring the discharge of tritium from Sizewell B over a period of one month. Milk samples were taken from two farms nearest the site and analysed for tritium and carbon-14 (for reassurance purposes). No increases above normal levels were observed.

SCOTLAND

5.8 Chapelcross, Dumfries and Galloway



In June of 2004, Magnox Electric (part of BNG) formally notified the Scottish Environment Protection Agency 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 Magnox Electric. 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 the Scottish Environment Protection Agency. The end of power generation at Chapelcross also brought an end to the discharge of the radioactive gas, argon-41. As discharges only took place whilst the power station was operating, the amount of argon-41 discharged to the atmosphere in 2004 was a factor of ten lower than in 2003.

In August 2004, BNFL and Magnox Electric plc. made a joint application to transfer the authorisations held for Chapelcross from BNFL to Magnox Electric plc. The transfer was granted in 2005.

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 2004 are presented in Tables 5.9(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 in intertidal areas remained at similar levels to those detected in recent years. Gamma dose rates in 2004 are lower than those measured in 2003 but are not unusual as they are similar to previous years. These small variations are not thought to be significant because radionuclide concentrations in the underlying substrates did not reduce correspondingly (Figure 5.1). Reductions in dose rate compared to 2003 were also observed at other Scottish sites.

The dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.027 mSv in 2004 which was less than 3% of the dose limit for members of the public of 1 mSv (Table 5.2). The reduction in dose from 0.037 mSv in 2003 was due to the lower gamma dose rates reported from the re-calibrated instruments. 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 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 2004 resulted in three items with radioactivity above background being found and removed. This compares with 21 items in 2003, three 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 2003. 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 0.029 mSv, which was less than 3% of the dose limit for members of the public of 1 mSv. Most of the dose is due to consumption of local foodstuffs. The annual dose contribution from argon-41, calculated from an atmospheric transport model (see Appendix 2) was much less than 0.005 mSv. 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 5.9(c)). The annual dose from inhaling air containing caesium-137 at these concentrations was estimated to be much less than 0.005 mSv.

5.9 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 Magnox Electric (part of BNG). 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.

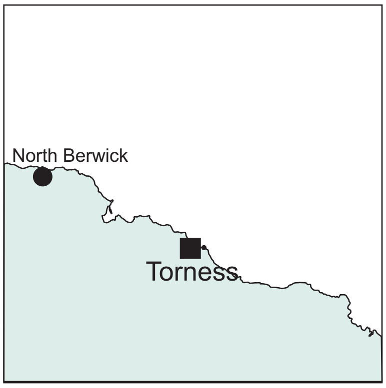
Environmental monitoring in the area considers the effects of both sites together. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental 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 2004 are shown in Tables 5.10(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 squat lobsters decreased substantially in 2004. However, that in the common lobster doubled. 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 2004, 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). This includes a contribution from the Sellafield – derived technetium-99 in shellfish.

The dose to a separate critical group of shellfish collectors who use local beaches was 0.010 mSv or 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 0.022 mSv which was approximately 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.

5.10 Torness, East Lothian



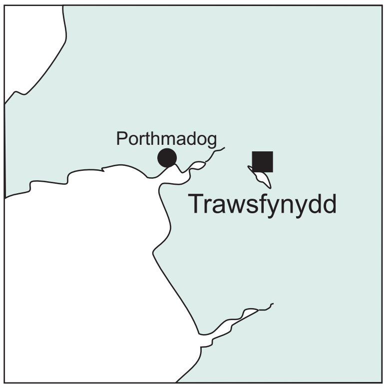
This station, which is powered by two AGRs, came into operation at the end of 1987. A review of the monitoring programme at this site was undertaken in 2000, and resulted in increased sampling of milk, vegetables, fruit, seafood, seawater, seaweed and soil. Various species of plants were monitored as 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.

The results of this monitoring in 2004 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. Technetium-99 concentrations in marine samples reduced by more than a factor of ten in 2004. This is probably due to the reductions in discharge of this radionuclide from Sellafield though a similar effect was not observed at Dounreay and Hartlepool to the north and south of Torness. The dose to fish and shellfish consumers (the critical group) 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).

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 0.016 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

WALES

5.11 Trawsfynydd, Gwynedd



This station is being decommissioned but low level discharges continued during 2004 under an authorisation 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 eggs and carrots 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 blackberries and sloes 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 2004.

The critical group for terrestrial foods at Trawsfynydd in 2004 received doses of 0.005 mSv, which was 0.5% 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 difficult to distinguish from background levels and were similar to those in 2003. The predominant radionuclide is caesium-137. The time trend of concentrations of caesium-137 in sediments is shown in Figure 5.2. A substantial decline in levels was observed in the late 1990s in line with reducing discharges. The observed levels now are mainly affected by sample variability. In 2004, the concentration in lake mud near the power station reduced. This is most likely to be due the normal sampling variability, which is expected in sediments from the lake bed.

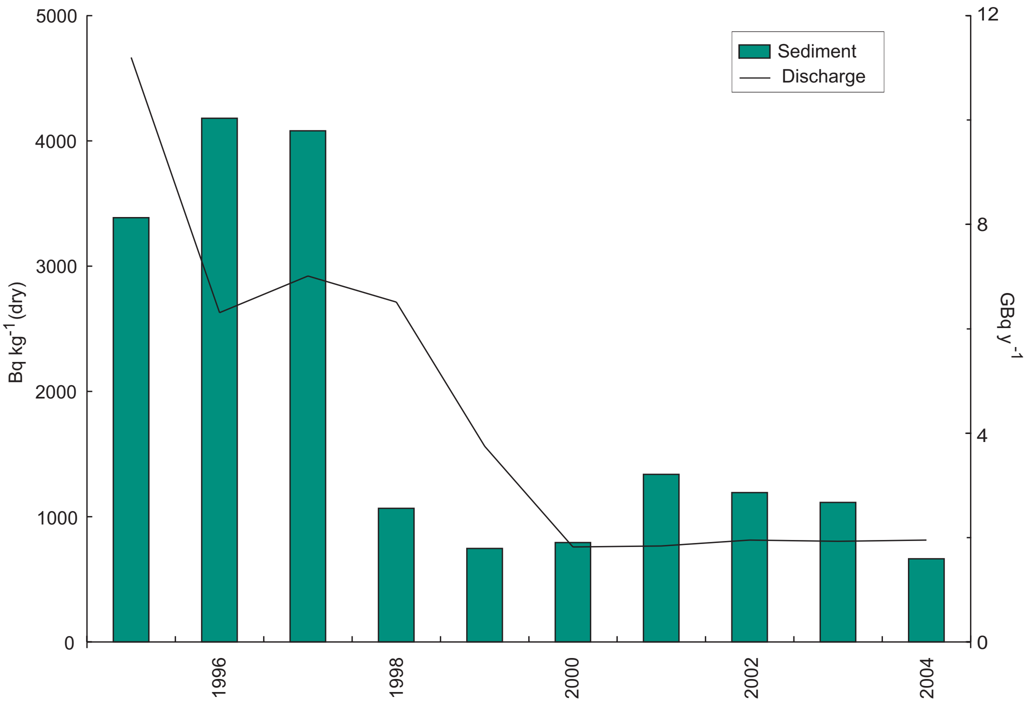
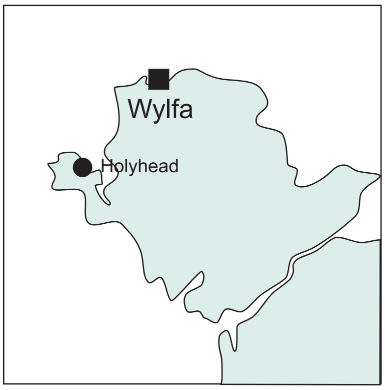


Figure 5.2 Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake

Concentrations of radiocaesium in fish in 2004 were similar to those in 2003. The activity concentrations in sediments and the residual activity in the fish that result from earlier discharges predominate at this stage. Low concentrations of other radionuclides including actinides are also detected, particularly in lake sediments. However, the actinide concentrations in fish are very low and it is the effects of caesium-137, which dominate the fish consumption and external radiation pathways. The dose to the critical group of anglers was 0.015 mSv in 2004, which was less than 2% of the dose limit for members of the public of 1 mSv. The reduction from the estimate of 0.032 mSv in 2003 was due to a reduction in the observed concentrations in lake sediments. It is these that are used as the basis for external radiation calculations in view of the difficulty in establishing the increase in measured dose rates above natural background levels.

5.12 Wylfa, Isle of Anglesey



This station generates electricity from two Magnox reactors. Gaseous and liquid wastes from this station were discharged in 2004 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 2004 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 2003, and continued to show the effects of technetium-99 from Sellafield. A habits survey was undertaken in 2004. For marine pathways, the critical group remained as fish and shellfish consumers with an additional element of beach occupancy; however, consumption and occupancy rates reduced (Appendix 4). The dose to the critical group of high-rate 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). The reduction from 0.012 mSv in 2003 was largely due to the new estimates of consumption and occupancy rates. Gamma dose rates, measured using portable instruments were similar to those found in 2003.

5. Nuclear power stations

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 April 2004, the site operators reported that the weekly advisory levels for tritium and carbon-14 had been exceeded. The Food Standards Agency undertook extra analyses of individual weekly samples of local milk but found no elevated concentrations of either radionuclide.

Table 5.1. Individual radiation exposures – nuclear power stations, 2004

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
England						
Berkeley and Oldbury	Seafood consumers	0.006	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.005	-	<0.005	-	<0.005
Bradwell	Seafood consumers	0.007	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Dungeness	Seafood consumers	0.013	<0.005	-	0.010	-
	Inhabitants and consumers of locally grown food	0.11	-	<0.005	-	0.11
Hartlepool	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b,c]	<0.005	-	<0.005	-	-
Heysham	Seafood consumers	0.068	0.048	-	0.020	-
	Consumers of locally grown food[b]	0.005	-	0.005	-	-
Hinkley Point	Seafood consumers	0.017	<0.005	-	0.013	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Sizewell	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.040	-	<0.005	-	0.038
Scotland						
Chapelcross	Seafood consumers	0.027	0.009	-	0.018	-
	Inhabitants and consumers of locally grown food[b]	0.029	-	0.026	-	<0.005
Hunterston	Seafood consumers	<0.005	<0.005	-	-	-
	Beach occupants	0.010	-	-	0.010	-
	Consumers of locally grown food[b]	0.022	-	0.022	-	-
Torness	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	0.016	-	0.016	-	-
Wales						
Trawsfynydd	Anglers	0.015	<0.005	-	0.010	-
	Consumers of locally grown food[b]	0.005	-	0.005	-	-
Wylfa	Seafood consumers	<0.005	<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*
[c] *Excluding possible enhancement of natural radionuclides. See Section 5*

Table 5.2(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2004

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	^{155}Eu	^{238}Pu
Marine samples									
Salmon	Beachley	2	<25			<0.09	0.22	<0.20	
Bass	River Severn	1	2600			0.32	3.0	<0.13	
Elvers	River Severn	1	<25			<0.17	<0.14	<0.27	
Shrimps	Guscar	2	880	43		<0.12	0.58	<0.15	0.00033
Seaweed	Near pipeline	2[E]			6.6	<2.3	<2.2		
Mud	Hills Flats	2				1.5	36	<2.1	
Sediment	Hills Flats	2[E]					36		
Mud	1 km south of Oldbury	2				2.4	38	<2.1	
Sediment	1 km south of Oldbury	2[E]					40		
Sediment	2 km south west of Berkeley	2[E]					41		
Sediment	Sharpness	2[E]					32		
Seawater	Local beach	2[E]				<0.38	<0.33		

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		<0.22				
Bass	River Severn	1		<0.16				
Elvers	River Severn	1		<0.30				
Shrimps	Guscar	2	0.0019	0.0018	0.000027	0.000060		
Seaweed	Near pipeline	2[E]		<2.9				
Mud	Hills Flats	2		<2.2				
Sediment	Hills Flats	2[E]		<1.8				
Mud	1 km south of Oldbury	2		<2.2				
Sediment	1 km south of Oldbury	2[E]		<1.9				
Sediment	2 km south west of Berkeley	2[E]		<2.3				
Sediment	Sharpness	2[E]		<1.9				
Seawater	Local beach	2[E]		<0.46			<0.79	3.2

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	<4.0	17	<0.58	<0.28	<0.31		
Milk	max		<4.3	21	<0.73	<0.30	<0.33		
Apples		1	<4.0	18	<0.40	<0.30	<0.30		
Blackberries		1	<3.0	17	<0.40	<0.30	<0.30		
Cabbage		1	<4.0	<3.0	0.30	<0.30	<0.30		
Honey		1	<5.0	100	0.80	<0.20	<0.20		
Onions		1	<4.0	5.0	<0.40	<0.30	<0.40		
Potatoes		1	<4.0	25	<0.40	<0.30	<0.30		
Runner beans		1	<4.0	3.0	0.30	<0.30	<0.40		
Wheat		1	<6.0	110	1.0	<0.30	<0.30		
Freshwater	Gloucester and Sharpness Canal	2[E]	<4.0		<1.0	<0.39	<0.37	<0.038	0.22
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.43	<0.40	<0.037	0.25

[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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.2(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2004

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1 m over intertidal areas			
1km south of Oldbury	Mud	2[F]	0.072
1km south of Oldbury	Mud	1	0.086
1km south of Oldbury	Mud and stones	1	0.087
2km south west of Berkeley	Mud	1	0.076
2km south west of Berkeley	Mud and rock	1	0.072
Guscar Rocks	Mud	1	0.10
Guscar Rocks	Mud and salt marsh	1	0.084
Lydney Rocks	Mud	1	0.077
Lydney Rocks	Mud and rock	1	0.11
Sharpness	Salt marsh	2	0.083
Hills Flats	Mud	2[F]	0.073
Hills Flats	Salt marsh	2	0.083
Aust Rock	Mud	2[F]	0.086

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 5.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{60}Co	^{65}Zn	^{99}Tc	^{134}Cs	^{137}Cs	^{155}Eu
Marine samples								
Sole	Bradwell	2	<0.09	<0.26		<0.09	0.59	<0.14
Bass	Pipeline	1	<0.04	<0.11		0.11	1.6	<0.12
Mullet	Pipeline	1	<0.05	<0.14		<0.06	0.96	<0.10
Lobsters	West Mersea	1	<0.05	<0.15		<0.06	0.30	<0.17
Native oysters	Tollesbury N. Channel	1	<0.04	<0.10		<0.04	0.57	<0.11
Pacific oysters	Goldhanger Creek	2	<0.13	<0.34		<0.13	0.40	<0.20
Winkles	Pipeline	2	<0.16	<0.39		<0.17	0.70	<0.31
Winkles	Heybridge Basin	2	<0.19	<0.43		<0.19	0.88	<0.45
Fucus vesiculosus	Waterside	2	<0.10	<0.22	5.9	0.18	3.1	<0.21
Seaweed	Bradwell	1[E]	<0.92		21	<0.80	2.2	
Leaf beet	Tollesbury	1	<0.08	<0.19		<0.08	<0.06	<0.11
Samphire	Tollesbury	1	<0.02	<0.08		0.04	0.70	<0.08
Sediment	Pipeline	2[E]	<0.53				5.6	
Sediment	Maldon	1[E]	<0.72				28	
Sediment	West Mersea	2[E]	<0.89				16	
Sediment	Waterside	2[E]	<1.1				25	
Sediment	1.5 km east of pipeline	2[E]	<1.1				<1.7	
Seawater	Bradwell	2[E]	<0.40			<0.38	<0.35	

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									
Sole	Bradwell	2			<0.07				
Bass	Pipeline	1			<0.11				
Mullet	Pipeline	1			<0.06				
Lobsters	West Mersea	1			<0.25				
Native oysters	Tollesbury N. Channel	1	0.00027	0.0014	0.0026	*	0.00013		
Pacific oysters	Goldhanger Creek	2			<0.19				
Winkles	Pipeline	2			<0.23				
Winkles	Heybridge Basin	2			<0.58				
Fucus vesiculosus	Waterside	2			<0.29				180
Seaweed	Bradwell	1[E]			<1.0				
Leaf beet	Tollesbury	1			<0.06				
Samphire	Tollesbury	1			<0.12				
Sediment	Pipeline	2[E]			<0.82				
Sediment	Maldon	1[E]			<0.95				
Sediment	West Mersea	2[E]			<1.2				
Sediment	Waterside	2[E]			<1.5				
Sediment	1.5 km east of pipeline	2[E]			<1.6				
Seawater	Bradwell	2[E]			<0.51			<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	^{60}Co	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples										
Milk		5	<4.1	19	<0.55	<0.29	<0.27	<0.30		
Milk	max		<4.5	21	<0.83	<0.33	<0.28	<0.35		
Apples		1	<4.0	19	<0.40	<0.40	<0.30	<0.40		
Blackberries		1	<4.0	13	0.50	<0.30	<0.30	<0.30		
Cabbage		1	<4.0	11	<0.70	<0.40	<0.30	<0.40		
Carrots		1	<4.0	12	<0.40	<0.30	<0.30	<0.40		
Lucerne		1	<4.0	18	0.80	<0.40	<0.30	<0.40		
Potatoes		1	<4.0	20	0.60	<0.30	<0.40	<0.40		
Wheat		1	<6.0	110	0.20	<0.30	<0.30	<0.30		
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.50	<0.46	<0.41	<0.050	0.30
Freshwater	Coastal ditch 3	1[E]	21		<1.0	<0.47	<0.44	<0.38	<0.60	8.0
Freshwater	Coastal ditch 4	1[E]	46		<1.0	<0.31	<0.29	<0.27	<0.49	17

* *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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.3(b). Monitoring of radiation dose rates near Bradwell, 2004

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Bradwell Beach	Sand and shingle	1	0.077
Bradwell Beach	Pebbles and sand	1	0.068
Beach opposite power station, N side of estuary	Mud	1	0.069
Beach opposite power station, N side of estuary	Salt marsh	1	0.071
0.5km E of pipeline	Sand and shale	1	0.066
0.5km E of pipeline	Pebbles and sand	1	0.063
Waterside	Mud	1	0.067
Waterside	Sand and shingle	1	0.056
West Mersea	Mud	1	0.070
West Mersea	Mud and shingle	1	0.061
Maldon	Mud	1	0.069

Table 5.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2004

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	^{134}Cs	^{137}Cs
Marine samples										
Plaice	Pipeline	2	<25	<25		<0.12			<0.13	<0.14
Cod	Pipeline	2		<25		<0.05			<0.05	0.30
Bass	Pipeline	1		<25		<0.05			<0.05	0.47
Crabs	Hastings	1				<0.06			<0.05	0.04
Shrimps	Pipeline	2	<25	<25	29	<0.16			<0.15	<0.17
Whelks	Pipeline	2				<0.11	<0.030		<0.05	<0.06
Cuttlefish	Hastings	1				<0.03			<0.03	0.04
Fucus vesiculosus	Copt Point	1						8.5		
Seaweed	Copt Point	2[E]				<2.0		15	<1.7	<1.5
Mud and sand	Rye Harbour	2				<0.55			<0.61	1.1
Sediment	Rye Harbour 1	1[E]				1.5				<0.88
Sediment	Rye Harbour 2	1[E]				<0.73				<0.56
Sediment	Camber Sands	2[E]				<0.64				<0.54
Sediment	Pilot Sands	1[E]				<0.59				<0.44
Seawater	Pipeline	2		2.9						
Seawater	Dungeness South	2[E]				<0.47			<0.44	<0.41

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										
Plaice	Pipeline	2	<0.20			<0.13				
Cod	Pipeline	2	<0.11			<0.13				
Bass	Pipeline	1	<0.15			<0.23				
Crabs	Hastings	1	<0.15			<0.15				
Shrimps	Pipeline	2	<0.27			<0.26				
Whelks	Pipeline	2	<0.15	0.00058	0.0027	0.0033	*	0.00025		
Cuttlefish	Hastings	1	<0.09			<0.08				
Seaweed	Copt Point	2[E]				<2.1				
Mud and sand	Rye Harbour	2	<1.3	0.043	0.25	0.21	0.0024	0.011		
Sediment	Rye Harbour 1	1[E]				<1.5				600
Sediment	Rye Harbour 2	1[E]				<1.1				580
Sediment	Camber Sands	2[E]				<1.0				
Sediment	Pilot Sands	1[E]				<0.70				
Seawater	Dungeness South	2[E]				<0.61			<3.3	9.7

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	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial Samples										
Milk		3	<4.0	16	<0.45	<0.33	<0.28	<0.29		
Milk	max			21	<0.60	<0.40	<0.30	<0.30		
Blackberries		1	<4.0	9.0	<0.30	<0.10	<0.30	<0.30		
Honey		1	<5.0	73	<0.40	<0.20	<0.20	<0.20		
Peas		1	<6.0	86	<0.40	<0.50	<0.40	<0.40		
Potatoes		1	5.0	18	<0.30	<0.50	<0.40	<0.40		
Sea kale		1	<4.0	9.0	1.6	<0.30	<0.30	1.3		
Wheat		1	<6.0	81	<0.60	<0.40	<0.30	<0.30		
Grass		1				<0.30	<0.30	<0.30		
Freshwater	Long Pits	2[E]	<5.4		<1.0	<0.47	<0.44	<0.39	<0.035	0.17
Freshwater	Well number 2	1[E]	<4.0		<1.0	<0.46	<0.42	<0.40	<0.030	0.24
Freshwater	Reservoir	1[E]	<4.0		<1.0	<0.46	<0.45	<0.40	<0.030	0.18

* *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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.4(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2004

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Littlestone-on-Sea	Pebbles and sand	1	0.059
Littlestone-on-Sea	Pebbles and shingle	1	0.048
Greatstone-on-Sea	Sand	2	0.056
Dungeness East	Shingle	1	0.049
Dungeness East	Pebbles	1	0.056
Dungeness South	Pebbles	1	0.051
Dungeness South	Pebbles and shingle	1	0.049
Jury Gap	Pebbles and sand	1	0.058
Rye Bay	Sand	2	0.058
Rye Harbour	Mud and sand	2[F]	0.068
Mean beta dose rates			μSv h^{-1}
Rye Harbour	Mud and sand	2[F]	*

** Not detected by the method used*

[F] Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency

Table 5.5(a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2004

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	^{99}Tc	^{131}I	^{137}Cs	^{155}Eu
Marine samples											
Plaice	Pipeline	2	<25	<25	22	<0.04	<0.04		*	0.22	<0.10
Cod	Pipeline	2				<0.05	<0.05		<0.40	0.47	<0.11
Crabs	Pipeline	2			42	<0.06	<0.06		*	<0.06	<0.18
Winkles	Paddy's Hole	2	<25	<25		<0.05	<0.05		<0.29	0.28	<0.11
Fucus vesiculosus	Pilot Station	2				<0.06	<0.06	65	<0.45	0.16	<0.11
Seaweed	Pilot Station	2[E]					<1.4	94	<5.0	<1.1	
Sediment	Seaton Carew	2[E]					<0.73			<0.60	
Sediment	Paddy's Hole	2[E]					<1.3			<8.4	
Sediment	North Gare	2[E]					<0.57			<0.62	
Sediment	Greatham Creek	2[E]					<1.2			12	
Sea coal	North Sands	2[E]					<0.60			2.0	
Sea coal	Carr House Sands	2[E]					<1.3			<1.2	
Sea coal	Seaton Sands	2[E]					<0.81			<0.71	
Seawater	North Gare	2		2.3							
Seawater	North Gare	2[E]					<0.41			<0.34	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{210}Pb	^{210}Po	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples											
Plaice	Pipeline	2					<0.08				
Cod	Pipeline	2					<0.09				
Crabs	Pipeline	2			0.00041	0.0024	0.0023	*	*		
Winkles	Paddy's Hole	2	2.3	25	0.012	0.079	0.037	0.000094	0.00011		
Fucus vesiculosus	Pilot Station	2	1.9	3.0			<0.07				220
Seaweed	Pilot Station	2[E]					<1.4				
Sediment	Seaton Carew	2[E]					<0.95				
Sediment	Paddy's Hole	2[E]					<2.0				770
Sediment	North Gare	2[E]					<0.72				300
Sediment	Greatham Creek	2[E]					<1.8				980
Sea coal	North Sands	2[E]					<0.88				
Sea coal	Carr House Sands	2[E]					<1.7				
Sea coal	Seaton Sands	2[E]					<1.2				
Seawater	North Gare	2[E]					<0.45			<2.9	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		6	<4.6	15	<0.65	<0.29	<0.29		
Milk	max		<6.8	21	<0.83	<0.35	<0.35		
Apples		1	14	12	<0.40	<0.40	<0.40		
Blackberries		1	<3.0	15	<0.40	<0.30	<0.30		
Cabbage		1	<4.0	4.0	<0.70	<0.30	<0.30		
Carrots		1	5.0	8.0	<0.40	<0.30	<0.40		
Honey		1	<6.0	80	<0.40	<0.20	<0.20		
Potatoes		1	4.0	17	<0.40	<0.40	<0.40		
Runner beans		1	<4.0	4.0	<0.40	<0.30	<0.40		
Wheat		1	<5.0	86	<0.70	<0.40	<0.30		
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.45	<0.39	<0.061	0.12
Freshwater	Borehole, Dalton Piercy	2[E]	<4.0		<1.0	<0.41	<0.33	<0.060	0.13

* *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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.5(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2004

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	0.061
Seaton Carew	Sand	2	0.065
Greatham Creek Bird Hide	Mud and pebbles	1	0.087
Greatham Creek Bird Hide	Salt marsh	1	0.078
North Gare	Sand	2	0.061
Paddy's Hole	Winkle bed	2[F]	0.19
Paddy's Hole	Mud and pebbles	1	0.17
Paddy's Hole	Pebbles and rock	1	0.18
Carr House	Sand	2	0.063
Seaton Sands	Sand	2	0.058

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 5.6(a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2004

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
Marine samples										
Flounder	Flookburgh	4			110	<0.09	<0.09			<0.86
Plaice	Morecambe	4	<25	<25		<0.14	<0.13	0.027	4.8	<1.4
Bass	Morecambe	2				<0.11	<0.10			<1.0
Whitebait	Sunderland Point	1				<0.06	0.11	1.3		<0.61
Shrimps	Flookburgh	4			130	<0.11	<0.10		6.9	<1.1
Cockles	Middleton Sands	2				<0.06	1.3			2.1
Cockles[b]	Flookburgh	4			120	<0.06	1.6	0.52	29	2.5
Winkles	Red Nab Point	4				<0.09	0.73			3.1
Mussels	Morecambe	4	<56	<71	140	<0.06	0.62		220	3.8
Fucus vesiculosus	Half Moon Bay	4				<0.09	0.46		1300	<0.78
Seaweed	Half Moon Bay	2[E]					<3.4		3100	<20
Mud and sand	Flookburgh	4				<0.64	<0.53			<7.3
Sediment	Flookburgh	1[E]					<0.59			<4.8
Mud and sand	Half Moon Bay	4				<0.80	3.4			<14
Sediment	Half Moon Bay	2[E]					<0.95			
Sediment	Pott's Corner	2[E]					<0.74			
Sediment	Pipeline	2[E]					<0.96			
Mud and sand	Morecambe Central Pier	4				<0.87	3.2			<16
Sediment	Morecambe Central Pier	2[E]					<2.2			
Sediment	Sunderland Point	4[E]					1.8			<5.7
Sediment	Conder Green	4[E]					<1.3			<6.1
Sediment	Sand Gate Marsh	4[E]					<1.3			<7.0
Turf	Conder Green	4				<0.96	3.8			<11
Turf	Sand Gate Marsh	4				<0.77	<1.4			<8.2
Samphire	Cockerham Marsh	1				<0.07	<0.07			<0.75
Seawater	Pipeline	2		17						
Seawater	Heysham Harbour	2[E]					<0.43			<3.1

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu
Marine samples										
Flounder	Flookburgh	4	<0.16	<0.25	<0.09	13	<0.47	<0.28	<0.22	0.00043
Plaice	Morecambe	4	<0.26	<0.31	<0.14	4.0	<0.67	<0.39	<0.28	
Bass	Morecambe	2	<0.21	<0.27	<0.11	9.5	<0.60	<0.31	<0.26	
Whitebait	Sunderland Point	1	<0.12	<0.16	<0.07	5.5	<0.29	<0.18	<0.12	0.090
Shrimps	Flookburgh	4	<0.20	<0.32	<0.11	4.4	<0.60	<0.29	<0.26	0.0042
Cockles	Middleton Sands	2	<0.10	0.66	<0.06	3.3	<0.32	<0.14	<0.15	0.36
Cockles[b]	Flookburgh	4	<0.11	0.68	<0.06	3.9	<0.29	<0.16	<0.13	0.40
Winkles	Red Nab Point	4	<0.14	1.4	<0.08	4.9	<0.37	<0.20	<0.17	0.37
Mussels	Morecambe	4	<0.11	0.97	<0.06	3.8	<0.30	<0.17	<0.14	0.42
Fucus vesiculosus	Half Moon Bay	4	<0.16	1.4	<0.09	4.4	<0.47	<0.26	<0.23	
Seaweed	Half Moon Bay	2[E]	<3.4	<16	<2.7	14	<8.9			
Mud and sand	Flookburgh	4	<1.1	<2.7	<0.74	250	<5.3	<1.8	<2.4	
Sediment	Flookburgh	1[E]		<6.5	<0.51	360	<2.7	<2.7	<1.4	
Mud and sand	Half Moon Bay	4	<1.3	8.7	<0.95	140	<4.7	<2.1	<2.2	11
Sediment	Half Moon Bay	2[E]				33				
Sediment	Pott's Corner	2[E]				37				
Sediment	Pipeline	2[E]				23				
Mud and sand	Morecambe Central Pier	4	<1.3	7.3	<1.0	180	<5.9	<2.3	<2.9	
Sediment	Morecambe Central Pier	2[E]				130				
Sediment	Sunderland Point	4[E]		5.9	<0.76	91	<2.9	<3.5	<1.6	
Sediment	Conder Green	4[E]		<6.2	<0.71	160	<3.2	<3.9	<1.7	
Sediment	Sand Gate Marsh	4[E]		<6.6	<0.84	130	<3.5	<4.4	<2.0	
Turf	Conder Green	4	<1.6	<5.2	<1.2	290	<6.8	<2.8	<3.2	
Turf	Sand Gate Marsh	4	<1.3	<2.8	<0.87	180	<5.7	<2.0	<2.6	
Samphire	Cockerham Marsh	1	<0.13	<0.17	<0.07	1.8	<0.40	<0.18	<0.17	
Seawater	Half Moon Bay	1			0.002	0.16				
Seawater	Heysham Harbour	2[E]	<0.53		<0.41	<0.36	<1.5			

Table 5.6(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Total alpha	Total beta
Marine samples									
Flounder	Flookburgh	4	0.0028		0.0056	*	*		
Plaice	Morecambe	4			<0.34				
Bass	Morecambe	2			<0.35				
Whitebait	Sunderland Point	1	0.54	6.5	0.81	0.0046	0.0020		
Shrimps	Flookburgh	4	0.024	0.16	0.040	*	0.000050		
Cockles	Middleton Sands	2	2.0		5.7	*	0.0070		
Cockles[b]	Flookburgh	4	2.2	18	5.9	*	0.011		
Winkles	Red Nab Point	4	1.9		3.6	0.010	0.0075		
Mussels	Morecambe	4	2.5		4.5	*	0.0060		
Fucus vesiculosus	Half Moon Bay	4			0.87				
Seaweed	Half Moon Bay	2[E]			<3.5				
Mud and sand	Flookburgh	4			72				
Sediment	Flookburgh	1[E]			190			710	1100
Mud and sand	Half Moon Bay	4	63		120	*	*		
Sediment	Half Moon Bay	2[E]			29				
Sediment	Pott's Corner	2[E]			12				
Sediment	Pipeline	2[E]			21				
Mud and sand	Morecambe Central Pier	4			130				
Sediment	Morecambe Central Pier	2[E]			110				
Sediment	Sunderland Point	4[E]			80			480	730
Sediment	Conder Green	4[E]			120			580	800
Sediment	Sand Gate Marsh	4[E]			99			440	820
Turf	Conder Green	4			190				
Turf	Sand Gate Marsh	4			93				
Samphire	Cockerham Marsh	1			1.2				310
Seawater	Heysham Harbour	2[E]			<0.53			<2.2	14

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	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	Total alpha	Total beta
Terrestrial samples													
Milk		6	<4.0	17	<0.48	<0.31	<2.3	<0.30	<0.28	<0.31	<1.4		
Milk	max			22	<0.55	<0.35	<2.6	<0.38	<0.30	<0.33	<1.5		
Apples		1	4.0	10	<0.40	<0.40	<2.2	<0.20	<0.30	<0.30	<1.1		
Barley		1	<5.0	110	<0.60	<0.30	<2.6	<0.30	<0.30	0.40	<1.2		
Blackberries		1	4.0	30	0.40	<0.30	<1.6	<0.30	<0.20	<0.30	<1.0		
Cabbage		1	<4.0	10	<0.70	<0.40	<2.1	<0.20	<0.30	<0.30	<1.3		
Honey		1	8.0	85	<0.30	<0.20	<1.9	<0.20	<0.20	0.20	<1.4		
Onions		1	<4.0	11	<0.40	<0.30	<2.6	<0.30	<0.30	<0.30	<1.3		
Potatoes		1	5.0	24	<0.40	<0.40	<3.3	<0.30	<0.30	<0.40	<1.5		
Sprouts		1	<4.0	15	<0.30	<0.30	<2.2	<0.30	<0.30	0.30	<0.90		
Freshwater	Lancaster	2[E]	<4.0		<1.0	<0.48			<0.46	<0.41		<0.030	<0.11

* *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 17 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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.6(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2004

Location	Ground type	No. of sampling observations	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1 m over intertidal areas			
Greenodd	Salt marsh	2	0.078
Sand Gate Marsh	Salt marsh	4[F]	0.085
Sand Gate Marsh	Salt marsh	3	0.091
Sand Gate Marsh	Salt marsh and mud	1	0.092
Flookburgh	Mud and sand	4[F]	0.093
Flookburgh	Salt marsh	1	0.097
High Foulshaw	Salt marsh	4[F]	0.079
High Foulshaw	Salt marsh	2	0.080
High Foulshaw	Grass and salt marsh	2	0.081
Arnside Marsh	Salt marsh	4[F]	0.087
Arnside 1	Mud	1	0.078
Arnside 1	Mud and sand	2	0.076
Arnside 1	Pebbles and sand	1	0.075
Arnside 2	Salt marsh	2	0.099
Arnside 2	Salt marsh and mud	1	0.10
Arnside 2	Grass and salt marsh	1	0.098
Morecambe Central Pier	Mussel bed	4[F]	0.073
Morecambe Central Pier	Mud and sand	4[F]	0.074
Morecambe Central Pier	Pebbles and sand	1	0.080
Morecambe Central Pier	Rock and sand	1	0.081
Half Moon Bay	Mud and sand	4[F]	0.074
Half Moon Bay	Sand and stones	1	0.072
Half Moon Bay	Pebbles and sand	1	0.069
Heysham pipelines	Sand	1	0.075
Heysham pipelines	Sand and stones	1	0.081
Middleton Sands	Sand	1	0.074
Middleton Sands	Pebbles and sand	1	0.067
Sunderland	Mud	3	0.090
Sunderland	Mud and sand	1	0.094
Sunderland Point	Mud	3	0.088
Sunderland Point	Mud and sand	1	0.095
Colloway Marsh	Salt marsh	4[F]	0.13
Colloway Marsh	Salt marsh	2	0.089
Colloway Marsh	Grass and salt marsh	2	0.10
Lancaster	Grass and mud	1	0.078
Lancaster	Grass	3	0.079
Aldcliffe Marsh	Salt marsh	4[F]	0.093
Aldcliffe Marsh	Grass and salt marsh	4	0.10
Conder Green	Mud and sand	4[F]	0.091
Conder Green	Salt marsh	4[F]	0.10
Conder Green	Grass and mud	4	0.091
Cockerham Marsh	Salt marsh	4[F]	0.10
Cockerham Marsh	Salt marsh	3	0.098
Cockerham Marsh	Grass and salt marsh	1	0.097

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 5.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2004

Material	Location	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{99}Tc	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples												
Cod	Stolford	2	310	320	34	<0.06	<0.05	<0.16		<0.13	<0.06	1.3
Shrimps	Stolford	2	370	370	38	<0.17	<0.14	<0.42		<0.32	<0.18	1.0
Whelks	Stolford	1		2200	55	<0.13	<0.13	<0.34		<0.31	<0.14	0.44
Fucus vesiculosus	Pipeline	2				0.30	<0.07	<0.18		<0.15	<0.22	4.6
Seaweed	Pipeline	2[E]					<2.4		12	<11	<1.9	<3.2
Mud	1.6 km east of pipeline	2				<0.74	<0.71	<1.6		<1.9	2.2	44
Sediment	1.6 km east of pipeline	2[E]					<1.1					35
Sediment	Pipeline	2[E]					<1.3					41
Sediment	0.8 km west of pipeline	2[E]					<0.64					6.7
Sediment	Stolford	2[E]					<0.79					25
Sediment	Steart Flats	2[E]					<1.1					37
Mud and sand	River Parrett	2				<0.86	<0.62	<1.9		<1.9	1.2	35
Sediment	River Parrett	2[E]					<1.3					39
Seawater	Pipeline	1		26								
Seawater	Pipeline	2[E]					<0.41				<0.37	<0.35

Material	Location	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{144}Ce	^{155}Eu	^{239}Pu+ ^{238}Pu	^{240}Pu	^{241}Am	Total alpha	Total beta
Marine samples									
Cod	Stolford	2	<0.26	<0.12			<0.14		
Shrimps[b]	Stolford	2	<0.59	<0.22	0.00012	0.00075	0.00067		
Whelks	Stolford	1	<0.71	<0.29			<0.27		
Fucus vesiculosus	Pipeline	2	<0.33	<0.15			<0.14		170
Seaweed	Pipeline	2[E]	<6.2				<2.6		
Mud	1.6 km east of pipeline	2	<3.9	<2.1			<2.9		
Sediment	1.6 km east of pipeline	2[E]					<1.5		
Sediment	Pipeline	2[E]					<1.8		
Sediment	0.8 km west of pipeline	2[E]					<0.87		
Sediment	Stolford	2[E]					<1.1		
Sediment	Steart Flats	2[E]					<1.6		
Mud and sand	River Parrett	2	<5.7	<2.4			<2.5		
Sediment	River Parrett	2[E]					<1.8		
Seawater	Pipeline	2[E]	<1.4				<0.56	<2.2	14

Material	Location or selection[c]	No. of sampling observations[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	<4.0	18	<0.50	<0.30	<0.26	<0.28		
Milk	max		<4.3	21	<0.53	<0.33	<0.28	<0.33		
Apples		1	<4.0	9.0	<0.40	<0.10	<0.40	<0.40		
Blackberries		1	<4.0	37	1.0	<0.30	<0.30	<0.30		
Cabbage		1	<4.0	13	<0.70	<0.30	<0.30	<0.30		
Onions		1	<4.0	17	<0.40	<0.30	<0.30	<0.30		
Potatoes		1	<4.0	28	1.2	<0.60	<0.40	<0.40		
Runner beans		1	<4.0	8.0	<0.40	<0.40	<0.40	<0.40		
Wheat		1	<5.0	93	0.40	<0.40	<0.30	<0.40		
Freshwater	Durleigh Reservoir	2[E]	<4.0		<1.0	<0.40	<0.36	<0.32	0.041	0.22
Freshwater	Ashford Reservoir	2[E]	<4.0		<1.0	<0.37	<0.35	<0.31	0.029	0.12

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

[b] *The concentration of $^{243+244}$Cm was 0.000018 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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2004

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	0.065
Burnham	Sand	2	0.063
River Parrett	Mud and sand	2[F]	0.076
Steart Flats	Sand	1	0.070
Steart Flats	NA	1	0.071
Stolford	Sand and stones	2	0.083
Hinkley Point	Sand and stones	2	0.077
Kilve	Rock and stones	2	0.079
Watchet Harbour	Pebbles and shingle	2	0.093
Blue Anchor Bay	Shingle and stones	1	0.074
Blue Anchor Bay	Pebbles and shingle	1	0.067

NA Not available

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 5.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{60}Co	^{110m}Ag	^{134}Cs	^{137}Cs	^{155}Eu
Marine samples									
Cod	Sizewell	1			<0.03	<0.06	<0.03	0.51	<0.07
Sole	Sizewell	1	<25		<0.06	<0.10	<0.06	0.18	<0.12
Crabs	Sizewell	2		31	<0.11	<0.22	<0.12	0.34	<0.23
Shrimps	Sizewell	1			<0.03	<0.07	<0.04	0.06	<0.10
Oyster	Blyth Estuary	1			<0.11	<0.19	<0.11	<0.10	<0.18
Mussels	River Alde	1	<25		<0.12	<0.20	<0.11	0.20	<0.18
Sand	Aldeburgh	2			<0.23	<0.47	<0.28	0.44	<0.67
Sediment	Rifle range	2[E]			<0.87			<0.70	
Sediment	Aldeburgh	2[E]			<0.68			<0.64	
Sediment	Southwold	2[E]			<1.5			16	
Seawater	Aldeburgh	2	<1.8						
Seawater	Sizewell	2[E]			<0.41		<0.38	<0.34	

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 beta
Marine samples								
Cod	Sizewell	1			<0.04			
Sole	Sizewell	1			<0.16			
Crabs	Sizewell	2	0.000061	0.00040	0.00062	*	0.000025	
Shrimps	Sizewell	1	0.00032	0.0019	0.0011	0.000013	0.000017	
Oyster	Blyth Estuary	1			<0.21			
Mussels	River Alde	1			<0.08			
Sand	Aldeburgh	2			<0.72			
Sediment	Rifle range	2[E]			<1.1			
Sediment	Aldeburgh	2[E]			<0.87			
Sediment	Southwold	2[E]			<1.9			900
Seawater	Sizewell	2[E]			<0.49			

Nuclear power

Table 5.8(a). continued

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	^{110m}Ag	^{134}Cs	^{137}Cs	Total Cs
Terrestrial samples										
Milk		7	<4.0	20	<0.59		<0.29	<0.27	<0.28	
Milk	max		<4.3	21	<0.70		<0.33	<0.30	<0.30	
Apples		1	<4.0	14	1.0		<0.40	<0.40	<0.40	
Blackberries		1	<4.0	18	<0.40		<0.30	<0.30	<0.40	
Bovine muscle		1	<5.0	55	2.3	0.023	<0.30			0.14
Bovine offal		1	<6.0	13	<0.60	0.035	<0.20			0.27
Cabbage		1	<4.0	11	1.9		<0.30	<0.30	<0.30	
Carrots		1	<4.0	10	0.10		<0.30	<0.20	<0.30	
Honey		1	<7.0	77	<0.40		<0.20	<0.20	<0.20	
Ovine muscle		1	<5.0	39	<0.70	<0.011	<0.30			0.061
Ovine offal		1	<7.0	35	<0.70	0.12	<0.30			0.22
Potatoes		1	<4.0	29	1.2		<0.30	<0.30	<0.40	
Runner beans		1	5.0	4.0	<0.40		<0.30	<0.20	<0.30	
Wheat		1	<5.0	73	1.8		<0.30	<0.30	<0.40	
Freshwater	Nature reserve	2[E]	<4.0		<1.0			<0.46	<0.41	
Freshwater	The Meare	2[E]	<4.0		<1.0			<0.45	<0.40	
Freshwater	Leisure Park	2[E]	<4.0		<1.0			<0.46	<0.38	

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							
Bovine muscle		1	<0.00020	<0.00020	0.00080		
Bovine offal		1	<0.00020	0.0024	0.00090		
Ovine muscle		1	<0.00020	<0.00020	0.00030		
Ovine offal		1	<0.00020	<0.00030	0.00030		
Freshwater	Nature reserve	2[E]				<0.025	0.24
Freshwater	The Meare	2[E]				<0.15	0.87
Freshwater	Leisure Park	2[E]				<0.025	0.26

* *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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.8(b). Monitoring of radiation dose rates near Sizewell, 2004

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Sizewell Beach	Pebbles and shingle	2	0.057
Dunwich	Pebbles	1	0.057
Dunwich	Pebbles and shingle	1	0.055
Rifle Range	Pebbles and sand	1	0.052
Rifle Range	Pebbles and shingle	1	0.052
Aldeburgh	Sand and stones	2[F]	0.047
Aldeburgh	Pebbles and sand	1	0.052
Aldeburgh	Pebbles and shingle	1	0.054
Southwold Harbour	Mud and pebbles	1	0.068
Southwold Harbour	Salt marsh and mud	1	0.069

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 5.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Marine samples												
Flounder	Inner Solway	4	<4.5	110	<0.13	<0.12	<0.34	<0.10	<0.48	<0.72	2.7	<1.2
Lemon sole	Inner Solway	4			<0.10	<0.10	<0.21		<0.25	<0.26		<0.72
Plaice	Inner Solway	3			<0.15	<0.13	<0.39		<0.91	<1.3		<1.3
Salmon	Inner Solway	1	5.5		<0.10	<0.10	<0.16		<0.15	<0.14		<0.46
Shrimps	Inner Solway	4	<6.9		<0.11	<0.10	<0.23	0.10	<0.35	<0.53	1.2	<0.77
Cockles	North Solway	7[F,S]	<8.6	99	<0.07	1.6	<0.12	0.48	<0.19	<0.24	18	<1.4
Mussels	North Solway	8[F,S]	<9.8	91	<0.07	0.55	<0.15	0.60	<0.20	<0.26	240	<1.6
Winkles	Southerness	4	<8.7		<0.14	1.6	<0.31	0.47	<0.40	<0.62	180	4.6
Seaweed	Pipeline	4			<0.10	0.60	<0.13		<0.11	<0.12		<0.34
Sediment	Pipeline	4	<4.0		<0.10	1.9	<0.39		<0.42	<0.64		6.0
Salt marsh	Dornoch Brow	4			<0.11	2.5	<0.34		<0.78	<0.83		7.2
Seawater	Pipeline	4	9.1		<0.10	<0.10	<0.10		<0.10	<0.10		<0.26
Seawater (high tide)	Pipeline	3	8.6		<0.10	<0.10	<0.10		<0.10	<0.10		<0.28
Seawater	Southerness	4	8.9		<0.10	<0.10	<0.10		<0.10	<0.10		<0.23

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu
Marine samples												
Flounder	Inner Solway	4	<0.61	<0.33	<0.12	15	<0.73	<0.16	<0.30	0.0052	0.021	
Lemon sole	Inner Solway	1	<0.10	<0.20	<0.10	0.55	<0.47	<0.11	<0.20			
Plaice	Inner Solway	3	<0.16	<0.31	<0.13	<0.21	<0.85	<0.16	<0.30			
Salmon	Inner Solway	1	<0.10	<0.13	<0.10	0.15	<0.34	<0.10	<0.17			
Shrimps	Inner Solway	4	<0.14	<0.22	<0.10	3.5	<0.52	<0.13	<0.21	0.0033	0.020	
Cockles	North Solway	7[F,S]	<0.10	<0.58	<0.08	3.6	<0.30	<0.13	<0.14	0.72	3.9	32
Mussels	North Solway	8[F,S]	<0.11	0.74	<0.08	2.3	<0.29	<0.13	<0.13	0.62	3.2	26
Winkles	Southerness	4	<0.30	2.0	<0.14	1.5	<0.75	<0.17	<0.29	0.18	1.0	
Seaweed	Pipeline	4	<0.10	1.1	<0.10	7.1	<0.25	<0.10	<0.27	0.25	1.4	
Sediment	Pipeline	4	<0.16	3.6	<0.17	170	<1.3	0.67	<1.0	16	78	
Salt marsh	Dornoch Brow	4	<0.14	4.9	<0.14	170	<1.2	<071	1.2	7.4	38	
Seawater	Pipeline	4	<0.10	<0.10	<0.10	0.25	<0.17	<0.10	<0.10			
Seawater (high tide)	Pipeline	3	<0.10	<0.10	<0.10	<0.14	<0.18	<0.10	<0.10			
Seawater	Southerness	4	<0.10	<0.10	<0.10	<0.13	<0.16	<0.10	<0.10	0.0014	0.0066	

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							
Flounder	Inner Solway	4	0.037	<0.0013	<0.0013		
Lemon sole	Inner Solway	1	<0.13				
Plaice	Inner Solway	3	<0.14				
Salmon	Inner Solway	1	<0.16				
Shrimps	Inner Solway	4	0.039	<0.00057	<0.00057		
Cockles	North Solway	7[F,S]	9.8	*	0.016		
Mussels	North Solway	8[F,S]	5.4	*	0.0063		
Winkles	Southerness	4	2.1	<0.0020	<0.0020		
Seaweed	Pipeline	4	1.3	<0.0080	<0.0080	12	460
Sediment	Pipeline	4	140	<1.8	<1.8		
Salt marsh	Dornoch Brow	4	84	<0.067	<0.067		
Seawater	Pipeline	4	<0.10				
Seawater (high tide)	Pipeline	3	<0.10				
Seawater	Southerness	4	0.012	<0.00032	<0.00032		

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	^{95}Zr	^{95}Nb	^{106}Ru
Terrestrial samples										
Milk		12	<18	<15	<1.4	<0.05	<0.10	<0.22	<0.41	<0.40
Milk	max		54	16	<2.9			<0.27	<0.94	
Apples		5	<32	<15	<0.50	<0.05	<0.079	<0.17	<0.22	<0.38
Apples	max		120				0.14	<0.25	<0.39	<0.51
Barley		2	<7.8	67	<0.77	<0.05	0.25	<0.15	<0.14	<0.43
Barley	max		11		<0.97		0.31	<0.17	<0.19	<0.44
Cabbage		2	8.8	<15	<0.50	<0.05	<0.11	<0.09	<0.11	<0.24
Cabbage	max		9.6					<0.10	<0.13	<0.26
Carrots		1	<5.0	<15	0.53	<0.05	0.32	<0.07	<0.05	<0.28
Comfrey		1	9.2	17	0.68	<0.06	0.20	<0.12	<0.09	<0.45
Damsons		1	<5.0	21	<0.50	<0.05	0.25	<0.15	<0.15	<0.38
Elderberries		1	<5.0	21	<0.50	<0.05	0.64	<0.16	<0.18	<0.43
Goose		1	<5.0	31	<0.57	<0.06	<0.10	<0.18	<0.18	<0.51
Maize		1	<5.0	30	0.98	<0.05	<0.10	<0.08	<0.06	<0.38
Mallard		1	<5.0	39	<0.80	<0.05	5.1	<0.08	<0.07	<0.28
Nettles		1		19	27	<0.06	1.6	<0.12	<0.08	<0.50
Partridge		1	<5.0	18	<1.1	<0.05	0.22	<0.07	<0.07	<0.23
Peas		1	<5.0	24	1.1	<0.05	0.51	<0.15	<0.15	<0.43
Pheasant		1	<5.0	26	<0.50	<0.05	<0.10	<0.14	<0.17	<0.36
Potatoes		5	<7.8	<17	<0.52	<0.05	<0.091	<0.13	<0.19	<0.28
Potatoes	max		14	21	0.60		0.11	<0.27	<0.45	<0.43
Rhubarb		1	30	<15	<0.50	<0.05	<0.10	<0.05	<0.05	<0.11
Rosehips		1	5.2	26	<0.63	<0.05	1.3	<0.11	<0.08	<0.45
Turnips		3	<22	<15	<0.52	<0.05	<0.14	<0.13	<0.14	<0.29
Turnips	max		50		0.56		0.17	<0.17	<0.18	<0.44
Grass		6	<13	<18	<1.1	<0.05	<0.21	<0.27	<0.40	<0.46
Grass	max		41	23	2.9		0.37	<0.34	<0.65	<0.53
Soil		6	<15	<22	<3.2	<0.05	<0.67	<0.19	<0.14	<0.51
Soil	max		49	36	7.1	<0.06	1.2	<0.22	0.18	<0.59

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am	Total alpha	Total beta
Terrestrial samples										
Milk		12	<0.05	<0.05	<0.05	<0.27		<0.07		
Milk	max		<0.06							
Apples		5	<0.05	<0.05	<0.05	<0.33		<0.12		
Apples	max		<0.06	<0.06		<0.40		<0.15		
Barley		2	<0.05	<0.05	<0.05	<0.33		<0.15		
Barley	max					<0.35				
Cabbage		2	<0.05	<0.05	<0.05	<0.17		<0.07		
Cabbage	max					<0.18				
Carrots		1	<0.05	<0.05	<0.05	<0.18		<0.09		
Comfrey		1	<0.05	<0.05	0.07	<0.29		<0.16		
Damsons		1	<0.05	<0.05	<0.05	<0.27		<0.13		
Elderberries		1	<0.05	<0.05	<0.05	<0.30		<0.12		
Goose		1	<0.08	<0.05	0.76	<0.38		<0.17		
Maize		1	<0.05	<0.05	<0.05	<0.28		<0.13		
Mallard		1	<0.05	<0.05	2.9	<0.19		<0.07		
Nettles		1	<0.06	<0.05	<0.06	<0.35		<0.14		
Partridge		1	<0.05	<0.05	1.1	<0.15		<0.06		
Peas		1	<0.05	<0.05	<0.05	<0.32		<0.13		
Pheasant		1	<0.05	<0.05	0.73	<0.27		<0.11		
Potatoes		5	<0.05	<0.05	<0.27	<0.20		<0.08		
Potatoes	max				1.2	<0.32		<0.13		
Rhubarb		1	<0.05	<0.05	<0.05	<0.07		<0.05		
Rosehips		1	<0.05	<0.05	<0.05	<0.37		<0.13		
Turnips		3	<0.05	<0.05	<0.06	<0.20		<0.09		
Turnips	max				0.08	<0.30		<0.13		
Grass		6	<0.05	<0.05	<0.05	<0.33		<0.12	<2.9	250
Grass	max		<0.06			<0.38		<0.16	7.7	320
Soil		6	<0.07	<0.06	7.5	<0.50	1.0	<0.51	270	710
Soil	max		<0.09	<0.08	11	<0.58	1.4	1.9	330	800

[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 5.9(b). Monitoring of radiation dose rates near Chapelcross, 2004

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Southerness	Winkle bed	4	0.073
Glencaple Harbour	Mud and sand	4	0.086
Priestside Bank	Salt marsh	4	<0.064
Powfoot Merse	Mud	4	<0.069
Pipeline	Sand	4	0.078
Pipeline	Salt marsh	4	0.087
Battlehill	Sand	4	0.076
Dornoch Brow	Mud and sand	4	0.082
Dornoch Brow	Salt marsh	4	0.072
Browhouses	NA	4	0.075
Mean beta dose rates			µSv 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 5.9(c). Radioactivity in air near Chapelcross, 2004

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Eastriggs	11	<0.013	<0.0072	0.16
Kirtlebridge	11	<0.012	<0.0066	0.14
Brydekirk	11	<0.010	<0.0074	0.21

Table 5.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{14}C	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples														
Cod	Millport	1		<0.10	<0.15	<0.10	<0.19	<0.47		<0.52	<0.10	<0.14	<0.10	1.7
Hake	Millport	2		<0.10	<0.15	<0.10	<0.18	<0.37		<0.49	<0.11	<0.14	<0.10	1.6
Crabs	Millport	2	42	<0.10	<0.11	<0.10	<0.15	<0.19		<0.46	<0.10	<0.14	<0.10	<0.21
Nephrops	Millport	2		<0.10	<0.10	<0.10	<0.10	<0.19	63	<0.19	<0.10	<0.10	<0.10	1.0
Lobsters	Largs	1		<0.10	<0.11	0.25	<0.17	<0.28	400	<0.48	<0.10	<0.14	<0.10	1.7
Squat lobsters	Largs	4		<0.10	<0.10	<0.10	<0.13	<0.22	<0.91	<0.33	<0.10	<0.11	<0.10	0.30
Winkles	Pipeline	2		2.2	<0.24	1.3	<0.21	<0.25		<0.80	0.89	<0.21	<0.11	0.67
Scallops	Largs	4		<0.10	<0.12	<0.10	<0.16	<0.27		<0.46	<0.10	<0.13	<0.10	<0.28
Seaweed	N of pipeline	2		2.3	<0.12	0.52	<0.19	<0.23		<0.56	<0.10	<0.25	<0.10	0.68
Seaweed	Pipeline	1		2.4	<0.10	0.27	<0.12	<0.10		<0.38	<0.10	<0.11	<0.10	0.71
Ascophyllum nodosum	Pipeline	1		11	<0.25	0.88	<0.33	<0.76		<0.98	0.12	<0.23	<0.10	1.1
Seaweed	S of pipeline	2		7.1	<0.19	1.0	<0.26	<0.50		<0.86	<0.24	<0.24	<0.11	1.6
Sediment	Pipeline	1		<0.10	<0.17	<0.10	<0.25	<0.54		<0.67	<0.11	0.49	<0.10	15
Sediment	Millport	2		<0.10	<0.10	<0.10	<0.16	<0.12		<0.43	<0.10	<0.14	<0.10	5.2
Sediment	Ardneil Bay	2		<0.10	<0.10	<0.10	<0.14	<0.11		<0.39	<0.10	<0.12	<0.10	2.8
Sediment	Gulls Walk	2		<0.10	<0.70	<0.10	<0.19	<0.24		<0.50	<0.10	<0.24	<0.10	4.6

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	$^{243}Cm+^{244}Cm$
Marine samples									
Cod	Millport	1	<0.36	<0.10	<0.16			<0.16	
Hake	Millport	2	<0.36	<0.10	<0.17			<0.13	
Crabs	Millport	2	<0.33	<0.10	<0.16	0.096	0.74	0.0047	
Nephrops	Millport	2	<0.14	<0.10	<0.10			<0.10	
Lobsters	Largs	1	<0.34	<0.10	<0.16			1.2	
Squat lobsters	Largs	4	<0.23	<0.10	<0.11	0.0045	0.025	0.010	<0.00040
Winkles	Pipeline	2	<0.46	<0.12	<0.19	0.091	0.19	0.24	
Scallops	Largs	4	<0.30	<0.10	<0.13	0.00077	0.0022	0.0035	
Seaweed	N of pipeline	2	<0.36	<0.10	<0.18			<0.17	
Seaweed	Pipeline	1	<0.24	<0.10	<0.13			<0.11	
Ascophyllum nodosum	Pipeline	1	<0.62	<0.14	<0.29			<0.26	
Seaweed	S of pipeline	2	<0.53	<0.12	<0.25			<0.25	
Sediment	Pipeline	1	<0.68	<0.15	<0.31			0.43	
Sediment	Millport	2	<0.41	<0.11	<0.21			0.41	
Sediment	Ardneil Bay	2	<0.36	<0.11	<0.18			<0.18	
Sediment	Gulls Walk	2	<0.47	<0.12	<0.20			<0.21	

Table 5.10(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	^{106}Ru
Terrestrial Samples									
Milk		6	<4.9	<17	<1.4	<0.05	<0.094	<0.53	<0.41
Milk	max		<5.0	<19	<1.6		<0.10	<1.0	<0.46
Blackberries		1	<5.0	22	<0.50	<0.05	0.14	<0.16	<0.40
Cabbage		1	<5.0	<15	<0.50	<0.05	0.16	<0.05	<0.15
Carrots		2	<5.0	<15	<0.50	<0.05	0.15	<0.10	<0.37
Carrots	max						0.18	<0.13	<0.41
Crab apples		1	<5.0	27	<0.50	<0.05	0.24	<0.06	<0.42
Leeks		1	<5.0	<15	<0.50	<0.05	0.14	<0.09	<0.39
Mooli		1	<5.0	<15	<0.25	<0.05	<0.13	<0.12	<0.35
Nettles		1	5.6	19	4.2	<0.07	1.6	<0.09	<0.63
Onions		1	<5.0	<15	<0.50	<0.05	<0.10	<0.10	<0.41
Potatoes		4	<5.0	19	<0.50	<0.05	<0.10	<0.09	<0.30
Potatoes	max			21				<0.13	<0.40
Rowan berries		1	<5.0	29	<0.50	<0.05	0.36	<0.25	<0.43
Turnips		1	<5.0	<15	<0.50	<0.05	0.46	<0.07	<0.34
Winter greens		1	<5.0	<15	<0.66	<0.05	0.49	<0.12	<0.10
Grass		4	<5.0	<22	<0.50	<0.05	0.34	<0.36	<0.43
Grass	max			32			0.61	<0.57	<0.47
Soil		4	<5.0	<15	<5.0	<0.05	0.96	<0.20	<0.50
Soil	max				<15	<0.06	1.4	<0.26	<0.60

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am	Total alpha	Total beta
Terrestrial Samples										
Milk		6	<0.05	<0.05	<0.09	<0.27		<0.06		
Milk	max		<0.06		0.25	<0.29		<0.07		
Blackberries		1	<0.05	<0.05	<0.05	<0.28		<0.14		
Cabbage		1	<0.05	<0.05	<0.05	<0.10		<0.05		
Carrots		2	<0.05	<0.05	<0.05	<0.27		<0.11		
Carrots	max					<0.30		<0.14		
Crab apples		1	<0.05	<0.05	<0.05	<0.31		<0.13		
Leeks		1	<0.05	<0.05	<0.05	<0.28		<0.12		
Mooli		1	<0.05	<0.05	<0.05	<0.25		<0.11		
Nettles		1	<0.07	<0.06	<0.07	<0.44		<0.17		
Onions		1	<0.05	<0.05	<0.05	<0.31		<0.13		
Potatoes		4	<0.05	<0.05	<0.08	<0.21		<0.11		
Potatoes	max				0.14	<0.27		<0.15		
Rowan berries		1	<0.05	<0.05	0.10	<0.31		<0.12		
Turnips		1	<0.05	<0.05	0.18	<0.23		<0.08		
Winter greens		1	<0.05	<0.05	<0.05	<0.31		<0.13		
Grass		4	<0.06	<0.05	<0.13	<0.32		<0.11	<3.9	130
Grass	max				0.27	<0.35		<0.13	8.6	200
Soil		4	<0.08	<0.06	14	<0.50	0.68	<0.29	190	530
Soil	max		<0.09	<0.08	19	<0.62	0.81	0.39	250	650

[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 5.10(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2004

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Largs Bay	NA	2	0.052
Kilchatten Bay	NA	2	<0.047
Millport	NA	2	<0.051
Gulls Walk	Mud	2	0.060
0.5 km north of pipeline	Sand	2	0.057
0.5 km south of pipeline	Sand and stones	2	0.063
Ardneil Bay	NA	2	<0.047
Ardrossan Bay	NA	2	0.052

NA Not available

Table 5.10(c). Radioactivity in air near Hunterston, 2004

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Fencebay	12	<0.010	<0.0077	0.14
West Kilbride	10	<0.010	<0.0058	0.096
Crosbie Mains	10	<0.010	<0.0059	0.13

Table 5.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag
Marine samples										
Cod	Pipeline	1	<0.26	<0.23	<0.71	<1.4	<2.4		<2.2	<0.28
Fish	White Sands	1	<0.30	0.32	<0.79	<1.6	<2.7		<2.6	<0.31
Crabs[b]	Cove	1	<0.11	<0.11	<0.28	<0.29	<0.26	<0.22	<0.95	<0.11
Lobsters	Cove	1	<0.13	<0.13	<0.35	<0.37	<0.34	<0.85	<1.2	<0.14
Nephrops	Dunbar	4	<0.12	<0.11	<0.27	<0.40	<0.62		<0.89	<0.12
Winkles	Pipeline	2	<0.22	<0.19	<0.61	<1.1	<1.9		<1.9	<0.23
Fucus vesiculosus	Pipeline	2	<0.19	<0.39	<0.19	<0.26	<0.44	1.1	<0.47	<0.10
Fucus vesiculosus	Thornton Loch	2	<0.11	<0.19	<0.19	<0.25	<0.42		<0.46	<0.10
Fucus vesiculosus	White Sands	2	<0.10	<0.10	<0.22	<0.19	<0.18		<0.54	<0.10
Sediment	Dunbar Inner Harbour	2	<0.10	<0.10	<0.25	<0.26	<0.60		<0.62	<0.13
Sediment	Barns Ness	2	<0.10	<0.10	<0.26	<0.41	<0.30		<0.62	<0.11
Sediment	Thornton Loch	2	<0.10	<0.10	<0.16	<0.14	<0.15		<0.42	<0.10
Sediment	Heckies Hole	2	<0.10	<0.10	<0.23	<0.23	<0.29		<0.59	<0.10
Sediment	Eyemouth	2	<0.10	<0.10	<0.21	<0.17	<0.20		<0.55	<0.10
Salt marsh	Belhaven Bay	2	<0.10	<0.10	<0.33	<0.33	<0.49		<0.83	<0.13

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{137}Cs	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total alpha	Total beta
Marine samples									
Cod	Pipeline	1	0.43	<0.50			<0.29		
Seafood	White Sands	1	0.44	<0.65			<0.37		
Crabs[b]	Cove	1	<0.11	<0.29			<0.14		
Lobsters	Cove	1	0.42	<0.32			<0.21		
Nephrops	Dunbar	4	0.24	<0.23	0.0097	0.065	0.025		
Winkles	Pipeline	2	<0.26	<0.42			<0.24	11	240
Fucus vesiculosus	Pipeline	2	0.16	<0.16			<0.15		
Fucus vesiculosus	Thornton Loch	2	<0.17	<0.15			<0.14		
Fucus vesiculosus	White Sands	2	<0.15	<0.14			<0.19		
Sediment	Dunbar Inner Harbour	2	3.7	0.96			<0.23		
Sediment	Barns Ness	2	1.9	0.82			0.35		
Sediment	Thornton Loch	2	0.85	<0.24			<0.31		
Sediment	Heckies Hole	2	2.1	<0.46			<0.25		
Sediment	Eyemouth	2	1.8	0.54			<0.24		
Salt marsh	Belhaven Bay	2	4.2	0.73			<0.36		

Table 5.11(a). continued

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb
Terrestrial samples									
Milk		1	<5.0	<18	<1.1	<0.05	<0.10	<0.24	<0.43
Blackberries		1	<5.0	25	<0.51	<0.05	0.27	<0.05	<0.05
Broccoli		1	<5.0	<15	<1.7	<0.05	0.15	<0.22	<0.37
Carrots		1	<5.0	<15	0.34	<0.05	<0.10	<0.12	<0.16
Elderberries		1	4.2	21	<0.50	<0.05	<0.10	<0.21	<0.28
Potatoes		1	<5.0	22	<0.50	<0.05	<0.10	<0.08	<0.05
Rosehips		1	<1.8	46	<0.50	<0.05	0.43	<0.18	0.19
Rowanberries		1	<5.0	27	<0.50	<0.05	0.17	<0.11	<0.11
Spring cabbage		1	<5.0	<15	<0.50	<0.05	<0.10	<0.09	<0.06
Grass		6	<5.1	<32	<1.1	<0.06	<0.18	<0.33	<0.59
Grass	max		<5.5	46	2.6	<0.09	0.44	<0.56	<1.1
Soil		6	<5.0	<22	<2.6	<0.05	1.1	<0.23	<0.38
Soil	max			33	5.0	<0.06	2.8	<0.34	<0.73

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{106}Ru	^{110m}Ag	^{137}Cs	^{155}Eu	^{241}Am	Total alpha	Total beta
Terrestrial samples									
Milk		1	<0.43	<0.06	<0.05		<0.06		
Blackberries		1	<0.18	<0.05	<0.05		<0.05		
Broccoli		1	<0.40	<0.05	<0.05		<0.10		
Carrots		1	<0.24	<0.05	<0.05		<0.06		
Elderberries		1	<0.43	<0.05	<0.05		<0.13		
Potatoes		1	<0.33	<0.05	<0.05		<0.09		
Rosehips		1	<0.44	<0.05	<0.05		<0.14		
Rowanberries		1	<0.33	<0.05	<0.05		<0.08		
Spring cabbage		1	<0.43	<0.05	<0.05		<0.12		
Grass		6	<0.57	<0.07	<0.06		<0.16	<4.8	220
Grass	max		<0.87	<0.11	<0.08		<0.22	14	280
Soil		6	<0.45	<0.07	8.0	1.0	<0.24	310	710
Soil	max		<0.55	<0.08	12	1.7	0.31	400	980

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *The concentration of ^{14}C was 22 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*

Table 5.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2004

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	0.059
Dunbar Inner Harbour	Sand	2	0.098
Belhaven Bay	Salt marsh	2	0.060
Barns Ness	Mud, sand and stones	2	0.056
Skateraw	Sand	2	<0.049
Thornton Loch	Sand	2	<0.048
St Abbs Head	Mud	2	0.10
Eyemouth	Mud	2	0.066
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, 2004

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m-3		
		^{137}Cs	Total alpha	Total beta
Innerwick	12	<0.010	<0.0066	0.11
Cockburnspath	12	<0.010	<0.0080	0.15

Table 5.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2004

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	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu
Freshwater samples												
Brown trout	Lake	6		27		<0.14	3.1	<1.8	<0.58	<0.17	67	<0.43
Rainbow trout	Lake	6				<0.09		<0.93	<0.23	<0.10	1.4	<0.28
Perch	Lake	5				<0.17	1.3	<2.5	<0.78	<0.26	110	<0.54
Rudd	Lake	1				<0.09		<1.5	<0.52	<0.12	71	<0.28
Mud	Pipeline	1				17		<18	<7.8	1.9	1500	8.1
Mud, sand and stones	Pipeline	1				6.1		<15	<5.6	2.2	930	<2.9
Sediment	Lake shore	2[E]				<0.87	<7.0		<12	<1.2	700	
Sediment	Bailey Bridge	1[E]				<1.8	5.4		<14	<1.6	330	
Sediment	Fish farm	2[E]				4.7	11		<12	<2.0	760	
Sediment	Footbridge	2[E]				<0.84	<3.0		<6.0	<0.67	160	
Sediment	Cae Adda	2[E]				<1.2	1.5		<11	<1.2	270	
Freshwater	Bailey Bridge	1	<1.4									
Freshwater	Cold Lagoon	2								*	0.01	
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.40				<0.36	<0.32	
Freshwater	Gwylan Stream	2[E]	<4.0		<1.0	<0.47				<0.46	<0.39	
Freshwater	Diversion culvert	2[E]	<4.0		<1.1	<0.49				<0.45	<0.40	
Freshwater	Hot Lagoon	2[E]	<4.0		<1.0	<0.44				<0.41	<0.37	
Freshwater	Afon Prysor	2[E]	<4.0		<1.0	<0.50				<0.47	<0.40	
Freshwater	Lake	2[E]	<4.0		<1.0	<0.49				<0.46	<0.40	

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
Freshwater samples										
Brown trout	Lake	6	<0.40	0.000098	0.00038	0.00071	*	*		
Rainbow trout	Lake	6	<0.25			<0.31				
Perch	Lake	5	<0.50	0.000073	0.00026	0.00054	0.000033	0.000014		
Rudd	Lake	1	<0.42			<0.63				
Mud	Pipeline	1	<6.0			42				
Mud, sand and stones	Pipeline	1	<4.1			17				
Sediment	Lake shore	2[E]		0.60	2.2	7.1				
Sediment	Bailey Bridge	1[E]		1.7	4.6	<0.67				
Sediment	Fish farm	2[E]		2.6	6.2	13				
Sediment	Footbridge	2[E]		<0.46	0.49	9.2				
Sediment	Cae Adda	2[E]		<1.0	1.1	3.2				
Freshwater	Public supply	2[E]							<0.020	<0.10
Freshwater	Gwylan Stream	2[E]							<0.020	<0.17
Freshwater	Diversion culvert	2[E]							<0.068	<0.20
Freshwater	Hot Lagoon	2[E]							<0.031	<0.12
Freshwater	Afon Prysor	2[E]							<0.020	<0.12
Freshwater	Lake	2[E]							<0.020	<0.16

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	^{125}Sb	^{134}Cs	^{137}Cs
Terrestrial Samples										
Milk		2	<4.0	18		<0.29	0.060	<0.65		
Milk	max			19		<0.30	0.067			
Blackberries		1	<3.0	14	<0.30	<0.20			<0.20	0.50
Cabbage		1	<4.0	<3.0	<0.60	<0.50			<0.40	<0.40
Carrots		1	<4.0	8.0	0.40	<0.30		<0.60	<0.30	<0.30
Eggs		1	<5.0	15	2.4	<0.20		<0.70	<0.30	<0.30
Ovine muscle		2	<5.0	37		<0.30	<0.011	<0.65		
Ovine muscle	max			45		<0.40	0.013	<0.70		
Ovine offal		2	<8.5	29		<0.25	0.42	<0.65		
Ovine offal	max		<10	41		<0.30	0.63	<0.70		
Potatoes		1	<4.0	16	<0.30	<0.40			<0.30	<0.40
Sloe berries		1	<4.0	20	<0.40	<0.40		<0.90	<0.30	0.70

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1} Total Cs	^{154}Eu	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Terrestrial Samples								
Milk		2	0.28	<0.36	<0.51			
Milk	max		0.43	<0.40	<0.58			
Blackberries		1				<0.00020	0.00030	<0.00040
Carrots		1		<0.30	<0.40	<0.00020	0.00090	0.0011
Eggs		1		<0.60	<1.1	<0.00030	<0.00010	<0.00030
Ovine muscle		2	0.51	<0.40	<0.65	<0.00040	<0.00025	<0.00030
Ovine muscle	max		0.57		<0.70	<0.00050	<0.00030	
Ovine offal		2	0.42	<0.50	<0.85	<0.00020	<0.00025	<0.00035
Ovine offal	max		0.53	<0.60	<1.1	<0.00030	0.00030	<0.00040
Potatoes		1				<0.00030	0.00030	0.00040
Sloe berries		1		<0.60	<0.90	<0.00020	<0.00020	0.00070

** 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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency

Table 5.12(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2004

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Stones	2[F]	0.093
Footbridge	Pebbles and stones	1	0.096
Footbridge	Pebbles and rock	1	0.10
Nant Islyn Bay	Stones	2[F]	0.11
West of footbridge	Stones	2[F]	0.10
Lake shore	Pebbles and stones	1	0.090
Lake shore	Pebbles and rock	1	0.087
Bailey Bridge	Pebbles	1	0.086
Fish Farm	Pebbles	1	0.10
Fish Farm	Pebbles and rock	1	0.10
Cae Adda	Mud and pebbles	1	0.090
Cae Adda	Pebbles and rock	1	0.083

[F] Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency

Table 5.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2004

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	^{125}Sb	^{137}Cs	^{238}Pu
Marine samples										
Plaice	Pipeline	2	<25	<25	53	<0.06		<0.13	1.5	
Crabs	Pipeline	2				<0.05	1.8	<0.11	0.44	0.0024
Lobsters	Pipeline	2				<0.04	180	<0.10	0.54	
Winkles	Cemaes Bay	2	<25	<25	35	<0.10		<0.25	0.58	0.034
Fucus vesiculosus	Cemaes Bay	2				<0.05	280	<0.13	0.86	
Seaweed	Cemaes Bay	2[E]				<1.6	760	<7.6	<1.2	
Sediment	Cemaes Bay	2[E]				<0.57			6.0	
Sediment	Cemlyn Bay	2[E]				<0.50			3.6	
Seawater	Cemaes Bay	2[E]				<0.48			<0.41	
Seawater	Cemlyn Bay	2[E]				<0.48			<0.41	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples									
Plaice	Pipeline	2			<0.06				
Crabs	Pipeline	2	0.014		0.041	*	0.000095		
Lobsters	Pipeline	2			<0.08				200
Winkles	Cemaes Bay	2	0.19	1.5	0.26	0.00020	0.00032		
Fucus vesiculosus	Cemaes Bay	2			<0.18				
Seaweed	Cemaes Bay	2[E]			<1.6				
Sediment	Cemaes Bay	2[E]			<1.4				
Sediment	Cemlyn Bay	2[E]			<0.69				
Seawater	Cemaes Bay	2[E]			<0.54			<1.3	<6.8
Seawater	Cemlyn Bay	2[E]			<0.53			<2.8	16

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	<4.3	18	<0.53	<0.31	<0.31		
Milk	max		<4.8	20	<0.60	<0.33	<0.33		
Apples		1	<3.0	6.0	0.40	<0.50	<0.40		
Blackberries		1	<4.0	29	3.6	<0.30	<0.30		
Cabbage		1	<4.0	<3.0	<0.60	<0.40	<0.30		
Honey		1	<7.0	99	<0.30	<0.30	<0.20		
Oats		1	<6.0	120	0.90	<0.40	<0.50		
Plums		1	<4.0	8.0	<0.30	<0.40	<0.30		
Potatoes		1	<4.0	14	0.80	<0.50	<0.50		
Swede		1	4.0	<3.0	<0.30	<0.40	<0.40		
Freshwater	Public supply	1[E]	<4.0		<1.0	<0.50	<0.39	<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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.13(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2004

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]	0.052
Cemaes Bay	Sand and stones	1	0.069
Cemaes Bay	Rock and sand	1	0.069
Cemlyn Bay	Pebbles and stones	1	0.069
Cemlyn Bay	NA	1	0.075

NA Not available

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

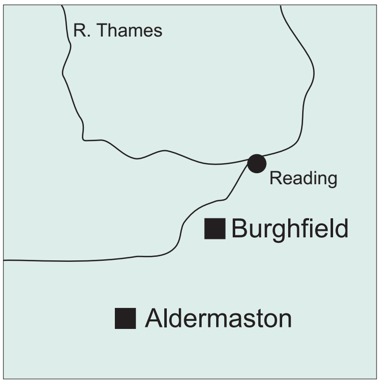
6. DEFENCE ESTABLISHMENTS

This section considers the results of monitoring by the Environment Agency, Food Standards Agency and the Scottish Environment Protection Agency undertaken routinely near nine defence-related establishments in the UK. In addition, the MoD makes arrangements for monitoring at other defence sites where contamination may occur. Low-level gaseous discharges 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, 2004).

In 2004, there was concern about historic firings of soluble cobalt-60 sources contained in radioactive "miss distance" indicators in the head of Rapier missiles at the former Royal Artillery Range Hebrides, South Uist. As a consequence an environmental monitoring survey was conducted on behalf of MoD in May 2004. The survey covered the marine and terrestrial sectors and two reports have been published (Woodcock and Boltwood, 2004a and b).

About 5600 missile firings were made from South Uist out to sea close to the island of Benbecula, starting in 1970 and finishing in 1981. In addition small amounts of waste were buried in a fenced compound. The environmental survey outside the fenced area comprised sampling for marine sediment, seaweed, seafood, soil cores and area monitoring using dose rate detectors. No cobalt-60 was detected in any samples and the risks to the local population are considered negligible.

6.1 Aldermaston, Berkshire

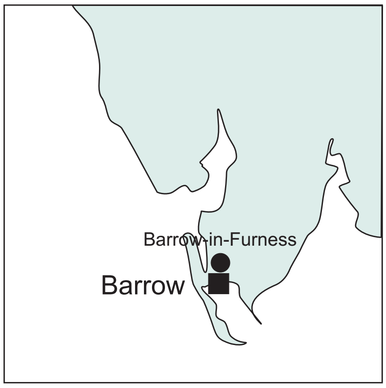


The Atomic Weapons Establishment (AWE) at Aldermaston is authorised to discharge low levels of radioactive waste to the environment. In 2004, the site was authorised to discharge aqueous radioactive waste to the River Thames at Pangbourne, to the sewage works at Silchester and to Aldermaston Stream. From April 2005, the site is no longer authorised to discharge aqueous waste to the River Thames at Pangbourne. 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 nuclear establishments located in the Thames catchment.

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 2003. Levels of tritium were generally below the LoD though some enhancements were observed in sediments collected from road gullypots very close to the site. 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 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). Consumption of locally harvested crayfish was also considered as a pathway for radiation exposure. Exposures were much less than 0.005 mSv using consumption data from the habits survey. The total alpha and total beta activity concentrations in the freshwater samples were below the WHO screening levels for drinking water. 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 2003. Natural background or weapon test fallout would have made a significant contribution to the levels detected. There were decreases in the reported results for caesium-137 in soils but the sampling locations were different from those in 2003. 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 2004, 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 2004, 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 2004.

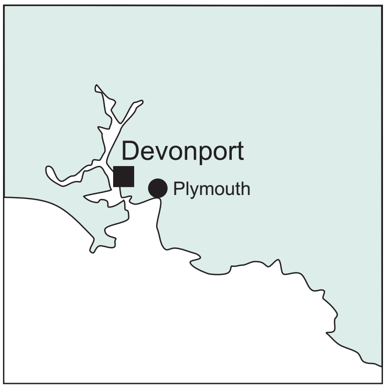
6.3 Derby, Derbyshire

Rolls-Royce Marine Power Operations Ltd. (RRMPOL) 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 Megaloughton Lane 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 the low-level waste repository at Drigg. Following a public consultation the Environment Agency issued new authorisations for RRMPOL which took effect from 1 July 2004. The new authorisations include reduced discharge limits for both sites and they closed off the Hilts Quarry disposal route for solid wastes (Environment Agency, 2004k).

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 total beta activity levels in river water from the River Derwent were less than the WHO screening levels for drinking water and doses from using the river as a source of drinking water would be 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. RRMPOL 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 (Table 9.14).

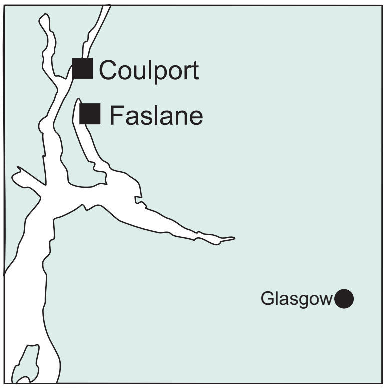
6.4 Devonport, Devon



Devonport consists of two parts: the Naval Base which is owned and operated by the MoD, and Devonport Royal Dockyard which is owned and operated by Devonport Royal Dockyard Limited (DRDL). DRDL refits, refuels, repairs and maintains the Royal Navy's nuclear powered submarines and has an authorisation granted by the Environment Agency to discharge liquid wastes to the Hamaoze, which is part of the Tamar Estuary and to the local sewer and gases, mists and dusts to atmosphere. The MoD Naval Base is permitted to discharge liquid wastes to the sewer under an administrative agreement with the Environment Agency.

The routine monitoring programme in 2004 consisted of measurements of gamma dose rate and analysis of fish, shellfish, fruit, grass and sediments. The results given in Tables 6.3(a) and (b) were similar to those in 2003 where comparisons can be drawn. Trace quantities of caesium-137, technetium-99 and americum-241 were found in the marine environment. These were most likely to have originated from Chernobyl and from spent fuel reprocessing elsewhere. Activation products were below LoDs. A habits survey in 2004 has established that there are two dominant critical groups for marine pathways, (i) fish and shellfish consumers and (ii) occupants of houseboats. Taking account of relevant consumption of marine foods and occupancy times, doses to both groups were 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 was less than 0.005 mSv. The radiological significance of this site continued to be low.

6.5 Faslane and Coulport, Argyll and Bute



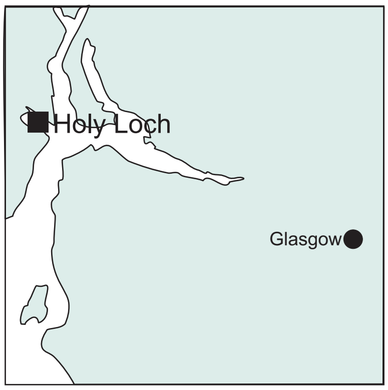
The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport. Babcock Naval Services, a subsidiary of Babcock Support Services Limited, operate at HMNB Clyde in partnership with MoD. However, MoD remains in control of the undertaking, through the Naval Base Commander, Clyde, in relation to radioactive waste disposal.

Work on the new effluent plant that the MoD plan to build at Faslane has been subject to delays and is now not scheduled to be commissioned until 2008. The Scottish Environment Protection Agency is currently processing the application made by MoD in 2003, which relates to the disposal of liquid and gaseous wastes from the proposed plant.

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 the Scottish Environment Protection Agency and the MoD. The discharges made during 2004 are shown in Appendix 1. The disposal of solid radioactive waste from each site is also made under letters of agreement between the Scottish Environment Protection Agency and the MoD. Disposals of solid waste from the sites resumed in 2004, as BNFL lifted the general embargo that they had previously placed on MoD(N) waste.

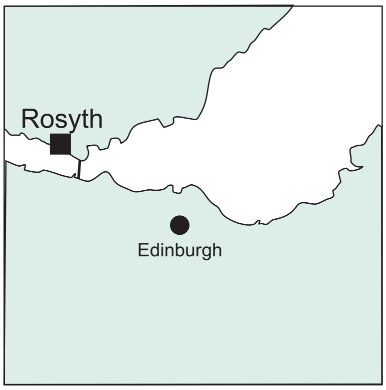
Habit surveys have been used to investigate exposure pathways, the most recent of which identified fish consumption and external radiation from the shore as the major pathways of exposure. The scope of the monitoring programme reflects these pathways and included the analysis of seawater, sediment and 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 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 reduced in 2004 (Table 6.3(b)). However, the detected activity of cobalt-60 in sediment from the loch was similar to that for 2003. The external radiation dose to the critical group was less than 0.005 mSv in 2004, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 6.2).

6.7 Rosyth, Fife

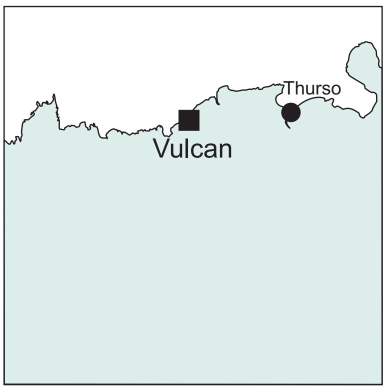


Following the Government decision to have nuclear submarine refit work carried out at Devonport, submarines are no longer re-equipped, maintained or refuelled at the Rosyth site. The site is operated by Babcock Engineering Services who have completed assessment work in preparation of site decommissioning, which is expected to commence in 2005.

In March 2003, Rosyth Royal Dockyard Limited applied to the Scottish Environment Protection Agency for an authorisation to dispose of solid, liquid and gaseous radioactive waste that will arise during the decommissioning of the Rosyth site. The Scottish Environment Protection Agency, following an open consultation, published its determination of the application in September 2004 (Scottish Environment Protection Agency, 2004). New limits took effect on 1st November 2004, however, no decommissioning wastes were discharged in 2004. Operational wastes continued to be discharged under separate, continuing, authorisations for such wastes.

The Scottish Environment Protection Agency's routine 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 2004 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 MoD (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, 2004

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{57}Co	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples									
Pike	Newbridge	1		<25	<0.03	<0.05			
Pike	Outfall (Pangbourne)	1		<25	<0.03	0.18			
Pike	Staines	1	<25	<25	<0.03	0.12			
Pike	Shepperton	1	<25	<25	<0.04	0.16			
Pike	Teddington	1	<25	<25	<0.04	0.11			
Flounder	Beckton	1		<25	<0.03	0.25			
Signal crayfish	Thatcham	1	<25	<25	<0.13	<0.15			
Nuphar lutea	Newbridge	1		<25	<0.05	<0.05			
Nuphar lutea	Staines	1		<25	<0.02	<0.04			
Clay	Outfall (Pangbourne)	1			<0.38	2.9			
Sediment	Pangbourne	4[E]				11	12	<1.3	12
Sediment	Mapledurham	4[E]				22	10	<0.65	10
Sediment	Aldermaston	4[E]				<3.5	14	<0.74	13
Sediment	Spring Lane	4[E]				<1.7	11	<0.70	10
Sediment	Stream draining south	4[E]				<2.6	14	<0.79	15
Sediment	Reading (Kennet)	4[E]				4.8	15	<0.71	14
Gullypot sediment	Falcon Gate	1[E]		100		<2.9	15	<0.73	17
Gullypot sediment	Main Gate	1[E]		35		<0.56	16	<0.88	15
Gullypot sediment	Tadley Entrance	1[E]		<25		1.9	6.9	0.48	8.8
Gullypot sediment	Burghfield Gate	1[E]		<25		<1.8	15	<0.73	14
Freshwater	Pangbourne	4[E]		<4.0		<0.39	0.013	<0.0058	0.010
Freshwater	Mapledurham	4[E]		<4.0		<0.39	0.015	<0.0050	<0.011
Freshwater	Aldermaston	4[E]		<8.5		<0.40	<0.011	<0.0053	0.0083
Freshwater	Spring Lane	4[E]		<5.3		<0.41	<0.0070	<0.0050	<0.0058
Freshwater	Reading (Kennet)	4[E]		<4.0		<0.39	0.0093	<0.0050	<0.0060
Crude liquid effluent	Silchester treatment works	4[E]		18		<0.34	<0.0068	<0.0050	<0.0063
Liquid effluent	Silchester treatment works	4[E]		18		<0.35	<0.0063	<0.0050	<0.0055
Sewage sludge	Silchester treatment works	4[E]		<25		<1.9	0.55	<0.038	0.51

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
Freshwater samples									
Pike	Newbridge	1	0.000063	0.00022	0.00041	*	*		
Pike	Outfall (Pangbourne)	1	<0.0000071	0.000062	0.000046	*	*		
Pike	Staines	1			<0.10				
Pike	Shepperton	1			<0.14				
Pike	Teddington	1			<0.15				
Flounder	Beckton	1			<0.06				
Signal crayfish	Thatcham	1	0.000041	0.00019	0.00033	*	*		
Nuphar lutea	Newbridge	1			<0.12				
Nuphar lutea	Staines	1			<0.03				
Clay	Outfall (Pangbourne)	1			<0.86				
Sediment	Pangbourne	4[E]	<0.46	<0.29	<0.98			320	490
Sediment	Mapledurham	4[E]	<0.73	<0.86	<0.94			220	390
Sediment	Aldermaston	4[E]	<0.51	3.2	<1.2			260	510
Sediment	Spring Lane	4[E]	<0.42	<0.27	<1.0			270	460
Sediment	Stream draining south	4[E]	<0.46	<0.37	1.6			400	710
Sediment	Reading (Kennet)	4[E]	<0.57	<0.43	<0.93			260	510
Gullypot sediment	Falcon Gate	1[E]	<0.55	0.44	<3.7			370	600
Gullypot sediment	Main Gate	1[E]	<0.45	<0.36	<0.84			620	600
Gullypot sediment	Tadley Entrance	1[E]	<0.34	0.20	<1.0			510	600
Gullypot sediment	Burghfield Gate	1[E]	<0.60	<0.30	<2.3			240	330
Freshwater	Pangbourne	4[E]	<0.0080	<0.0050	<0.015			<0.039	0.25
Freshwater	Mapledurham	4[E]	<0.011	<0.0050	<0.011			<0.039	0.20
Freshwater	Aldermaston	4[E]	<0.0093	<0.0053	<0.018			<0.025	0.16
Freshwater	Spring Lane	4[E]	<0.0085	<0.0050	<0.011			<0.030	<0.14
Freshwater	Reading (Kennet)	4[E]	<0.0073	<0.0050	<0.0085			<0.028	<0.11
Crude liquid effluent	Silchester treatment works	4[E]	<0.0083	<0.0050	<0.53			<0.065	0.57
Liquid effluent	Silchester treatment works	4[E]	<0.012	<0.0053	<0.50			<0.055	0.55
Sewage sludge	Silchester treatment works	4[E]	<0.039	<0.018	<2.7			6.3	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	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples								
Milk		4	<4.0	<0.31				<0.0065
Milk	max			<0.33				
Beetroot		1	<4.0	<0.40				<0.030
Blackberries		1	5.0	<0.30				<0.029
Cabbage		1	<4.0	<0.30	0.0062	<0.00080	0.0062	0.032
Carrots		1	<4.0	<0.30				<0.030
Honey		1	11	<0.20				<0.023
Runner beans		1	10	<0.30				<0.030
Rabbit		1	6.0	<0.30				<0.031
Wheat		1	<6.0	<0.40				<0.030
Grass	Location 2	1[E]	34	<15	0.39	<0.12	0.49	
Grass	Location 3	1[E]	37	<3.5	<0.30	<0.20	0.25	
Grass	Location 4	1[E]	<25	<8.2	<0.62	<0.26	<0.58	
Grass	Location 7	1[E]	68	<3.5	0.23	<0.11	0.23	
Soil	Location 1	1[E]	28	19	27	1.2	29	
Soil	Location 2	1[E]	<25	4.6	10	<0.63	8.2	
Soil	Location 3	1[E]	29	7.3	11	<0.45	11	
Soil	Location 4	1[E]	<25	17	13	<2.4	15	
Soil	Location 7	1[E]	<25	16	18	<0.90	20	
Soil		4						36
Soil	max				7.8	0.29	7.2	45

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		4	<0.00011	<0.00011	<0.00018		
Milk	max		<0.00013	<0.00013	<0.00020		
Beetroot		1	<0.00020	<0.00030	<0.00030		
Blackberries		1	0.00010	<0.00010	<0.00020		
Cabbage		1	<0.00020	<0.00020	<0.00030		
Carrots		1	<0.00010	<0.00020	0.00070		
Honey		1	<0.00030	<0.00020	<0.00030		
Runner beans		1	<0.00010	<0.00020	<0.00030		
Rabbit		1	<0.00060	<0.00050	<0.00030		
Wheat		1	<0.00020	<0.00020	<0.00040		
Grass	Location 2	1[E]	<0.80	<0.34		8.1	70
Grass	Location 3	1[E]	<0.26	0.30		1.3	170
Grass	Location 4	1[E]	<0.19	<0.090		<1.0	130
Grass	Location 7	1[E]	<0.13	<0.080		4.8	160
Soil	Location 1	1[E]	<0.70	0.55		280	660
Soil	Location 2	1[E]	<0.61	0.80		110	200
Soil	Location 3	1[E]	<1.2	<0.62		260	450
Soil	Location 4	1[E]	<0.74	<0.43		210	360
Soil	Location 7	1[E]	<0.65	0.59		390	570

** 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'. '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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 6.1(b). Monitoring of radiation dose rates near Aldermaston, 2004

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over riverbank			
Pangbourne	Mud	1	0.060
Pangbourne	Grass and mud	1	0.069
Pangbourne	Grass and marsh	2	0.064
Mapledurham	Mud and pebbles	1	0.066
Mapledurham	Mud and stones	1	0.065
Mapledurham	Grass and mud	2	0.064

Table 6.2. Individual radiation exposures - defence sites, 2004

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 harvested crayfish	<0.005	<0.005	-	-	-
	Consumers of locally grown food[b,c]	<0.005	-	<0.005	-	-
Derby	Consumers of drinking water	<0.005	-	-	-	<0.005
Devonport	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Houseboat occupants	<0.005	-	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Faslane	Seafood consumers	<0.005	<0.005	-	<0.005	-
Holy Loch	Anglers	<0.005	-	-	<0.005	-
Rosyth	Boat users	<0.005	-	-	<0.005	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*
[c] *Includes a component due to natural sources of radionuclides*

Defence

Table 6.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2004

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	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{95}Nb	^{106}Ru	^{110m}Ag
Barrow												
Grass	Barrow	2[F]		<4.0								
Derby												
Mud	River Derwent, downstream	4						<1.4				
Mud	River Derwent, upstream	1						<0.72				
Water	River Derwent, downstream	4						<0.48				
Water	River Derwent, upstream	1						<0.46				
Water	Fritchley Brook, downstream of Hilt's Quarry	1		<4.0				<0.47				
Devonport												
Dogfish	Plymouth Sound	1[F]				<0.14	<0.29	<0.13	<0.35	<0.80	<1.5	<0.24
Crabs	Plymouth Sound	2[F]			21	<0.16	<0.44	<0.14	<0.40	<1.9	<1.5	<0.28
Mussels	River Lynher	1[F]	<25	<25		<0.22	<0.92	<0.18	<0.55	*	<2.0	<0.39
Winkles	River Lynher	1[F]	<25	<25		<0.14	<0.27	<0.13	<0.32	<0.75	<1.4	<0.23
Fucus vesiculosus[c]	Kinterbury	2[F]				<0.07	<0.09	<0.07	<0.18	<0.18	<0.57	<0.12
Mud[d]	Kinterbury	2[F]				<0.80	<1.0	<0.72	<1.8	<2.3	<6.4	<1.3
Sediment	Torpoint (South)	2		<32				<1.0				
Sediment	Lopwell	2		<62				<1.4				
Seawater	Torpoint (South)	2		<4.0	<4.0			<0.50				
Seawater	Millbrook Lake	2		<4.0	<4.0			<0.42				
Blackberries		1[F]		<4.0				<0.30		<0.30	<2.4	<0.30
Grass	Devonport	3[F]		<4.3				<0.30		<0.33	<2.1	<0.27
Grass	max			<5.0				<0.40		<0.40	<2.5	<0.30
Faslane												
Fish	Carnban boatyard	2				<0.10	<0.15	<0.10	<0.19	<0.29	<0.53	<0.12
Sediment	Carnban boatyard	2				<0.10	<0.14	<0.10	<0.20	<0.39	<0.55	<0.10
Seawater	Carnban boatyard	1		3.5								
Holy Loch												
Sediment	Mid Loch	1				<0.10	<0.16	<0.10	<0.32	<0.23	<0.73	<0.11
Rosyth												
Crabs	East of dockyard	1				<0.10	<0.10	<0.10	<0.10	<0.12	<0.24	<0.10
Fucus vesiculosus	East of dockyard	1				<0.10	<0.10	<0.10	<0.17	<0.12	<0.44	<0.10
Seaweed	East of dockyard	1				<0.10	<0.10	<0.10	<0.17	<0.13	<0.44	<0.10
Sediment	East of dockyard	2				<0.10	<0.15	<0.10	<0.22	<0.49	<0.55	<0.10
Sediment	Port Edgar	2				<0.10	<0.28	<0.10	<0.42	<1.2	<0.99	<0.16
Sediment	West of dockyard	2				<0.15	<0.45	<0.15	<0.52	<1.9	<1.5	<0.23
Sediment	Blackness Castle	2				<0.10	<0.29	<0.10	<0.42	<1.2	<1.0	<0.17
Sediment	Burntisland Bay	2				<0.10	<0.15	<0.10	<0.22	<0.56	<0.54	<0.10
Seawater	East of dockyard	1		<1.0								

Table 6.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{124}Sb	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{228}Th	^{230}Th
Derby												
Water	Fritchley Brook, downstream of Hilt's Quarry	1					<0.41				<0.017	<0.026
Devonport												
Dogfish	Plymouth Sound	1[F]	<0.80	<0.31	*	<0.13	0.28	<0.55	<0.38	<0.20		
Crabs	Plymouth Sound	2[F]	<1.3	<0.29	*	<0.14	<0.12	<0.54	<0.38	<0.20		
Mussels	River Lynher	1[F]	<3.5	<0.37	*	<0.19	<0.14	<0.73	<0.45	<0.23		
Winkles	River Lynher	1[F]	<0.76	<0.33	*	<0.15	<0.12	<0.72	<0.35	<0.30		
Fucus vesiculosus[c]	Kinterbury	2[F]	<0.15	<0.15	<0.72	<0.07	<0.06	<0.36	<0.21	<0.18		
Mud[d]	Kinterbury	2[F]	<2.1	<1.8	*	<0.92	3.5	<4.2	<2.1	<2.1		
Sediment	Torpoint (South)	2					<1.2					
Sediment	Lopwell	2					5.1					
Blackberries		1[F]				<0.30	<0.30	<2.0				
Grass	Devonport	3[F]				<0.27	<0.27	<1.1				
Grass	max					<0.30	<0.30	<1.3				
Faslane												
Fish	Carnban boatyard	2		<0.17		<0.10	1.0	<0.38	<0.12	<0.19		
Sediment	Carnban boatyard	2		<0.17		<0.10	5.8	<0.51	<0.12	<0.52		
Holy Loch												
Sediment	Mid Loch	1		<0.22		<0.10	6.6	<0.78	<0.16	0.57		
Rosyth												
Crabs	East of dockyard	1		<0.10		<0.10	<0.10	<0.18	<0.10	<0.10		
Fucus vesiculosus	East of dockyard	1		<0.12		<0.10	0.27	<0.30	<0.10	<0.15		
Seaweed	East of dockyard	1		<0.12		<0.10	<0.10	<0.32	<0.10	<0.16		
Sediment	East of dockyard	2		<0.16		<0.10	1.2	<0.47	<0.13	0.35		
Sediment	Port Edgar	2		<0.29		<0.13	12	<1.1	<0.22	1.3		
Sediment	West of dockyard	2		<0.40		<0.17	15	<1.2	<0.22	<0.93		
Sediment	Blackness Castle	2		<0.29		<0.13	11	<0.56	<0.21	1.1		
Sediment	Burntisland Bay	2		<0.15		<0.10	0.41	<0.56	<0.12	<0.32		

Table 6.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}							
			^{232}Th	Total U	^{234}U	^{235}U	^{238}U	^{241}Am	Total alpha	Total beta
Derby										
Mud	River Derwent, downstream	4			33	<1.1	31		510	650
Mud	River Derwent, upstream	1			15	<1.2	17			
Grass		4[F]		0.43						
Grass	max			0.66	0.17	0.0064	0.14			
Soil		4[F]		79						
Soil	max			110	27	0.94	23			
Water	River Derwent, downstream	4							<0.035	0.16
Water	River Derwent, upstream	1							0.030	0.14
Water	Fritchley Brook, downstream of Hilt's Quarry	1	<0.0060		0.022	<0.0050	0.016		0.053	0.22
Devonport										
Dogfish	Plymouth Sound	1[F]						<0.10		
Crabs	Plymouth Sound	2[F]						<0.10		
Mussels	River Lynher	1[F]						<0.12		
Winkles	River Lynher	1[F]						<0.26		
Fucus vesiculosus[c]	Kinterbury	2[F]						<0.23		
Mud[d]	Kinterbury	2[F]						0.18		
Faslane										
Fish	Carnban boatyard	2						<0.18		
Sediment	Carnban boatyard	2						<0.21		
Holy Loch										
Sediment	Mid Loch	1						<0.30		
Rosyth										
Crabs	East of dockyard	1						<0.10		
Fucus vesiculosus	East of dockyard	1						<0.14		
Seaweed	East of dockyard	1						<0.15		
Sediment	East of dockyard	2						<0.14		
Sediment	Port Edgar	2						1.1		
Sediment	West of dockyard	2						2.2		
Sediment	Blackness Castle	2						<1.8		
Sediment	Burntisland Bay	2						<0.21		

** Not detected by the method used*

[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 concentration of ^{99}Tc was 0.20 Bq kg^{-1}*

[d] *The concentrations of ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were 0.025, 0.51, .0017 and 0.0011 Bq kg^{-1} respectively*

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the environment agencies*

Table 6.3(b). Monitoring of radiation dose rates near defence establishments, 2004

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]	0.078
Devonport	Torpoint South	Mud and rock	1	0.11
Devonport	Torpoint South	Shale	1	0.11
Devonport	Lopwell	Mud and pebbles	1	0.11
Devonport	Lopwell	Shale	1	0.11
Faslane	Gareloch Head	Mud, sand and stones	2	0.059
Faslane	Gulley Bridge Pier	Sand and stones	2	0.057
Faslane	Rhu	Gravel	2	0.060
Faslane	Rosneath	Sand and gravel	2	0.056
Faslane	Carnban boatyard	Mud and sand	2	0.073
Holy Loch	North Sandbank	Mud and sand	1	<0.047
Holy Loch	Kilmun Pier	Sand and stones	1	0.050
Holy Loch	Mid-Loch	Sand	1	<0.047
Rosyth	Blackness Castle	Mud and sand	2	<0.051
Rosyth	Burntisland Bay	Sand	2	<0.047
Rosyth	East of Dockyard	Sand	2	<0.049
Rosyth	Port Edgar	Mud	2	0.056
Rosyth	West of Dockyard	Mud and sand	2	<0.047

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the environment agencies*

7. RADIOCHEMICAL PRODUCTION

GE Healthcare 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 considered applications by Amersham plc (now GE Healthcare) to change its authorisations at the Amersham and Cardiff sites and significantly more rigorous authorisations were introduced in 2004 (Environment Agency, 2004m).

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, 2004n). 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. The revised authorisations came into effect in 2005.

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.

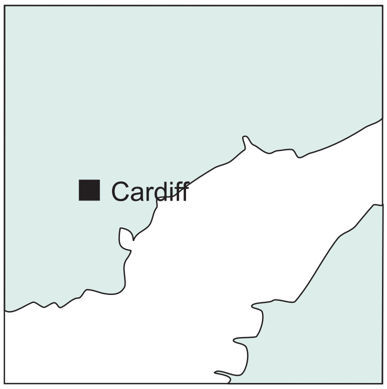
The results are presented in Tables 7.1(a) and (b). The concentration of carbon-14 in fish was typical of the background level and its radiological significance was low. Tritium concentrations in biota in the Thames and the Grand Union Canal were at the LoD. Concentrations in material from Maple Lodge Sewage Works were similar to those in 2003. Total alpha and total beta activities in water were below the WHO screening levels for drinking water. The caesium-137 detected in mud from the canal is unlikely to be due to discharges from Amersham. Gamma dose rates above the banks of the canal were indistinguishable from background.

The activity concentrations in milk, grass and soil crops were generally lower than the limits of detection. However, low levels of tritium, sulphur-35, and iodine-125 were detected in a few samples. Caesium-137 activity detected in soil near the site is likely to be due to global fallout from testing of weapons or from the Chernobyl accident. It is possible that the relatively high total alpha concentration in soil (1200 Bq kg^{-1}) could be due to sources on the Amersham site. This will be investigated in 2005.

A consumption and occupancy habits survey in the vicinity of the site was undertaken in 2004. Considering pathways downstream of the release point for discharges of liquid effluents, no consumers of fish, shellfish or freshwater plants were identified directly. However, there was hearsay evidence of fish consumption, albeit occasional and at low rates. To allow for this, a consumption rate of 1 kg $year^{-1}$ for fish has therefore been assumed. Occupancy of the river and canal banks was confirmed as continuing by anglers and others, and this pathway has also been assessed. The dose in 2004 from fish consumption and external radiation 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 local terrestrial food consumers was assessed as being less than 0.017 mSv, which was less than 2% of the annual dose limit for members of the public. This estimate includes a contribution of 0.011 mSv from modelled concentrations of discharged radionuclides in air.

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. a tenant on the site, made no discharges from the site in 2004 and its authorisation was revoked with effect from 1st April 2004.

On 19th July 2004, the Environment Agency issued an Enforcement Notice to GE Healthcare requiring the company to carry out a full investigation of ground contamination near the Cardiff site (Environment Agency, 2004p). The contamination had been found by the company in ground outside the boundary of the Site Nuclear Licence, but still on land owned by GE Healthcare. The contamination was due to a crack in the pipeline for discharge to the YP sewer, which has now been repaired. Samples taken in the ground near the pipeline indicated low levels of contamination and the investigation has now been completed.

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).

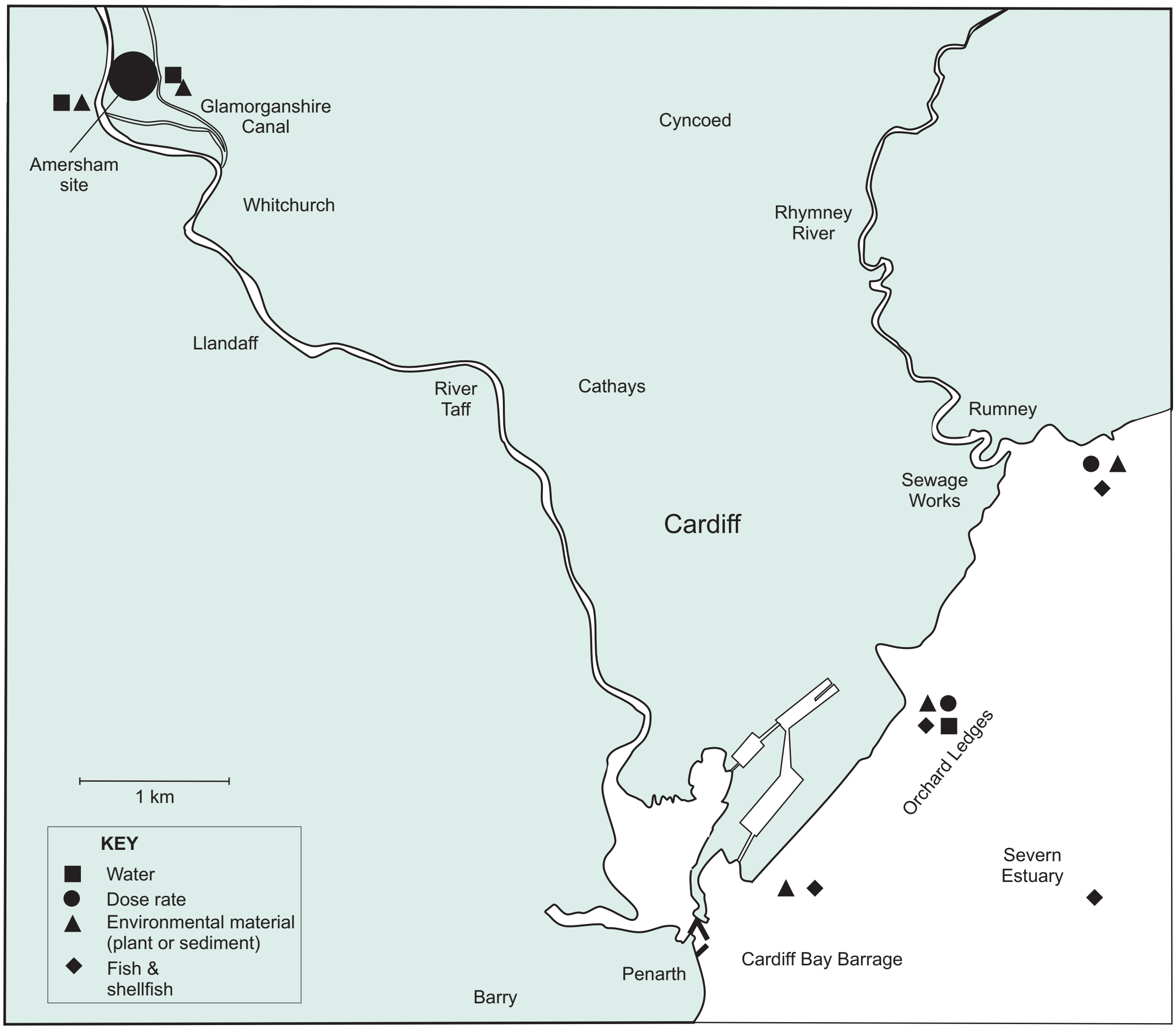


Figure 7.1 Monitoring locations at Cardiff (excluding farms)

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.

The results of routine monitoring in 2004 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 virtually all of the total tritium in marine samples was associated with organic matter. The 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. There were reductions in the concentrations of both tritium and carbon-14 in seafood in 2004, despite small increases in discharges. The lower tritium levels were most probably due to a reduction in the organically bound components of the discharge.

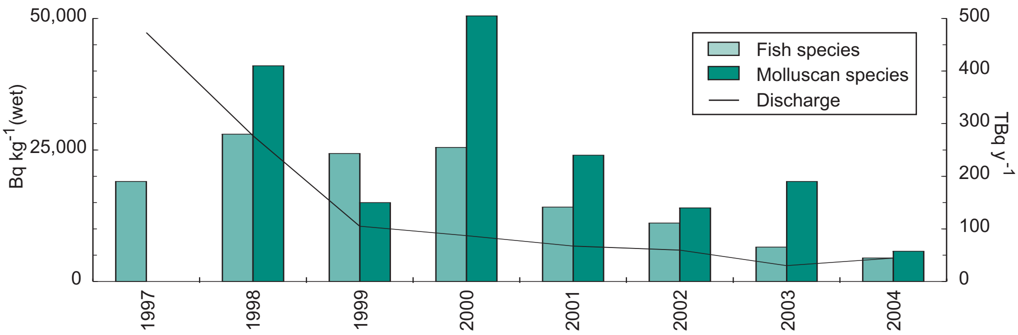


Figure 7.2 Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

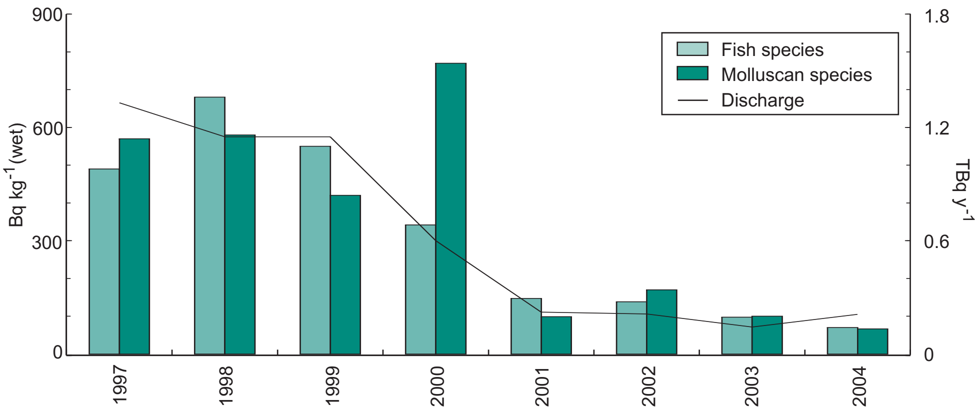


Figure 7.3 Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

Radiochemical

7. Radiochemical production

In April 2004, the Environment Agency issued a new authorisation for the site. Limits were reduced for all the radionuclides and the management conditions were improved. The new authorisation required the introduction of new technology, which should reduce the discharges of tritium and carbon-14 in future. GE Healthcare began work on a new treatment process called 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 arisings of carbon 14 and tritium will be treated where possible to reduce and recycle the radionuclides. This will significantly reduce the discharges of tritium and carbon-14 in future. Discharges of organic tritium in 2004 were similar to those in 2003. The current levels of discharge are likely to be maintained until the end of 2005 when the plant is expected to become fully operational.

Tritium continued to be detected in water from the River Taff and the Glamorganshire Canal, neither of which is used as a source of water for the public water supply. Concentrations in run-off from the site into the River Taff decreased in 2004 from 220 (2003) to 61 Bq l^{-1}. The data suggest that a significant proportion of the tritium present in water is associated with organic matter. Concentrations in sediment from the local canal increased from 100 (2003) to 410 Bq kg^{-1}. Both freshwater and sediment can be affected by episodic events and there are difficulties in obtaining representative samples. There were also increases in seawater concentrations from 6.5 (2003) to 30 Bq l^{-1}. In part, the latter observation could be due to the increase in discharges of tritium in 2004. In any event, the effect was localised and was not observed further afield in the Bristol Channel (Section 9), or indeed in seafood.

Concentrations of other radionuclides in aquatic samples were low and can largely be explained by other sources such as Chernobyl, 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 0.017 mSv which was less than 2% 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 2003 was 0.024 mSv and 0.031 mSv in 2002. If the dose coefficient for tritium was increased to account for new evidence from an experiment involving the uptake and retention of tritium fed to rats (see Appendix 5), the dose in 2004 would increase by a small amount from 0.017 mSv to 0.022 mSv. For anglers on the banks of the River Taff, the dose from inadvertently ingesting sediment and occupancy of the river bank water was estimated to be much less than 0.005 mSv. There was a small contribution to this dose from the presence of tritium and other radionuclides from the site, however, the largest contribution was estimated from the inadvertent ingestion of caesium-137 which is more likely to be due to other sources.

The habits survey in 2003 identified consumers of wildfowl collected near Cardiff. Although samples of wildfowl were not monitored in 2004, 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 2004 (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 0.018 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, 2004

Material	Location	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{32}P	^{35}S	^{57}Co	^{58}Co	^{65}Zn
Freshwater samples										
Pike	Newbridge	1		<25				<0.03	<0.08	<0.16
Pike	Outfall (Grand Union Canal)	1	<25	<25	19			<0.05	<0.18	<0.31
Pike	Staines	1	<25	<25				<0.03	<0.09	<0.11
Pike	Shepperton	1	<25	<25				<0.04	<0.14	<0.17
Pike	Teddington	1	<25	<25				<0.04	<0.12	<0.18
Flounder	Beckton	1		<25				<0.03	<0.16	<0.19
Nuphar lutea	Newbridge	1		<25				<0.05	<0.33	<0.20
Nuphar lutea	Outfall (Grand Union Canal)	1		<25				<0.03	<0.23	<0.17
Nuphar lutea	Staines	1		<25				<0.02	<0.06	<0.11
Watercress	River Chess	1						<0.01	<0.09	<0.09
Mud	Outfall (Grand Union Canal)	1						<0.64	<1.6	<1.9
Sediment	Outfall (Grand Union Canal)	2[E]						<2.2		<1.5
Sediment	Upstream of outfall (Grand Union Canal)	2[E]						<5.6		<3.6
Freshwater	Maple Cross	2[E]		<4.0				<1.2		<0.74
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]		<4.0				<1.6		<0.95
Freshwater	River Chess	1[E]		<4.0	<4.0			<1.5		<0.97
Freshwater	River Misbourne downstream	1[E]		<4.0	<4.0			<1.6		<0.97
Freshwater	River Misbourne (Chalfont St Giles)	1[E]		<4.0	<4.0			<1.5		<0.97
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		<14		<3.1	<1.0	<1.4	<0.36	<1.2
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]		<25		<2.1	<1.2	<1.4	<0.36	<0.96
Final effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		<15		<3.1	<1.0	<1.6	<0.39	<0.96

Material	Location	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{125}I	^{131}I	^{134}Cs	^{137}Cs	^{234}U	^{235}U	^{238}U	^{238}Pu
Freshwater samples										
Pike	Newbridge	1		*	<0.06	<0.05				0.000063
Pike	Outfall (Grand Union Canal)	1		*	<0.11	0.10				
Pike	Staines	1		*	<0.04	0.12				
Pike	Shepperton	1		*	<0.05	0.16				
Pike	Teddington	1		*	<0.06	0.11				
Flounder	Beckton	1		*	<0.06	0.25				
Nuphar lutea	Newbridge	1		*	<0.07	<0.05				
Nuphar lutea	Outfall (Grand Union Canal)	1		*	<0.05	<0.04				
Nuphar lutea	Staines	1		*	<0.04	<0.04				
Watercress	River Chess	1		*	<0.02	<0.02				
Mud	Outfall (Grand Union Canal)	1		*	<0.94	23	3.4	0.10	3.1	
Sediment	Outfall (Grand Union Canal)	2[E]	<0.27	<0.56		<0.88				
Sediment	Upstream of outfall (Grand Union Canal)	2[E]	<0.71	<1.2		8.8				
Freshwater	Maple Cross	2[E]	<0.17	<0.28		<0.33				
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<0.20	<0.34		<0.41				
Freshwater	River Chess	1[E]	<0.19	<0.39		<0.41				
Freshwater	River Misbourne downstream		1[E]	<0.19	<0.41		<0.39			
Freshwater	River Misbourne (Chalfont St Giles)	1[E]	<0.20	<0.40		<0.40				
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<1.1			<0.36				
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<1.2			<0.36				
Final effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<1.1			<0.40				

Radiochemical

Table 7.1(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}			
			$^{239}Pu+^{240}Pu$	^{241}Am	Total alpha	Total beta
Freshwater samples						
Pike	Newbridge	1	0.00022	0.00041		
Pike	Outfall (Grand Union Canal)	1		<0.08		
Pike	Staines	1		<0.10		
Pike	Shepperton	1		<0.14		
Pike	Teddington	1		<0.15		
Flounder	Beckton	1		<0.06		
Nuphar lutea	Newbridge	1		<0.12		
Nuphar lutea	Outfall (Grand Union Canal)	1		<0.03		
Nuphar lutea	Staines	1		<0.03		
Watercress	River Chess	1		<0.02		
Mud	Outfall (Grand Union Canal)	1		<2.2		
Sediment	Outfall (Grand Union Canal)	2[E]			280	490
Sediment	Upstream of outfall (Grand Union Canal)	2[E]			340	490
Freshwater	Maple Cross	2[E]			<0.064	0.53
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]			<0.058	0.19
Freshwater	River Chess	1[E]			<0.020	0.12
Freshwater	River Misbourne downstream	1[E]			<0.030	<0.10
Freshwater	River Misbourne (Chalfont St Giles)	1[E]			<0.030	0.11
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		<0.51	<0.80	3.2
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]		<0.55	<1.4	6.8
Final effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		<0.54	<0.051	0.60

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{35}S	^{57}Co	^{75}Se	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples												
Milk		2	<4.1	<0.41		<0.38	<0.035	<0.014	<0.26	<0.30		
Milk	max		<4.3	<0.43		<0.40	<0.039	<0.017	<0.28			
Apples		1	<4.0	<0.40		<0.40	<0.052		<0.30	<0.40		
Beetroot		1	<4.0	<0.40		<0.40	<0.041		<0.30	<0.40		
Blackberries		1	9.0	2.1		<0.50	<0.062		<0.30	<0.30		
Carrots/parsnips			1	<4.0	0.40		<0.40	<0.073		<0.40	<0.40	
Marrow		1	<4.0	<0.10		<0.30	0.054		<0.20	<0.30		
Runner beans		1	<4.0	1.3		<0.30	<0.049		<0.20	<0.30		
Spinach		1	<4.0	<0.40		<0.30	<0.035		<0.30	<0.30		
Wheat		1	<6.0	<0.60		<0.30	<0.050		<0.20	<0.30		
Grass	Next to site	1[E]		3.8	<20		<2.5	<5.1		<5.7	10	120
Grass	Orchard next to site	1[E]		5.2	<19		<2.4	<5.1		<5.4	27	150
Grass	Water Meadows (River Chess)	1[E]		<1.0	<22		<2.9	<6.4		<6.5	1.6	67
Soil	Next to site	1[E]			<3.5		<0.46	<0.86		9.7	300	460
Soil	Orchard next to site	1[E]			<4.9		<0.64	<1.1		19	1200	390
Soil	Water Meadows (River Chess)	1[E]			<3.2		<0.41	<0.85		8.9	210	330

** Not detected by the method used*
[a] Except for milk, water and 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' 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 ^{3}H as tritiated water was <4.0 Bq l^{-1}
[e] The concentration of ^{3}H as tritiated water was <4.0 Bq kg^{-1}
[E] Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency

Table 7.1(b). Monitoring of radiation dose rates near Amersham, 2004

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m			
Grand Union Canal	Grass	1	0.057
Grand Union Canal	Grass and mud	1	0.058

Table 7.2. Individual radiation exposures – radiochemical sites, 2004

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]	0.017	-	0.006	-	-	0.011
Cardiff	Seafood consumers	0.017	0.013	-	<0.005	-	-
	Recreational users of River Taff	<0.005	-	-	<0.005	<0.005	-
	Consumers of locally grown food[b]	0.018	-	0.015	-	-	<0.005

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

Radiochemical

Table 7.3(a). Concentrations of radionuclides in food and the environment near Cardiff, 2004

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H[g]	^{3}H	^{14}C	^{99}Tc	^{125}I	^{131}I	^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am
Marine samples												
Flounder	East of new pipeline	2	7600	6600	96			*	<0.06	0.34	<0.12	<0.14
Sole	East of new pipeline	1		13000	150			*	<0.07	0.37	<0.16	<0.24
Mullet	East of new pipeline	1		270	51			*	<0.05	0.42	<0.12	<0.12
Whiting	East of new pipeline	1			18			*	<0.05	0.36	<0.09	<0.05
Lesser spotted dogfish	Off Orchard Ledges	2	1400	1200	53			*	<0.09	0.45	<0.15	<0.07
Skates/Rays	Off Orchard Ledges	2	1700	1600	70			*	<0.07	0.95	<0.08	<0.09
Mussels	Orchard Ledges	2	7900	5700	67			*	<0.16	0.40	<0.41	<0.59
Fucus vesiculosus	Orchard Ledges	2	53	77	11			*	<0.08	0.47	<0.15	<0.19
Seaweed	Orchard Ledges	2[E]		<46	<25	18	<0.37					
Mud	Orchard Ledges East	2	85	87				*	<1.2	24	<1.9	<1.6
Sediment	East of new pipeline	2[E]		130	<25		<0.40			<2.4		
Sediment	West of new pipeline	2[E]		170	<25		<0.82			32		
Seawater	Orchard Ledges East	2		5.3								
Seawater	Orchard Ledges	2[E]		30	<4.0		<0.25					

Material	Location or selection[b]	No. of sampling observ- ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			Organic ^{3}H[g]	^{3}H	^{14}C	^{32}P	^{35}S	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples													
Milk		7	<7.3	<9.3	21	<0.35	<0.54	<0.034		<0.27	<0.30		
Milk	max		<18	28	29	<0.40	<0.70	<0.040		<0.30	<0.33		
Barley		1		14	120		1.2	<0.046		<0.30	<0.40		
Cabbage		1	17	97	13		<0.70	<0.039		<0.30	<0.40		
Honey		1		15	63		0.60	<0.015		<0.20	<0.20		
Leeks		1	2.0	18	13		0.60	<0.049		<0.40	<0.30		
Onions		1	16	46	20		<0.40	<0.048		<0.30	<0.30		
Potatoes		1	17	65	23		<0.40	<0.045		<0.30	<0.30		
Rape oil		1		6.0	130		<0.80	<0.071		<0.30	<0.40		
Raspberries		1	1.0	80	25		0.80	<0.064		<0.30	<0.30		
Strawberries		1	10	54	12		0.70	<0.079		<0.30	0.50		
Swede		1	<15	11	13		0.70	<0.097		<0.40	<0.50		
Grass		5	<40	150	51					<0.30	<0.40		
	max		<66	510	60								
Silage		2	<11	<15	28								
	max		17	25	32								
Soil		3								<0.47	7.1		
	max									<0.50	7.7		
Sediment	Canal	2[E]		410	100			<1.3			9.5		
Freshwater[d]	Run off into River Taff	2[E]		61	<4.0			<0.30	<0.56		<0.39	<0.051	0.61
Freshwater[e]	Canal	2[E]		36	<4.0			<0.20	<0.59		<0.40	<0.041	<0.10
Freshwater[f]	River Taff	2[E]		18	<4.0			<0.17	<0.45		<0.32	<0.16	1.6

* *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*

[d] *The concentration of ^{3}H as tritiated water was <40 Bq l^{-1}*

[e] *The concentration of ^{3}H as tritiated water was 24 Bq l^{-1}*

[f] *The concentration of ^{3}H as tritiated water was <4.3 Bq l^{-1}*

[g] *The organic fraction may be higher than the total tritium value for some analyses due to uncertainties in the analytical methods for tritium. For dose assessments in this report, the higher of the two values has been used*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 7.3(b). Monitoring of radiation dose rates near Cardiff, 2004

Location	Ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over intertidal areas			
Orchard Ledges East	Mud	2[F]	0.079
East of Pipeline	Mud	1	0.075
East of Pipeline	Mud and sand	1	0.064
West of Pipeline	Stones	1	0.095
West of Pipeline	Rock and stones	1	0.10
Beta dose rates			$\mu Sv\ h^{-1}$
Orchard Ledges East	Mud	2[F]	*

* *Not detected by the method used*

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment 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 national Low Level Waste radioactive Waste Repository (LLWR) at Drigg 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 BNGSL.

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. In 2002, the Company submitted a Post-Closure Safety Case and an Operational Environmental Safety Case and the Environment Agency started a comprehensive review of the information submitted (Environment Agency, 2003d). That review is now complete (Environment Agency, 2005b) and has informed a review of the current authorisation and future regulations of radioactive waste disposal at the site. The review started in autumn 2004 with the publication of a 'Process and Considerations' document which outlines the information that will be required from BNFL in order to propose revisions to the current authorisations (Environment Agency, 2004q and r). The Environment Agency has now begun a public consultation on its proposals for the future regulation of radioactive waste disposals at the site (Environment Agency, 2005c).

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 LLWR is therefore subsumed within the Sellafield programme that is described in Section 3. The contribution to exposures due to LLWR discharges is negligible compared with that attributable to Sellafield and any effects of LLWR discharges in the marine environment could not, in 2004, 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 total 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 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 LLWR site moved eastwards towards a railway drain along the perimeter of the site. Radioactivity from the LLWR 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 2003 and were approximately the same as WHO screening values for drinking water. Low concentrations of tritium were detected.

Industrial/ landfill

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

Results for 2004 are given in Table 8.1. Evidence in support of the proposition that radioactivity in leachate from the LLWR 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 0.017 mSv which was less than 2% of the dose limit for members of the public of 1 mSv (Table 8.2).

8.2 Other landfill sites

Some organisations are authorised by the Scottish Environment Protection Agency 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 the Scottish Environment Protection Agency 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 leachate and borehole 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. 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 2004, there were no discharges and demolition of the plant began and is now complete. In November 2004, the authorisation was revoked by the Environment Agency.

The results of routine monitoring for natural radioactivity near the site in 2004 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 in 2004, were generally similar to those in 2003. 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, there were small enhancements for some radionuclides and marine species and it is these that form the basis of the dose assessment.

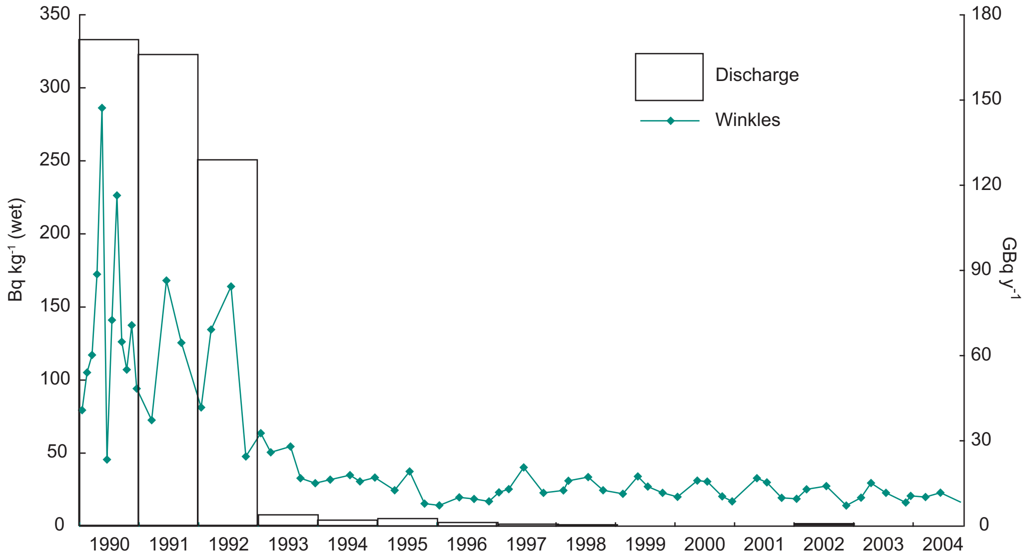


Figure 8.1 Polonium-210 discharge from Whitehaven and concentration in winkles at Parton

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 2004. The assessment is based on averaging the consumption rates over a five year period from 2000-2004. Dose coefficients for polonium-210 were updated in 2004 to reflect new results from research involving the consumption of mussels and cockles containing natural levels of polonium-210 (Appendix 5). A conservative gut transfer factor of 0.8 is taken to apply to seafood generally, but we have adopted a value of 0.5 for molluscs where specific experimental evidence is available.

The critical group dose from enhanced natural radionuclides (i.e. TNORM) was 0.41 mSv in 2004, the same as the estimate for 2003 (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 2004, these exposures added a further 0.22 mSv to the doses above resulting in a total dose to this group of up to 0.63 mSv. The estimated doses in 2004 are therefore below the dose limit for members of the public of 1 mSv.

8.4 Other industrial sites

Enhancement of natural radionuclides in the marine environment may result from operations carried out by Scotoil in Aberdeen. The company operates a cleaning facility for equipment from the oil and gas industry contaminated with enhanced levels of radionuclides of natural origin. Prior to these operations, a phosphogypsum process was operated on the site, which made discharges to sea. Scotoil is authorised by the Scottish Environment Protection Agency to discharge small amounts of radioactive waste to the sea near Aberdeen Harbour. The authorisation includes conditions requiring Scotoil to undertake environmental monitoring. The primary discharge is of radium-226 and radium-228 and includes lead-210 and polonium-210 in smaller quantities.

Fourteen samples of sediment were collected in April 2004 and the results of analysis by gamma spectrometry are given in Table 8.5. The radium-226 content of samples collected near to the discharge point showed no evidence for significant enhancement due to releases from the Scotoil operations and these samples were comparable with those collected from the north end of Aberdeen beach. Higher concentrations of lead-210 and radium-226 were found in sub-tidal samples from the Albert Basin and the River Dee. Further work would be needed to determine whether the difference is attributable to releases or natural accumulation processes which have been shown to cause disequilibrium in the uranium-238 decay series (Kershaw *et al*., 1988 and Reed, 1991).

Further monitoring of Aberdeen Beach carried out in 2005, found elevated levels of radioactivity at a small area of the beach. The preliminary results indicate that the risk to public health is negligible. The Scottish Environment Protection Agency is currently investigating where this radioactive material came from. The results from the 2005 survey and those of any further investigations will be reported in full in RIFE 11.

Overall the results of the survey do not indicate that beach users were subjected to an elevated risk of any significance. In addition previous surveys have included sampling of local mussels and it was concluded that it was unlikely that, should consumption occur, the dose from normal levels of natural radiation would be enhanced due to Scotoil operations (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999).

Table 8.1. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2004

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	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk		1	<4.0	15	<0.30	0.11	<0.0048	<2.2	<0.62	<0.015
Blackberries		1	7.0	23	<0.40	0.79		<1.8	<0.60	<0.039
Cabbage		1	<4.0	13	<0.20	0.41	<0.048	<2.2	<0.70	<0.025
Carrots		1	<4.0	22	<0.30	0.74		<1.7	<0.70	<0.024
Eggs		1	<5.0	57	<0.30	0.026		<2.5	<0.70	<0.044
Ovine muscle		1	9.0	34	<0.30	0.066	0.036	<2.9	<0.90	<0.026
Ovine offal		1	7.0	24	<0.40	0.070	<0.034	<1.6	<0.50	<0.026
Potatoes		1	6.0	17	<0.40	0.012	<0.030	<2.2	<0.70	<0.027
Grass		2					<0.025			
Grass	max						<0.026			
Sediment	Drigg Stream	4[E]			<1.1	<4.0		<8.0	<8.1	
Freshwater	Drigg Stream	4[E]	14		<0.46	0.10				
Freshwater	Railway Drain	1[E]	13		<0.48	1.9				

Material	Location or selection[a]	No. of sampling observ-ations[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	<0.28	<0.34	0.27				
Blackberries		1			0.19				
Cabbage		1			0.13				
Carrots		1			0.19				
Eggs		1			0.033				
Ovine muscle		1			1.0				
Ovine offal		1			0.91				
Potatoes		1			0.62				
Sediment	Drigg Stream	4[E]	<0.97	120		22	22	17	15
Freshwater	Drigg Stream	4[E]	<0.42	<0.39		<0.0080	<0.0068	<0.0055	<0.0058
Freshwater	Railway Drain	1[E]	<0.44	<0.41		<0.013	0.0060	<0.0050	<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
Milk		1					<0.00025	<0.00040	<0.041	<0.00048		
Blackberries		1					0.00030	0.0017	<0.044	0.0032		
Cabbage		1					0.00010	0.00050	<0.072	0.00080		
Carrots		1					0.00030	<0.00030	<0.047	<0.00040		
Eggs		1					<0.00020	<0.00020	<0.063	0.00030		
Ovine muscle		1					<0.00040	<0.00030	<0.040	0.00040		
Ovine offal		1					<0.00070	0.00070	<0.070	0.00080		
Potatoes		1					0.00020	0.00020	<0.042	0.00060		
Grass		2				0.045						
Grass	max		0.0080	<0.00080	0.0060	0.047						
Soil		2				36						
Soil	max		11	0.42	11	46						
Sediment	Drigg Stream	4[E]	29	<1.3	28		4.0	23	180	17	620	1100
Freshwater	Drigg Stream	4[E]	<0.012	<0.0050	<0.0090		<0.0088	<0.0075	<0.90	<0.011	<0.033	0.63
Freshwater	Railway Drain	1[E]	0.030	<0.0050	0.034		<0.0070	<0.0050	<1.0	<0.0070	0.16	3.6

[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 labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 8.2. Individual radiation exposures – industrial and landfill sites, 2004

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]	0.017	-	-	0.017	-	-
	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]	0.63	0.19	0.41	-	0.022	-

[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, 2004

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	8000	<15	<0.05	<0.05
City of Glasgow	Summerston Tip	1	670	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	21	<15	<0.05	<0.05
Dundee City	Riverside	1	8.7	<15	<0.05	<0.05
Fife	Balbarton	1	77	<15	<0.05	<0.05
Fife	Melville Wood	1	170	<15	<0.05	<0.05
Highland	Longman Tip	1	3.2	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	1800	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	7.0	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	<5.0	<15	<0.05	<0.05

Table 8.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2004

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}																
			Total ^{3}H	$^{3}H^{a}$	^{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		23	<4.0	<9.9	<0.47	<0.27	<18	<0.39								<0.11	1.4
Cambridgeshire																			
Milton Landfill, Cambridge	Site borehole	2		120		53	<0.53			<0.42		<0.013	<0.0090	<0.011	<0.0050	<0.0050	<0.0050	<1.2	65
Milton Landfill, Cambridge	Site drainage	1		8.2		<10	<0.52			<0.40		<0.0060	<0.0050	<0.0050	0.046	<0.0050	0.027	<0.060	0.41
Milton Landfill, Cambridge	Ground water borehole	2		<4.0		<9.8	<0.49			<0.39		<0.011	<0.0065	<0.0055	0.017	<0.0050	0.0085	<0.068	1.1
Milton Landfill, Cambridge	Phase 2 borehole 3.6	1		150		<9.6	<0.48			<0.39		<0.0060	<0.0050	<0.0050	0.036	<0.0050	0.029	0.075	0.12
Milton Landfill, Cambridge	Phase 2 borehole 3.7	2		37		<10	<0.50			<0.40		<0.013	<0.0065	<0.0070	<0.0050	<0.0050	<0.0075	<0.24	12
Carmarthenshire																			
Cefnbrynbrain		1									<1.0								
Cheshire																			
Northwich Tip	Borehole WM5G	2		11		<9.8	<0.51			<0.40		<0.013	<0.021	<0.0080	<0.0050	<0.0050	<0.0050	<0.28	4.2
Northwich Tip	Borehole WM6G	2		170		<11	<0.49			<0.40		<0.0075	<0.024	<0.0050	<0.0050	<0.0050	<0.0050	<1.1	9.2
Northwich Tip	Borehole WM20G	2		<4.0		<9.8	<0.51			<0.41		<0.016	<0.029	<0.0055	<0.0050	<0.0050	<0.0050	<5.0	<4.7
Cleveland																			
Bewley ICI Tip	On-site stream (downstream)	2		40		<9.9	<0.49			<0.39		<0.011	<0.0060	<0.0065	0.053	<0.0050	0.050	<0.55	7.4
Bewley ICI Tip	On-site stream (upstream)	2		<6.9		<10	<0.51			<0.39		<0.0085	<0.0065	<0.0060	0.036	<0.0050	0.028	<0.39	10
Cumbria																			
Rhodia Consumer Specialties Ltd, Hut Bank Quarry	Borehole	1		<4.0		<11	<0.48			<0.40		<0.0050	<0.0050	<0.0050	0.016	<0.0050	0.013	<0.13	16
Rhodia Consumer Specialties Ltd, Ufex	Leachate	2		<4.0		<41	<0.54			<0.45		<0.0055	<0.0050	<0.0050	3.8	0.15	3.8	7.3	52
Alco Landfill	Borehole	2		42	<4.0	<9.6	<0.49	<0.26	<0.81	<0.38								<0.12	1.6
BAE Systems Marine Ltd, Walney Island	Waste ponds water	1		5.0		<9.7	<0.48			<0.40		<0.0050	<0.0050	<0.0050	0.019	<0.0050	0.016	0.030	0.32
Greater London																			
Murex Ltd	Local water (East stream)	1		<4.0		<9.7	<0.51			<0.40		<0.0060	<0.0050	<0.0050	0.010	<0.0050	0.011	0.20	0.90
Murex Ltd	Local water (West stream)	1		<4.0		<9.3	<0.48			<0.39		<0.0060	<0.0050	<0.0060	0.028	<0.0060	0.012	<0.53	3.8
Glamorgan																			
Trecatti Landfill, Merthyr Tydfil	Raw Leachate	1	2000	1800	<4.0														
Trecatti Landfill, Merthyr Tydfil	Treated leachate	1	2000	1800	<4.0														

Table 8.4. continued

Area/ location	Sample source	No. of sampling observ- ations	Mean radioactivity concentration, Bq l^{-1}																
			Total ^{3}H	$^{3}H^{a}$	^{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		370	<4.0	<9.9	<0.48	<0.25	<0.59	<0.39								<0.16	3.9
Cilgwyn Quarry	2nd pit	2		<4.0	<4.0	<9.3	<0.47	<0.25	<0.61	<0.40								<0.040	<0.10
Hertfordshire																			
Braziers Landfill	Borehole W2	2		<4.5		<9.7	<0.48			<0.38		<0.012	<0.018	<0.0070	0.020	<0.0050	0.014	<0.14	0.18
Braziers Landfill	Borehole W5	2		<4.0		<9.8	<0.47			<0.39		<0.020	<0.0060	<0.0085	0.013	<0.0050	0.010	<0.095	0.36
Braziers Landfill	Borehole W9	2		<6.0		<9.8	<0.46			<0.38		<0.018	<0.0080	<0.0095	0.011	<0.0050	0.0085	<0.068	<0.13
Cole Green Landfill	Local water (culvert)	2		<4.0		<9.6	<0.48			<0.39		<0.0095	<0.0060	<0.0065	<0.013	<0.0070	0.013	<0.058	0.31
Cole Green Landfill	Static borehole	2		34		<10	<0.48			<0.40		<0.012	<0.0085	<0.0060	0.049	<0.0050	0.029	<0.19	6.4
Lancashire																			
Magnesium Electron, Swinton	Local water	1		<4.0		<9.8	<0.47			<0.38		<0.0070	<0.0050	<0.0050	0.0050	<0.0050	<0.0050	<0.040	0.58
Birkacre Mine Shaft	Pool	1		<4.0		<6.1	<0.31			<0.27		<0.0090	<0.030	<0.010	<0.0050	<0.0050	<0.0050	<0.030	0.17
Belthorne Mine Shaft	Local water (brook)	2		<4.0		<8.3	<0.45			<0.35		<0.0070	<0.023	<0.0065	<0.0050	<0.0050	<0.0060	<0.020	0.26
Clifton Marsh	Borehole 6	2		35		<9.8	<0.46			<0.39		<0.0085	<0.017	<0.0060	0.052	<0.0050	0.043	<0.21	2.0
Clifton Marsh	Borehole 19	1		6.0		<9.7	<0.47			<0.38		<0.0060	<0.010	<0.0050	<0.0090	<0.0050	<0.011	<0.090	0.68
Clifton Marsh	Borehole 40	1		<4.0		<9.3	<0.53			<0.41		<0.0050	<0.0050	<0.0050	0.0080	<0.0050	0.0050	<0.070	1.2
Clifton Marsh	Borehole 59	1		29		<10	<0.50			<0.40		<0.0070	<0.0050	<0.0050	<0.0070	<0.0050	<0.0060	<0.12	2.4
Ulnes Walton	River Lostock (downstream)	1		<4.0		<9.6	<0.50			<0.40		<0.0060	<0.0050	<0.0050	0.015	<0.0070	0.0090	<0.025	0.28
Ulnes Walton	River Lostock (upstream)	1		<4.0		<9.6	<0.50			<0.41		<0.0060	<0.0050	<0.0050	0.017	<0.0050	0.011	<0.052	0.56
Near Whittle Hill Quarry	River Lostock	2		<4.0		<9.4	<0.46			<0.40		<0.0070	<0.013	<0.0060	0.042	<0.0050	<0.044	<0.075	0.22
River Yarrow	Local water	1		<4.0		<6.7	<0.30			<0.27		<0.014	<0.049	0.068	0.014	<0.0050	0.011	<0.080	0.12
Merseyside																			
Sefton Meadows Tip	Local water	1		<4.0	<4.0	<9.7	<0.47	<0.21	<0.53	<0.40								0.14	0.25
Arpley Landfill	Borehole 25 (groundwater)	2		25	<4.0	<9.7	<0.47	<0.25	<0.57	<0.41								<0.16	0.41
Norfolk																			
Strumpshaw Landfill	Leachate (borehole BH2)	2		<4.0	<4.0	<9.7	<0.48	<0.20	<0.38	<0.39								<0.038	<0.11
Strumpshaw Landfill	Leachate (borehole BH3)	2		<4.0	<4.0	<9.7	<0.48	<0.20	<0.36	<0.38								<0.048	<0.12
Strumpshaw Landfill	Reservoir	1		<4.0	<4.0	<9.4	<0.46	<0.19	<0.41	<0.39								<0.020	<0.10
Strumpshaw Landfill	Water abstraction	1		<4.0	<4.0	<9.4	<0.49	<0.20	<0.43	<0.40								<0.050	0.14
Nottinghamshire																			
School of Agriculture, Nottingham	Local water (stream)	1		<4.0		<9.6	<0.45			<0.40		<0.012	0.010	<0.0060	0.12	<0.0050	0.0066	0.14	0.29
Oxfordshire																			
Stanford in the Vale	Local water	2		<4.0		<9.8	<0.50			<0.41		<0.0060	<0.0050	<0.0050	<0.0055	<0.0050	<0.0050	<0.0023	<0.10
Stanford in the Vale	Borehole 15	2		<4.0		<9.6	<0.48			<0.40		<0.0050	<0.0050	<0.0050	<0.0070	<0.0050	<0.0085	<0.032	<0.10

Table 8.4. continued

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, $Bq\ l^{-1}$ Total ^{3}H	^{3}H[a]	^{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	2		35	<4.0	<8.3	<0.38	<0.17	<0.58	<0.32								<1.0	6.7
South Gloucestershire																			
Berwick Lane Landfill, Hallen	Local water	2		28															
South Yorkshire																			
Beighton Tip, Sheffield	Local water	1		<4.0	<4.0	<9.6	<0.50	<0.21	<0.93	<0.39								<0.050	0.50
Beighton Tip, Sheffield	Borehole	1		57	<4.0	<9.7	<0.47	<0.21	<0.84	<0.39								<0.18	5.9
Sussex																			
Beddingham Quarry	Leachate (site 1)	2		220	<4.0	<10	<0.47	<0.25	<0.95	<0.38								<0.14	7.0
Beddingham Quarry	Stream (site 2)	2		<4.0	<4.0	<9.8	<0.48	<0.26	<0.94	<0.41								<0.031	<0.23
Beddingham Quarry	Leachate (site 3)	2		370	<4.0	<16	<0.50	<0.26	<0.97	<0.41								<0.42	21
Tyne and Wear																			
High Urpeth Tip	Local water (downstream)	1		<4.0		<8.8	<0.47			<0.39		<0.0070	<0.0070	<0.0070	<0.0050	<0.0050	<0.0050	<0.028	0.27
Kibblesworth Colliery		1		<4.0		<9.7	<0.49			<0.40		<0.010	<0.0080	<0.0060	0.028	<0.0050	0.0080	<0.24	1.1
Ryton Tip, Gateshead	Local water	1		<4.0	<4.0	<4.6	<0.27	<0.17	<2.0	<0.23								<0.070	0.49
West Yorkshire																			
Gelderd Road Tip, Leeds	Borehole	2		<14	<4.0	<9.8	<0.51	<0.25	<6.8	<0.41								<0.10	0.83
Dean House Farm Tip	Borehole	2		11	<4.0	<9.6	<0.48	<0.21	<0.72	<0.39								<0.15	2.8
Wilson Road Tip	Borehole	1		25	<4.0	25	<0.50	<0.20	<0.61	<0.42								<1.8	32

[a] *As tritiated water*

Table 8.5. Concentrations of natural radionuclides in the environment, 2004

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{210}Po	^{210}Pb	^{226}Ra	^{228}Ac	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Rhodia Consumer Specialities Ltd, Whitehaven												
Winkles	Saltom Bay	4	29	1.9								
Winkles	Parton	4	20	2.2			0.55	0.81	0.35	1.0	0.032	0.88
Winkles	North Harrington	1	26									
Winkles	Nethertown	4	15									
Winkles	Drigg	1					0.61	0.67	0.41			
Winkles	Tarn Bay	1	14									
Mussels	Parton	2	74	3.4								
Mussels	Nethertown	4	54	3.6								
Limpets	St Bees	2	14									
Cockles	Ravenglass	2	27									
Crabs	Parton	4	23	0.10			0.080	0.013	0.0073	0.060	0.0012	0.057
Crabs	Sellafield coastal area	4	14	0.12								
Lobsters	Parton	4	16	<0.0099			0.063	0.0097	0.0039	0.031	0.0010	0.028
Lobsters	Sellafield coastal area	4	17	<0.013								
Cod	Parton	2	1.2	<0.0029			0.026	0.0048	0.0030	0.0061	0.00025	0.0057
Flounder	Whitehaven	1	3.2									
Scotoil, Aberdeen												
Sediment	Aberdeen Beach north	1		<10	<10	<10						
Sediment	Aberdeen Beach pos 1	1		11	26	15						
Sediment	Aberdeen Beach pos 2	1		19	36	12						
Sediment	Aberdeen Beach pos 3	1		17	<10	11						
Sediment	Aberdeen Beach pos 4	1		14	8.9	16						
Sediment	Aberdeen Beach pos 5	1		<10	21	12						
Sediment	Aberdeen Beach pos 6	1		12	11	12						
Sediment	W of southern breakwater	1		15	<10	16						
Sediment	E of southern breakwater	1		10	<10	<10						
Sediment	Greyhope Bay	1		11	11	13						
Sediment	Nigg Bay	1		<10	<10	16						
Sediment	Victoria Dock	1		<7.8	18	23						
Sediment	Albert Basin	1		110	<5.5	30						
Sediment	River Dee	1		200	<6.9	20						
Other samples												
Winkles	Paddy's Hole (Hartlepool)	1	25	2.3								
Mussels	Ribble Estuary	1					0.25	0.43	0.15			
Limpets	Kirkcudbright	1	22									
Cockles	Southern North Sea	2					0.57	0.29	0.40			
Cockles	Ribble Estuary	1					0.58	0.51	0.22			
Cockles	Flookburgh	2	17									
Shrimps	Ribble Estuary	2					0.014	0.025	0.0063			
Brown trout	Ribble Link	1					0.080	0.024	0.033	0.048	0.0013	0.038
Fucus vesiculosus	Pilot station (Hartlepool)	1	3.0	1.9								
Seaweed	Kinlochbervie	1	4.3									
Sediment	Sandside Bay	1			<10	3.6						
Sediment	Ardneil Bay	1			<5.0	2.2						
Sediment	Barn's Ness	1			32	25						

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

9. CHERNOBYL AND REGIONAL MONITORING

9.1 Chernobyl

Radiocaesium is detected in sheep grazing certain upland areas in the United Kingdom 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 in order to prevent animals from entering the food chain above the action level of 1,000 Bq kg^{-1} of caesium; a level that was recommended by an EU expert committee in 1986. A programme of live monitoring allows food safety to be protected, whilst allowing established sheep farming practices to continue.

In summer 2004, 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 three farms where controls could be lifted and this decision was implemented in February 2005, leaving 11 farms subject to restrictions. The Welsh survey identified four farms where radiocaesium levels are consistently below the limit, and the process of lifting controls from these farms is underway. Once this is implemented there will be 355 farms in Wales subject to restrictions.

As has been the case in Wales and Scotland for several years, the radiocaesium monitoring of sheep carcasses at slaughterhouses ceased in Cumbria in May 2004, as there continued to be no results reported above the action level in sheep taken to slaughter. A full farm survey was conducted in Cumbria in 2004 and farms for future possible derestriction were identified.

There are still 375 farms, or part farms, and approximately 215,000 sheep within the restricted areas of England, Scotland and Wales. This represents a reduction of over 95% since 1986, when approximately 8,900 farms and 4,225,000 sheep 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-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.,* 2000) 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 stated. 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 conservative (Leonard *et al*., 1990) but also because, in practice, hatchery-reared or farmed fish are likely to contribute most to the diet and have much lower radiocaesium concentration. In 2004, 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 2004 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 2004, 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 2004.

The results are similar to those obtained in previous years. The dose to the critical group from consumption of terrestrial foodstuffs monitored in 2004 was 0.022 mSv (0.013 mSv in 2003) or less than 3% of the dose limit for members of the public of 1 mSv. It is worth noting that the increase in dose is due to higher limits of detection in the analysis for ruthenium, which affect the dose calculations. Actual doses would probably be lower, and similar to 2003.

The effects of liquid discharges from BNG Sellafield in the Irish Sea are discussed fully in Section 3. The dose to the critical group of Manx fish and shellfish consumers was 0.007 mSv in 2004 (similar to 2003) 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).

In 2004, 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 2003.

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 2004 was 0.010 mSv, which is 1% of the dose limit for members of the public.

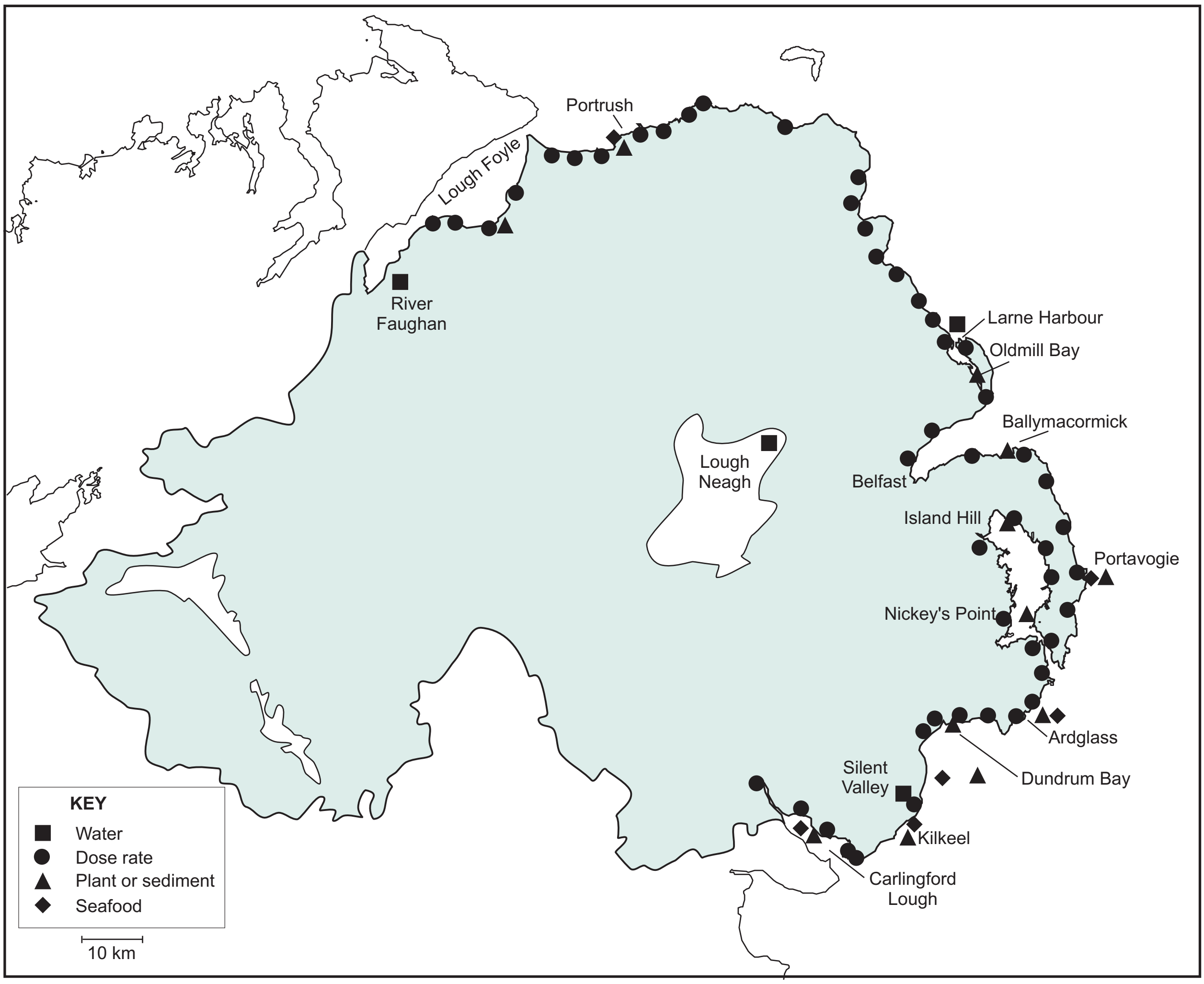


Figure 9.1 Monitoring locations in Northern Ireland

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 TDS. The design of the UK TDS 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 2004. 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 radionuclide was strontium-90 derived from weapons test fallout. The nationwide mean dose for a one-year-old child for all man-made radionuclides was low at 0.0018 mSv. There was a substantial decrease from the value of 0.023 mSv in 2003, mostly because of reduced LoDs of strontium-90 in samples.

The mean dose for a one-year-old child due to consumption of natural radionuclides (excluding potassium-40) was 0.15 mSv, similar to the value for 2003 of 0.14 mSv. In addition to potassium-40 the most important radionuclides continued to be lead-210 and polonium-210. 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 1% 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 2004. 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, 2005).

Where measurements are comparable, detected activity concentrations of all radionuclides in 2004 were similar to those for previous years. These results are summarised in Table 9.9. Tritium and sulphur-35 results were close to or 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 less than 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 2004 (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 2003.

Sampling of bread and meat continued in Scotland in 2004. 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 2003.

9.8 Airborne 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. The programme comprised two components (i) regular sampling and analysis on a quarterly basis and (ii) supplementary analysis on an ad-hoc basis by gamma spectrometry. 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 2003. 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 from drinking water sources throughout the UK continued in 2004 (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 were all below the WHO screening values for drinking water of 0.5 and 1.0 Bq l^{-1} for total alpha and total beta, respectively.

Results for the River Thames, which receives authorised discharges from GE Healthcare, 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 0.044 mSv in 2004 (Table 9.16). The 1-year-old age group received the highest dose. The estimated doses were dominated by natural radionuclides. The annual dose from artificial radionuclides in drinking water was less than 0.001 mSv.

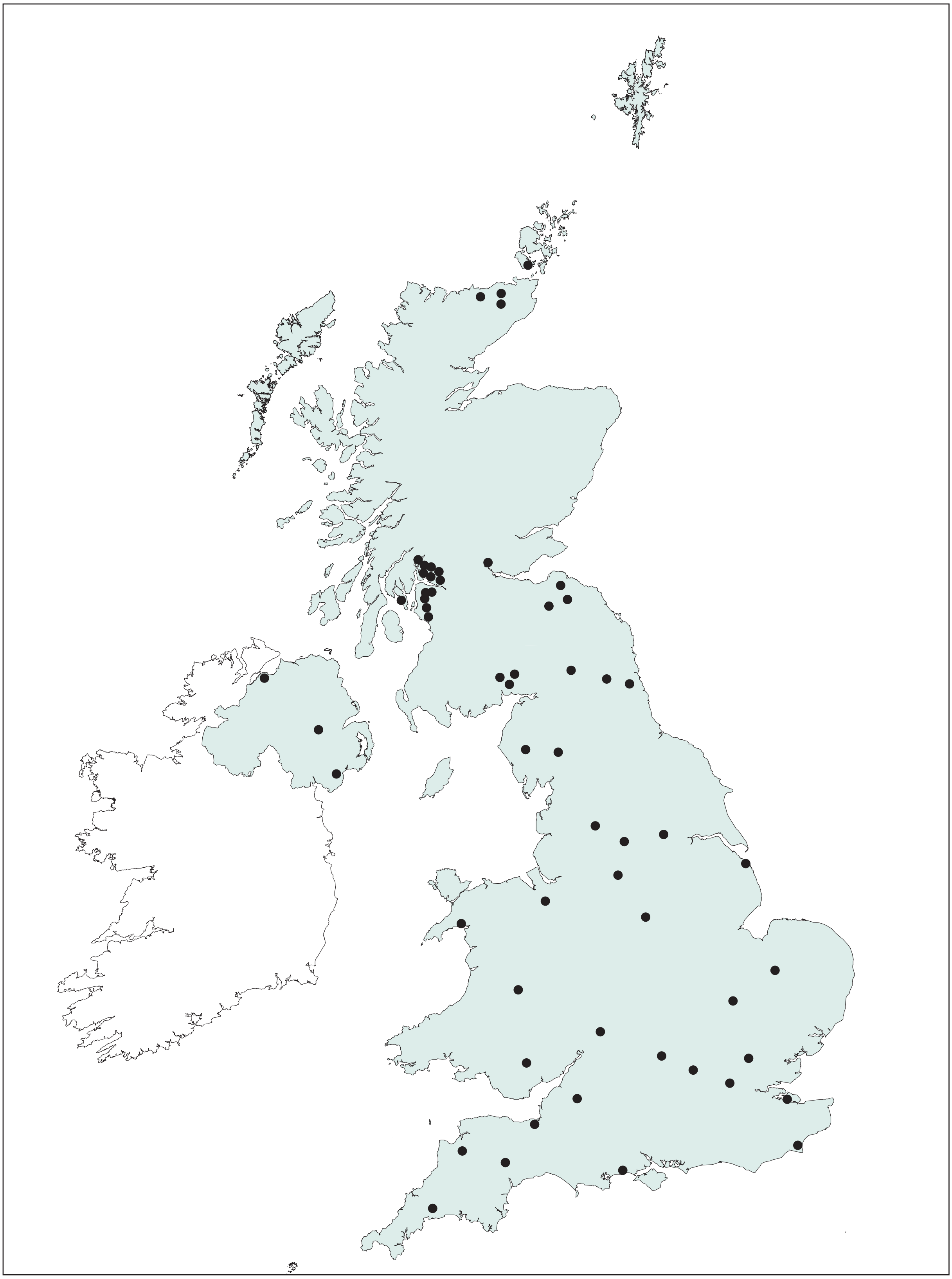


Figure 9.2 Drinking water sampling locations

9.9 Seawater surveys

The UK government is committed to preventing pollution of the marine environment from ionising radiation, with the ultimate aim of reducing concentrations in the environment to near background values for naturally occurring radioactive substances, and close to zero for artificial radioactive substances (Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, National Assembly for Wales and Scottish Executive, 2002). Therefore a programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling. The seawater surveys reported here also support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 2000b) and provide information that can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). Data have been used to examine the long distance transport of activity to the Arctic (Leonard *et al*., 1998; Kershaw *et al*., 1999) and to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). 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. Evidence to help gauge progress towards achievement of the Government's vision for radionuclides and other hazardous substances is set out in a recent report (Department of Environment, Food and Rural Affairs, 2005a).

The research vessel programme on radionuclide distribution currently comprises of annual surveys of the Bristol Channel/western English Channel and biannual surveys of the Irish Sea and the North Sea. The results of the 2004 cruises are presented in Figures 9.3 – 9.6. Shoreline sampling is also carried out around the UK, and the data are given in Table 9.17. Much of the shoreline sampling is directed at establishing whether the impacts of discharges from individual sites are detectable. Where appropriate, commentary is found in the relevant site section.

The 2004 caesium-137 data for the North Sea (Figure 9.3) show very low concentrations (less than 0.01 Bq l^{-1}) throughout the survey area that are only slightly above the global fallout levels in North Atlantic surface waters (approximately 0.0012 Bq l^{-1} in 2002 (Bailly du Bois pers. comm.)). The distribution in the North Sea is typical of that observed in the last 5 years. The highest concentrations were observed at two station sites close to the Norwegian coast, due to the input of Chernobyl-derived caesium-137 from the Baltic via the Skaggerak. In the previous three decades the impact of discharges from the reprocessing plants at Sellafield and La Hague has been readily apparent, carried by the prevailing residual currents from the Irish Sea and the Channel, respectively (Povinec *et al*., 2003). The concentrations of caesium-137 in the North Sea has tended to follow the temporal trends of the discharges, albeit with a time lag. The maximum discharge of caesium-137 occurred at Sellafield in 1975 and caesium-137 concentrations of up to 0.5 Bq l^{-1} were measured in the late 1970s. Due to significantly decreasing discharges after 1978, remobilisation of caesium-137 from contaminated sediments in the Irish Sea is most likely to be the dominant source of water contamination for most of the North Sea (McCubbin *et al*., 2002).

Concentrations of caesium-137 in the western English Channel (average activity 0.002 Bq l^{-1}) were, within experimental error, similar to the background level resulting from global fallout (Figure 9.6).

The concentrations of tritium observed in the North Sea (Figure 9.4) were generally lower than those observed in the Irish Sea (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2004) due to the influence of discharges from Sellafield and other nuclear sites. In the Bristol Channel, the combined effects of discharges from Cardiff, Oldbury and Hinkley Point are evident (Figure 9.5).

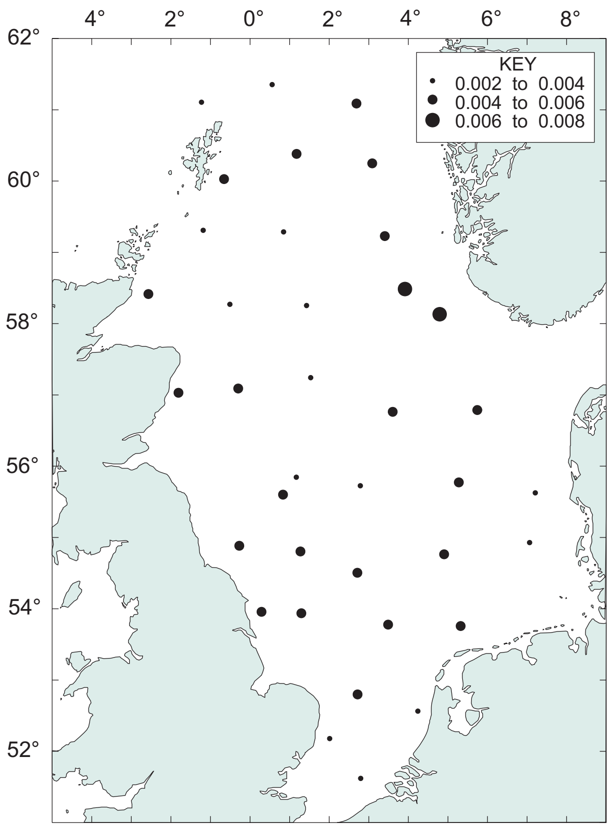


Figure 9.3 Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the North Sea, August-September 2004

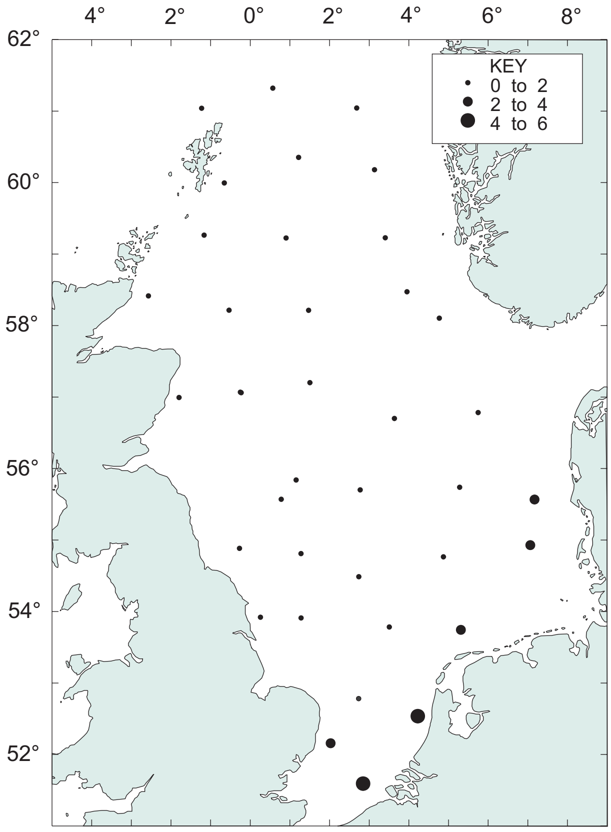


Figure 9.4 Concentrations (Bq l^{-1}) of tritium in surface water from the North Sea, August-September 2004

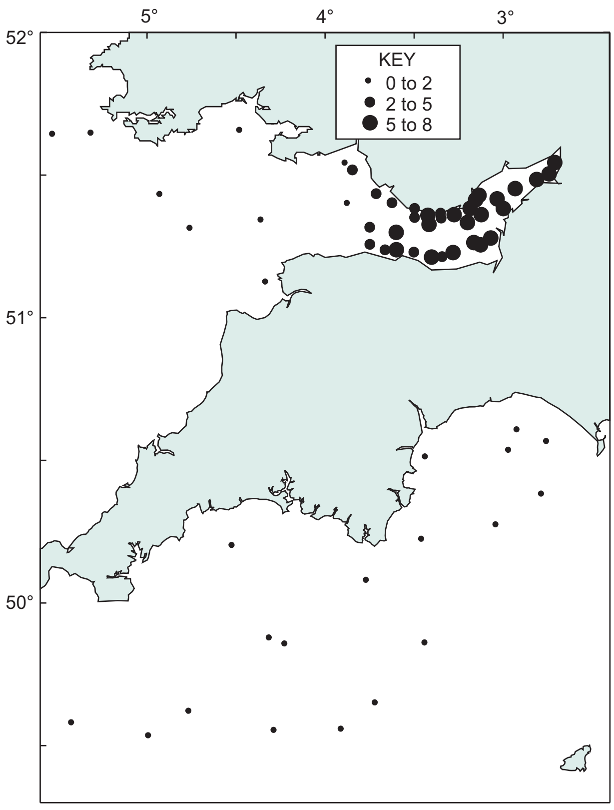


Figure 9.5 Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel and western English Channel, September-October 2004

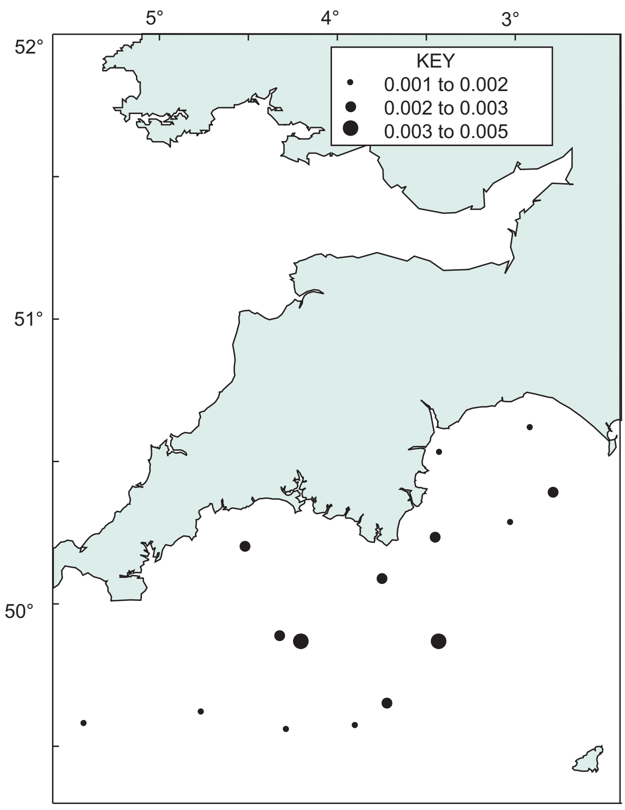


Figure 9.6 Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the western English Channel, September-October 2004

Technetium-99 concentrations in seawater are now decreasing following the substantial increases observed since 1994. The results of research cruises to study this radionuclide have been published by Leonard *et al*. (1997a and b, 2004) and McCubbin *et al*. (2002). 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 2004 gave results of less than 1 and less than 10 Bq kg^{-1} respectively. These concentrations are similar to those for 2004. Caesium-137 was not detected.

Table 9.1. Concentrations of radiocaesium in the freshwater environment, 2004

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Branthwaite	Rainbow trout	1	<0.05	0.22
Narborough[b]	Rainbow trout	1	<0.05	0.23
Low Wath	Rainbow trout	1	<0.15	0.25
Devoke Water	Brown trout	1	<0.28	39
Devoke Water	Perch	1	<0.40	130
Devoke Water	Water	1	*	0.01
Gilcrux	Rainbow trout	1	<0.06	0.15
Ennerdale	Water	1	*	0.01
Scotland				
Loch Dee	Brown trout	1	<0.24	92
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 36, 0.000043, 0.00024 and 0.00036 Bq kg^{-1}(wet) respectively*

Table 9.2. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2004

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	^{154}Eu
Mackerel	Guernsey	2				<0.08			<0.77		0.15	<0.24
Mackerel	Jersey	1				<0.11			<1.1		<0.10	<0.34
Pollack	Jersey	2				<0.06			<0.57		0.23	<0.19
Bass	Guernsey	1				<0.07			<0.58		0.68	<0.21
Bass	Jersey	1				<0.06			<0.56		0.39	<0.19
Edible crabs	Guernsey	1				<0.07			<0.57		<0.05	<0.17
Edible crabs	Jersey	1				<0.06			<0.62		<0.06	<0.19
Edible crabs	Alderney	2	<25	<25	34	<0.12		0.42	<1.4		<0.09	<0.31
Spiny spider crab	Jersey	1				0.22			<0.43		<0.04	<0.13
Spiny spider crab	Alderney	2				<0.38			<1.7		<0.14	<0.47
Lobsters	Guernsey	1				<0.05			<0.52		0.07	<0.14
Lobsters	Jersey	1				<0.04		0.79	<0.42		0.09	<0.12
Lobsters	Alderney	1				0.08			<0.45		<0.05	<0.14
Oysters	Jersey											
	La Rocque	1				<0.06			<0.48		<0.05	<0.17
Limpets	Guernsey	1				<0.18			<2.1		<0.15	<0.52
Limpets	Jersey											
	La Rozel	1				0.05			<0.49		<0.05	<0.14
Toothed winkle	Alderney	1	<25	<25	19	<0.15	<0.063		<1.3		<0.10	<0.35
Scallops	Guernsey	2				<0.15			<1.4		<0.11	<0.42
Scallops	Jersey	2				<0.08			<0.46		<0.05	<0.15
Ormers	Guernsey	1				<0.04			<0.43		<0.04	<0.12
Porphyra	Guernsey											
	Fermain Bay	4				<0.10			<0.93		<0.08	<0.32
Porphyra	Jersey											
	Plemont Bay	4				<0.08			<0.83		<0.06	<0.24
Porphyra	Alderney											
	Quenard Point	2				<0.04			<0.32		<0.03	<0.12
Fucus vesiculosus	Jersey											
	La Rozel	4				<0.16	0.020	13	<0.60		<0.08	<0.23
Fucus vesiculosus	Alderney											
	Quenard Point	2								1.7		
Fucus serratus	Guernsey											
	Fermain Bay	4				<0.09	0.029	1.3	<0.53		<0.06	<0.19
Fucus serratus	Alderney											
	Quenard Point	4				0.17	0.033	1.2	<0.51		<0.05	<0.20
Laminaria digitata	Jersey											
	Verclut	4				<0.06			<0.41		<0.04	<0.14
Mud and sand	Guernsey											
	St. Sampson's Harbour	1				<0.24			<2.3		0.50	<0.72
Mud	Jersey											
	St Helier	1				4.2			<2.9		2.4	<0.84
Sand	Alderney											
	Lt. Crabbe Harbour	1				<0.24			<2.1		1.7	<0.71
Seawater	Guernsey	4									0.002	
Seawater	Jersey	1									0.003	
Seawater	Alderney											
	East	4		3.4							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	<0.23	<0.000066	0.00020	0.00042	*	*	95
Mackerel	Jersey	1	<0.22	0.000015	0.000045	0.000039	*	*	
Pollack	Jersey	2	<0.09			<0.05			130
Bass	Guernsey	1	<0.11	0.000024	0.000052	0.00039	*	*	130
Bass	Jersey	1	<0.17			<0.24			110
Edible crabs	Guernsey	1	<0.10	0.00028	0.00090	0.0034	*	0.00045	92
Edible crabs	Jersey	1	<0.19	0.00041	0.0010	0.0027	0.000023	0.00035	86
Edible crabs	Alderney	2	<0.19	0.00041	0.00086	0.0028	<0.000011	0.00050	53
Spiny spider crab	Jersey	1	<0.09			<0.05			72
Spiny spider crab	Alderney	2	<0.29	0.0013	0.0029	0.0051	<0.000031	0.00093	39
Lobsters	Guernsey	1	<0.10			<0.05			59
Lobsters	Jersey	1	<0.11	0.00022	0.00064	0.0044	0.000023	0.00058	88
Lobsters	Alderney	1	<0.16	0.00055	0.0012	0.015	0.000099	0.0030	32
Oysters	Jersey								
	La Rocque	1	<0.09	0.0017	0.0048	0.0051	*	0.00063	80
Limpets	Guernsey	1	<0.25			<0.13			54
Limpets	Jersey								
	La Rozel	1	<0.15	0.0028	0.0073	0.011	0.000026	0.0012	84
Toothed winkle	Alderney	1	<0.18	0.0066	0.018	0.026	0.00023	0.0038	42
Scallops	Guernsey	2	<0.23	0.00082	0.0027	0.0019	<0.000015	0.00022	100
Scallops	Jersey	2	<0.11	0.0021	0.0056	0.0041	*	0.00038	88
Ormers	Guernsey	1	<0.13			<0.19			77
Porphyra	Guernsey								
	Fermain Bay	4	<0.15	0.0025	0.0093	0.0095	<0.000036	0.0011	150
Porphyra	Jersey								
	Plemont Bay	4	<0.14			<0.12			150
Porphyra	Alderney								
	Quenard Point	2	<0.09			<0.13			100
Fucus vesiculosus	Jersey								
	La Rozel	4	<0.15	0.0075	0.021	0.0067	0.000073	0.0010	190
Fucus serratus	Guernsey								
	Fermain Bay	4	<0.12	0.0046	0.018	0.0075	0.000094	0.0010	190
Fucus serratus	Alderney								
	Quenard Point	4	<0.13	0.0065	0.022	0.0090	0.000088	0.0011	210
Laminaria digitata	Jersey								
	Verclut	4	<0.11			<0.12			200
Mud and sand	Guernsey								
	St. Sampson's Harbour	1	<0.58	0.023	0.087	0.087	*	0.0081	500
Mud	Jersey								
	St Helier	1	1.1	0.60	1.6	3.0	0.0072	0.34	620
Sand	Alderney								
	Lt. Crabbe Harbour	1	<0.56			<0.84			390

** Not detected by the method used*

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

Table 9.3. Concentrations of radionuclides in food and the environment from the Isle of Man, 2004[c]

Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
		^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Aquatic samples											
Cod	3	<0.06	<0.15	<0.14	<0.12		<0.52	<0.14	<0.06	2.4	<0.30
Herring	4	<0.10	<0.24	<0.29	<0.38		<0.86	<0.21	<0.10	0.85	<0.47
Lobsters	4	<0.05	<0.13	<0.17	<0.22	180	<0.47	<0.12	<0.05	0.40	<0.28
Scallops	4	<0.07	<0.21	<0.42	<0.83		<0.70	<0.16	<0.07	0.41	<0.34
Fucus vesiculosus	4	<0.10	<0.19	<0.22	<0.28	840	<0.58	<0.29	<0.07	0.88	<0.32
Sediment	1[E]	<0.82		<1.4	<0.66		<4.9	<4.2	<0.69	6.6	<2.2

Material	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
Aquatic samples								
Cod	3	0.000053	0.00023	0.00061	*	*		
Herring	4	0.000045	0.00023	0.00036	*	*		
Lobsters	4			<0.14				170
Scallops	4	0.014	0.082	0.044	*	0.000061		
Fucus vesiculosus	4			<0.24				840
Sediment	1[E]						370	820

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	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Terrestrial samples												
Milk		2	<4.0	19	<0.58	<0.36	0.044	<0.84	<0.93	<0.0030	<2.4	<0.64
Milk	max			22	<0.63	<0.40	0.057	<0.85	<0.98		<2.5	<0.73
Cabbage		1	<4.0	6.0	1.5	<0.40	0.14	<0.60	<0.30	<0.014	<2.8	<0.60
Potatoes		1	<4.0	23	<0.40	<0.50	<0.011	<0.60	<0.40	0.015	<3.6	<0.70
Raspberries		1	<3.0	15	<0.40	<0.40	0.24	<0.50	<0.40		<3.5	<0.70

Material or selection[b]		No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{129}I	Total Cs	^{144}Ce	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples									
Milk		2	<0.020	0.085	<1.4	<0.00020	<0.00010	<0.028	<0.00020
Milk	max			0.092	<1.5				
Cabbage		1	<0.028	0.037	<1.2	<0.00040	0.00020	<0.073	<0.00030
Potatoes		1	<0.024	0.17	<1.7	<0.00030	<0.00020	<0.068	0.00020
Raspberries		1		<0.029	<1.4				

** 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 0.087 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, 2004

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	50	<0.05		<0.12	1.7	<0.11
Cod	North coast	3		<0.06		<0.14	2.2	<0.11
Haddock	Kilkeel	1		<0.05		<0.14	0.76	<0.15
Haddock	Portavogie	4		<0.09		<0.23	0.95	<0.23
Herring	Ardglass	2		<0.09		<0.25	0.86	<0.29
Saithe	North coast	1		<0.06		<0.17	3.4	<0.19
Spurdog	North coast	4		<0.06		<0.16	1.7	<0.15
Spurdog	Portavogie	3		<0.07		<0.19	1.7	<0.18
Spurdog	Portrush	1		<0.08		<0.16	1.2	<0.13
Whiting	Kilkeel	3		<0.06		<0.13	2.2	<0.12
Whiting	Portavogie	3		<0.05		<0.12	1.4	<0.12
Crabs	Kilkeel	3		<0.09		<0.25	0.27	<0.25
Lobsters	Ballycastle	4		<0.10	91	<0.24	0.18	<0.22
Lobsters	Kilkeel	4		<0.12	160	<0.27	0.30	<0.25
Nephrops	Kilkeel	4		<0.17		<0.40	0.74	<0.36
Nephrops	Portavogie	4		<0.07	54	<0.16	0.92	<0.14
Winkles	Ards Peninsula	4		<0.14		<0.43	0.38	<0.26
Mussels	Carlingford Lough	2		<0.13	20	<0.31	0.78	<0.25
Scallops	Western Irish Sea	2		<0.04		<0.09	0.28	<0.09
Clams	Co. Down	4		<0.18		<0.35	0.45	<0.25
Ascophyllum nodosum	Ardglass	3		<0.09		<0.24	0.49	<0.19
Ascophyllum nodosum	Carlingford Lough	1		<0.13		<0.26	0.88	<0.25
Fucus spp.	Carlingford Lough	3		<0.20	630	<0.41	0.79	<0.29
Fucus spp.	Portrush	4		<0.07		<0.14	0.10	<0.15
Fucus vesiculosus	Ardglass	2		<0.25	530	<0.56	0.89	<0.46
Rhodymenia spp.	Strangford Lough	3		<0.15	28	<0.34	0.90	<0.32
Mud	Carlingford Lough	2		<0.79		<2.4	67	<2.4
Mud	Dundrum Bay	2		<0.65		<1.7	7.6	<2.2
Mud	Oldmill Bay	2		<0.62		<1.7	24	<2.6
Mud	Strangford Lough -Nickey's point	2		<0.63		<1.8	33	<1.9
Mud	Ballymacormick	2		<0.51		<1.6	26	<1.8
Mud and sand	Carrichue House	1		<0.28		<0.91	1.8	<1.2
Mud, sand and stones	Carrichue House	1		<0.19		<0.55	1.5	<0.75
Sand	Portrush	2		<0.46		<1.2	<0.60	<1.3
Seawater	North of Larne	12			0.014		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			<0.10		
Cod	North coast	3			<0.07		
Haddock	Kilkeel	1			<0.15		
Haddock	Portavogie	4			<0.24		
Herring	Ardglass	2			<0.33		
Saithe	North coast	1			<0.18		
Spurdog	North coast	4			<0.12		
Spurdog	Portavogie	3			<0.16		
Spurdog	Portrush	1			<0.07		
Whiting	Kilkeel	3			<0.12		
Whiting	Portavogie	3	0.000059	0.00028	0.00043	*	*
Crabs	Kilkeel	3			<0.26		
Lobsters	Ballycastle	4			<0.19		
Lobsters	Kilkeel	4			<0.29		
Nephrops	Kilkeel	4			<0.40		
Nephrops	Portavogie	4	0.0061	0.037	0.14	*	0.00023
Winkles	Ards Peninsula	4	0.035	0.19	0.21	*	0.00021
Mussels	Carlingford Lough	2			<0.21		
Scallops	Western Irish Sea	2			<0.12		
Clams	Co. Down	4			<0.15		
Ascophyllum nodosum	Ardglass	3			<0.21		
Ascophyllum nodosum	Carlingford Lough	1			<0.31		
Fucus spp.	Carlingford Lough	3			<0.15		
Fucus spp.	Portrush	4			<0.14		
Fucus vesiculosus	Ardglass	2			<0.50		
Rhodymenia spp.	Strangford Lough	3	0.087	0.46	0.67	*	0.0012
Mud	Carlingford Lough	2	2.1	13	9.1	0.011	0.015
Mud	Dundrum Bay	2			<3.7		
Mud	Oldmill Bay	2	1.9	11	18	*	0.020
Mud	Strangford Lough -Nickey's point	2	1.6	9.5	10	0.015	0.013
Mud	Ballymacormick	2	1.8	12	18	0.022	0.021
Mud and sand	Carrichue House	1	0.025	0.19	0.26	*	*
Mud, sand and stones	Carrichue House	1			<0.88		
Sand	Portrush	2			<1.9		

* *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, 2004

Location	Ground type	No. of sampling observa-tions	Mean gamma dose rate in air at 1m, µGy h^{-1}
Narrow Water	Mud	1	0.093
Rostrevor	Sand	1	0.13
Mill Bay	Mud	1	0.10
Greencastle	Sand	1	0.089
Cranfield Bay	Sand	1	0.085
Annalong	Sand	1	0.12
Newcastle	Sand	1	0.096
Dundrum	Mud	1	0.097
Tyrella	Sand	1	0.087
Rocky Beach	Sand	1	0.090
Killough	Mud	1	0.10
Ardglass	Mud	1	0.098
Kilclief	Sand	1	0.077
Strangford	Shingle and stones	1	0.11
Nicky’s Point	Mud	1	0.089
Island Hill	Mud	1	0.086
Ards Maltings	Mud	1	0.086
Greyabbey	Sand	1	0.082
Kircubbin	Sand	1	0.095
Portaferry	Shingle and stones	1	0.10
Cloughy	Sand	1	0.083
Ballyhalbert	Sand	1	0.074
Ballywalter	Sand	1	0.077
Millisle	Sand	1	0.077
Groomsport	Sand	1	0.075
Helen’s Bay	Sand	1	0.075
Belfast Lough	Sand	1	0.064
Carrickfergus	Sand	1	0.063
Whitehead	Sand	1	0.067
Larne	Sand	1	0.066
Drains Bay	Sand	1	0.062
Ballygally	Sand	1	0.065
Half Way House	Sand	1	0.064
Glenarm	Sand	1	0.062
Carnlough	Sand	1	0.067
Red Bay	Sand	1	0.069
Cushendall	Sand and stones	1	0.071
Cushendun	Sand	1	0.066
Ballycastle	Sand	1	0.065
Giant’s Causeway	Sand	1	0.066
Port-Ballintrae	Sand	1	0.066
White Rocks	Sand	1	0.073
Blue Pool	Sand	1	0.073
Portstewart	Sand	2	0.064
Castlerock	Sand	2	0.067
Benone	Sand	2	0.071
Bellerena	Mud	2	0.065
Carrichue House	Mud	1	0.061
Eglington	Shingle	1	0.066
Lishally	Mud	1	0.079

Table 9.5. Concentrations of radionuclides in general diet (TDS survey), 2004[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	Runcorn	1	<3.1	32	<0.17	70	0.047	<0.07	0.020	0.050
Northern	Gateshead	1	5.4	39	<0.24	80	0.041	<0.06	0.10	0.065
Northern	Batley	1	3.6	50	<0.23	57	<0.042	<0.08	0.11	0.070
Central	Cambridge	1	<1.7	30	<0.20	65	0.053	<0.05	0.017	0.035
Central	Sudbury	1	<2.2	30	<0.22	70	0.075	<0.07	0.010	0.042
Central	Tamworth	1	2.9	40	<0.20	70	0.073	0.02	0.080	0.032
Southern	Barnstaple	1	5.1	40	<0.26	70	0.045	<0.08	0.030	0.070
Southern	Deal	1	<1.7	30	<0.20	70	0.041	0.05	<0.010	0.040
Southern	Gosport	1	<1.8	40	<0.30	70	<0.060	0.05	0.050	0.055
Wales	Merthyr Tydfil	1	<1.7	36	<0.15	80	0.064	0.06	0.11	0.090
Northern Ireland	Belfast	1	<1.8	40	<0.22	70	0.030	<0.07	0.030	0.030
Scotland	Kilmarnock[b]	1	<20	33	1.8		<0.050	<0.25		<0.055
Scotland	Huntly[c]	1	<20	29	<1.0		<0.050	0.27		0.084
Mean			<5.5	36	<0.40	70	<0.052	<0.09	<0.052	<0.055

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	Runcorn	1	0.040	0.00057	0.027	<0.00010	<0.000092	0.00013
Northern	Gateshead	1	0.024	<0.0021	<0.021	<0.00028	0.00050	0.0015
Northern	Batley	1	0.040	0.0014	<0.021	<0.00014	0.00016	0.00029
Central	Cambridge	1	0.026	0.00060	0.023	0.00011	<0.00020	0.00015
Central	Sudbury	1	0.027	0.00039	<0.022	0.00020	0.00010	0.00049
Central	Tamworth	1	0.042	0.00073	<0.021	<0.00014	0.00015	0.0012
Southern	Barnstaple	1	0.027	0.00047	<0.020	0.00020	0.00026	0.00027
Southern	Deal	1	0.033	0.00053	0.030	0.00012	0.00021	0.00018
Southern	Gosport	1	0.024	0.0013	<0.021	<0.00013	0.00012	0.00034
Wales	Merthyr Tydfil	1	0.033	0.00033	<0.021	<0.00025	0.00016	<0.000053
Northern Ireland	Belfast	1	0.034	0.00062	0.026	0.00010	0.00021	<0.00027
Scotland	Kilmarnock[b]	1	0.030	<0.010		0.00042	0.00078	0.00078
Scotland	Huntly[c]	1	0.041	<0.010		<0.00043	0.0010	0.0029
Mean			0.032	<0.0022	<0.023	<0.00020	<0.00030	<0.00066

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

[b] *The concentrations of ^{234}U, ^{235}U and ^{238}U were <0.050, <0.050 and <0.050 Bq kg^{-1} respectively*

[c] *The concentrations of ^{234}U, ^{235}U and ^{238}U were <0.050, <0.050 and <0.050 Bq kg^{-1} respectively*

Table 9.6. Concentrations of radionuclides in regional diet in Scotland, 2004

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	<0.58	83	<0.10	<0.06
East Lothian (North Berwick)	12	<5.0	<0.55	87	<0.10	<0.05
Highland (Dingwall)	12	<5.3	<1.0	85	<0.10	<0.06
Renfrewshire (Paisley)	12	<5.0	<0.72	79	<0.10	<0.05

Table 9.7. Estimates of radiation exposure from radionuclides in regional diet, 2004

Nuclide[a]	Exposure, mSv[b]
Man-made radionuclides	
Tritium	0.0001
Sulphur-35	0.0004
Strontium-90	0.0009
Caesium-137	0.0002
Plutonium-238	0.0002
Plutonium-239+240	0.0002
Americium-241	0.0005
Sub-total	0.0018
Natural radionuclides	
Carbon-14	0.01
Lead-210	0.04
Polonium-210	0.09
Radium-226	0.006
Uranium	0.0006
Thorium-232	0.0002
Sub-total	0.15
Total	0.15

[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, 2004[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	30	120	<0.098	<0.05	<0.027
Northern Ireland	4	33	87	0.12	<0.08	<0.024
Scotland	4	33	81	<0.14	<0.05	<0.030
Wales	4	31	88	<0.070	<0.05	<0.023

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

Table 9.9. Concentrations of radionuclides in milk remote from nuclear sites, 2004

Location	Selection[a]	No. of sampling observations[b]	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs
Co. Antrim		1	<4.0	13		0.026	0.16
Co. Armagh		1	<4.0	21		0.028	0.10
Cambridgeshire		1	<2.1	<13		0.022	0.057
Cheshire		1	<4.0	13		0.022	0.078
Clwyd		1	<5.5	17		0.027	0.062
Cornwall		1	<11	20		0.035	0.072
Devon		1	<7.0	16		0.033	0.065
Co. Down		1	<4.0	16		0.037	0.13
Co. Fermanagh		1	<4.0	24		0.028	0.094
Gloucestershire		2	<4.0	11		0.022	<0.052
	max			13		0.030	0.053
Guernsey		1	<2.1	12		0.030	0.059
Gwent		1	<2.0	14		0.041	0.055
Gwynedd		1	<4.0	15		0.035	0.058
Hampshire		1	<7.0	18		0.036	0.066
Humberside		1	<4.0	12		0.021	0.050
Kirkcudbrightshire		1	<5.8	<15	<0.52	<0.10	<0.05[c]
Kent		1	<9.0	23		0.021	<0.065
Lanarkshire		1	<5.0	<17	<0.53	<0.10	<0.05[c]
Lancashire		3	<4.0	9.7		0.024	0.078
	max			12		0.025	0.11
Leicestershire		1	<4.0	14		0.018	<0.050
Lincolnshire		1	<4.0	11		0.016	<0.045
Middlesex		1	11	19		0.018	0.068
Midlothian		1	<5.0	<15	<0.50	<0.10	<0.05[c]
North Yorkshire		2	<4.0	12		0.021	0.066
	max			17		0.023	0.081
Nairnshire		1	<5.0	<17	<0.50	<0.10	<0.05[c]
Norfolk		1	<4.0	12		0.017	0.056
Renfrewshire		1	<5.1	<15	<0.55	<0.10	<0.06[c]
Somerset		1	<4.0	16		0.024	0.078
Suffolk		1	<4.0	14		0.012	0.069
Tyneside		1	<4.0	13		0.030	0.066
Co. Tyrone		2	<2.4	16		0.029	0.11
	max		<4.0	18			
Mean Values							
Channel Islands			<2.1	12		0.030	0.059
England			<4.6	<14		0.023	<0.063
Northern Ireland			<2.8	17		0.029	0.12
Wales			<2.7	14		0.034	0.058
Scotland			<5.1	<16	<0.52	<0.10	<0.05[c]
United Kingdom			<4.4	<15	<0.52	<0.021	<0.059

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. 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, 2004[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
Channel Islands									
Guernsey	Blackberries	1	<4.0	18		0.10	0.025	0.17	0.093
	Lettuce	1	<4.0	9.0		0.015	0.031	0.092	0.035
Jersey	Potatoes	1	<4.0	17		<0.012	0.049		
	Strawberries	1	6.0	9.0		0.020	0.048		
Cornwall									
Newquay	Lettuce	1	<4.0	<3.0		0.23	0.036	0.12	0.064
	Potatoes	1	<4.0	26		0.034	<0.059	<0.041	0.0033
Cumbria									
Carlisle	Cabbage	1	7.0	<3.0		0.17	0.38	<0.032	0.012
	Gooseberries	1	<4.0	8.0		0.23	0.042	0.11	0.067
Devon									
Honiton	Lettuce	1	<4.0	3.0		0.085	0.034	0.060	0.037
	Raspberries	1	<4.0	18		0.24	<0.023	0.065	0.045
Dorset									
Swanage	Cabbage	1	<4.0	4.0		0.29	0.044	0.11	0.030
	Potatoes	1	<4.0	16		0.034	0.12	<0.031	0.0060
Dumfriesshire									
Dumfries	Lettuce	4	<5.0	<15	<0.50	<0.10	<0.05[b]		
East Lothian									
North Berwick	Lettuce	4	<5.0	<15	<0.50	<0.10	<0.07[b]		
Gloucestershire									
Cheltenham	Cabbage	1	<5.0	8.0		0.33	0.021	0.079	0.031
	Strawberries	1	<4.0	12		0.067	<0.011	<0.031	0.025
Gwynedd									
Pwllheli	Lettuce	1	<4.0	7.0		0.43	0.070	0.12	0.068
	Strawberries	1	<4.0	8.0		0.18	0.065	0.043	0.041
Hampshire									
Alton	Cabbage	1	<4.0	<3.0		0.33	<0.028	<0.040	0.021
	Potatoes	1	<4.0	15		<0.0070	<0.025	<0.036	0.0038
Kent									
Rochester	Raspberries	1	4.0	11		0.040	<0.028	<0.035	0.017
	Spring greens	1	<4.0	9.0		0.43	<0.030	0.10	0.065
Lancashire									
Clitheroe	Cabbage	1	<4.0	<3.0		0.28	<0.034	0.19	0.070
	Potatoes	1	<4.0	15		<0.0080	0.039	<0.037	0.0032
Southport	Cabbage	1	<4.0	<3.0		0.35	0.038	0.18	0.075
	Raspberries	1	<4.0	8.0		0.057	<0.014	0.068	0.060
Leicestershire									
Market Harborough	Cabbage	1	7.0	12		0.075	0.064	<0.037	0.0027
	Raspberries	1	5.0	16		<0.010	0.041	0.091	0.012
Lincolnshire									
Horncastle	Cabbage	1	<4.0	16		0.38	<0.026	0.15	0.034
	Potatoes	1	6.0	23		<0.0090	0.036	0.038	0.0045
Monmouthshire									
Monmouth	Cabbage/lettuce	1	5.0	<3.0		0.53	<0.022	0.43	0.20
	Potatoes	1	<4.0	15		0.026	0.038	<0.031	0.011
Norfolk									
Dereham	Cabbage	1	<4.0	12		0.17	<0.028	0.068	0.025
	Raspberries	1	<4.0	18		0.026	<0.030	0.046	0.020
Diss	Beetroot	1	<4.0	12		0.058	0.056	0.034	0.018
	Cabbage	1	<4.0	18		0.27	<0.028	0.14	0.053
Northumberland									
Otterburn	Cabbage	1	9.0	<3.0		0.23	<0.026	<0.031	0.0038
	Potatoes	1	<4.0	18		<0.0090	0.11	<0.035	0.0083
North Somerset									
Weston-Super-Mare	Lettuce	1	<4.0	5.0		0.15	0.039	0.11	0.055
	Raspberries	1	5.0	15		0.028	<0.026	0.076	0.028
North Yorkshire									
Scarborough	Cabbage	1	4.0	12		0.24	0.035	<0.033	0.032
	Radishes	1	<4.0	10		0.079	0.044	<0.042	0.013
Renfrewshire									
Paisley	Lettuce	4	<5.0	<15	<0.50	<0.10	<0.05[b]		
Ross-shire									
Dingwall	Lettuce	4	<5.0	<15	<0.50	<0.10	<0.06[b]		
Worcestershire									
Stourport-on-Severn	Cabbage	1	<4.0	11		0.051	<0.015	<0.037	0.014
	Potatoes	1	<3.0	24		0.012	<0.019	<0.036	0.0052
Yorkshire									
York	Spinach	1	<4.0	13		0.18	0.033	0.29	0.17
	Strawberries	1	<4.0	23		0.063	<0.031	<0.034	0.018
Mean Values									
Channel Isles			<4.5	13		<0.037	0.038	0.13	0.064
England			<4.4	<12		<0.15	<0.047	<0.075	0.032
Wales			<4.3	<8.3		0.29	<0.049	<0.16	0.081
Scotland			<5.0	<15	<0.50	<0.10	<0.05[b]		
Great Britain			<4.6	<13	<0.50	<0.14	<0.047	<0.083	0.037

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
Channel Islands									
Guernsey	Blackberries	1	0.0050	<0.00090	0.14	<0.00010	<0.00020	<0.00020	
	Lettuce	1	<0.0020	0.0031	0.051	0.00010	<0.00010	0.00030	
Jersey	Potatoes	1				<0.00010	<0.00010	<0.00020	
	Strawberries	1				<0.00020	<0.00020	<0.00020	
Cornwall									
Newquay	Lettuce	1	0.040	0.0027	<0.029	<0.00010	<0.00010	0.00060	
	Potatoes	1	0.019	<0.0012	<0.031	<0.00010	<0.00010	0.00030	
Cumbria									
Carlisle	Cabbage	1	<0.0060	<0.0012	<0.032	0.00010	0.00010	<0.00030	
	Gooseberries	1	0.0030	<0.00070	<0.031	<0.00010	<0.00020	0.00040	
Devon									
Honiton	Lettuce	1	0.030	<0.0012	<0.029	<0.00020	0.00010	<0.00020	
	Raspberries	1	0.049	<0.00080	<0.030	<0.00010	0.00010	<0.00020	
Dorset									
Swanage	Cabbage	1	0.044	<0.0010	<0.031	0.00010	0.00020	0.00050	
	Potatoes	1	<0.0040	0.0018	<0.030	<0.00030	<0.00010	<0.00030	
Dumfriesshire									
Dumfries	Lettuce	4							<0.58
East Lothian									
North Berwick	Lettuce	4							<0.34
Gloucestershire									
Cheltenham	Cabbage	1	0.017	0.0013	<0.031	0.00050	<0.00010	<0.00040	
	Strawberries	1	0.0040	0.0020	<0.030	<0.00020	0.00020	<0.00030	
Gwynedd									
Pwllheli	Lettuce	1	0.0070	0.0015	<0.030	<0.00020	<0.00030	0.00080	
	Strawberries	1	0.011	<0.00090	<0.029	<0.00010	0.00020	0.00040	
Hampshire									
Alton	Cabbage	1	<0.010	0.0024	<0.032	<0.00020	<0.00020	0.00050	
	Potatoes	1	0.0040	0.0014	<0.031	0.00010	<0.00010	<0.00040	
Kent									
Rochester	Raspberries	1	0.0070	<0.0010	<0.017	0.00010	<0.00010	<0.00050	
	Spring greens	1	0.042	0.0058	<0.031	<0.00020	<0.00020	0.00050	
Lancashire									
Clitheroe	Cabbage	1	0.043	<0.0025	<0.031	<0.00010	<0.00010	0.00070	
	Potatoes	1	0.0070	<0.0023	<0.030	<0.00020	0.00020	0.00060	
Southport	Cabbage	1	0.016	<0.0017	<0.031	<0.00020	<0.00010	<0.00030	
	Raspberries	1	<0.0020	<0.0020	<0.031	<0.00010	<0.00010	<0.00030	
Leicestershire									
Market Harborough	Cabbage	1	<0.0030	<0.00080	<0.031	0.00010	<0.00010	<0.00040	
	Raspberries	1	<0.0020	<0.00080	<0.031	0.00010	0.00010	<0.00040	
Lincolnshire									
Horncastle	Cabbage	1	<0.0050	0.0025	<0.032	0.00010	<0.00020	<0.00070	
	Potatoes	1	0.0030	0.0016	<0.030	<0.00010	0.00030	<0.00040	
Monmouthshire									
Monmouth	Cabbage / lettuce	1	0.019	0.0087	0.079	<0.00020	<0.00020	0.00050	
	Potatoes	1	<0.0050	0.0027	<0.031	0.00010	0.00020	<0.00020	
Norfolk									
Dereham	Cabbage	1	<0.0030	0.0046	0.032	<0.00050	<0.00030	<0.00040	
	Raspberries	1	<0.0020	<0.0010	<0.032	<0.00040	0.00020	<0.00030	
Diss	Beetroot	1	0.049	<0.0010	<0.030	<0.00040	<0.00020	0.00050	
	Cabbage	1	0.0090	0.0012	<0.030	<0.00030	<0.00020	<0.00060	
Northumberland									
Otterburn	Cabbage	1	<0.0060	<0.00090	<0.031	0.00010	<0.00020	0.00030	
	Potatoes	1	0.0060	0.0025	<0.030	<0.00020	<0.00020	0.00030	
North Somerset									
Weston-Super-Mare	Lettuce	1	0.017	0.0063	<0.032	<0.00010	0.00020	<0.00010	
	Raspberries	1	<0.0040	<0.00050	<0.031	<0.00010	0.00010	<0.00020	
North Yorkshire									
Scarborough	Cabbage	1	<0.0040	<0.0021	<0.031	<0.00010	<0.00020	0.00050	
	Radishes	1	0.11	0.0027	<0.031	<0.00020	<0.00030	0.00050	
Renfrewshire									
Paisley	Lettuce	4							<0.54
Ross-shire									
Dingwall	Lettuce	4							<0.69
Worcestershire									
Stourport-on-Severn	Cabbage	1	<0.0040	<0.00080	<0.028	<0.00010	<0.00010	<0.00030	
	Potatoes	1	0.0070	0.0020	<0.031	<0.00020	<0.00020	0.00020	
Yorkshire									
York	Spinach	1	0.037	<0.0032	<0.032	<0.00010	0.00010	0.00050	
	Strawberries	1	0.0070	0.0019	<0.031	<0.00020	<0.00020	0.00030	
Mean Values									
Channel Isles			<0.0035	<0.0020	0.093	<0.00013	<0.00015	<0.00023	
England			<0.017	<0.0019	<0.030	<0.00018	<0.00016	<0.00039	
Wales			<0.011	<0.0035	<0.042	<0.00015	<0.00023	<0.00048	
Scotland									<0.53
Great Britain			<0.017	<0.0021	<0.032	<0.00018	<0.00017	<0.00040	<0.53

[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, 2004

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	65	<1.4	56		<0.05	<2.2
(Dumfries)	Meat	4	<5.0	49	<3.0	72	<0.10	<0.07	<0.49
East Lothian	Bread	4	<5.5	68	<1.5	60		<0.05	<2.6
(North Berwick)	Meat	4	<5.1	32	<2.3	95	<0.10	<0.08	<0.49
Highland	Bread	4	<5.0	67	<1.9	59		<0.05	<2.2
(Dingwall)	Meat	4	<5.2	40	<2.2	89	<0.10	0.14	<0.60
Renfrewshire	Bread	4	<5.0	67	<2.3	54		<0.06	<3.8
(Paisley)	Meat	4	<5.0	48	<2.2	79	<0.10	<0.08	<0.38

Table 9.12. Concentrations of radionuclides in rainwater and air 2004

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	$^{239}Pu+^{240}Pu^{b}$	$^{241}Am^{b}$	Total alpha[c]	Total beta[c]
Ceredigion												
Aberporth	Rainwater	4	<1.2	1.1		<0.059			<0.000073	<0.000012		
	Air	4		0.0019		<0.00000050			<0.0000000014	<0.0000000030		
Co. Down												
Conlig	Rainwater	4		1.4		<0.018						
	Air	4		0.0019		<0.00000059						
Dumfries and Galloway												
Eskdalemuir	Rainwater	4	3.8	1.1		<0.0085						
	Air	4		0.0016		0.00000052						
North Yorkshire												
Dishforth	Rainwater	4		2.0		<0.037						
	Air	4		0.0014		<0.00000055						
Oxfordshire												
Chilton	Rainwater	4		1.1	<0.0013	<0.030					0.039	0.10
	Air	4		0.0015		<0.00000039						
	Air	14					0.00014	0.0000059				
Shetland												
Lerwick	Rainwater	4		1.8		<0.016						
	Air	4		0.0015		<0.00000047						
Suffolk												
Orfordness	Rainwater	4	<1.7	2.3		<0.043						
	Air	4		0.0021		<0.00000048						

Location	Sample	Mean radioactivity concentration[a] in rainwater and air: ^{40}K	^{60}Co	^{208}Tl	^{210}Pb	^{212}Pb	^{214}Pb	^{228}Th
Additional radionuclides detected by gamma spectrometry in some quarters								
Ceredigion								
Aberporth	Air	<0.000019			0.00011			
Co. Down								
Conlig	Rainwater				0.13			
	Air	0.000016			0.00011			
Dumfries and Galloway								
Eskdalemuir	Rainwater	0.11		0.017	0.064			
	Air	0.0000090		0.00000016	0.00010		0.0000016	
North Yorkshire								
Dishforth	Rainwater	0.42	0.022		0.00010			
Oxfordshire								
Chilton	Rainwater		0.00000038					
	Air				0.00011			
Lerwick	Rainwater	0.27	0.014		0.12			
	Air	0.000011			0.00010			
Suffolk								
Orfordness	Rainwater	0.91						
	Air	0.000017			0.00016	0.0000020		0.000081

[a] $Bq\ l^{-1}$ for rainwater and $Bq\ kg^{-1}$ for air
[b] Separate annual sample
[c] Bulked from 12 monthly samples

Table 9.13. Concentrations of radionuclides in sources of drinking water in Scotland, 2004

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	5	<1.1	<0.0041	<0.01		
Argyll and Bute	Auchengaich	1	<1.0	0.00750		<0.010	0.025
Argyll and Bute	Helensburgh Reservoir	3			<0.01	<0.010	0.032
Argyll and Bute	Loch Ascog	3			<0.01	<0.010	0.11
Argyll and Bute	Loch Eck	1	1.1	<0.0050		<0.034	0.023
Argyll and Bute	Loch Finlas	3			<0.01	<0.010	0.033
Clackmannanshire	Gartmorn	1	<1.0	0.0057		<0.010	0.079
Dumfries and Galloway	Black Esk	1	2.4	<0.0050		<0.010	0.019
Dumfries and Galloway	Winterhope	1	23	0.0053		<0.010	0.038
East Lothian	Hopes Reservoir	1	<1.0	<0.0050		<0.010	0.026
East Lothian	Thorters Reservoir	1	1.7	<0.0050		<0.010	0.049
East Lothian	Whiteadder	2			<0.01	<0.010	0.045
Highland	Loch Baligill	1	<1.0	0.0053		<0.010	0.039
Highland	Loch Calder	1			<0.01	<0.017	0.10
Highland	Loch Glass	6	<1.2	<0.0050	<0.01		
Highland	Loch Shurrerey	1	<1.0	<0.0050		<0.010	0.046
North Ayrshire	Camphill	1	1.5	<0.0050		<0.010	0.032
North Ayrshire	Knockendon Reservoir	3			<0.01	<0.011	0.082
North Ayrshire	Munnoch Reservoir	1	1.5	0.0050		<0.018	0.029
North Ayrshire	Outerwards	1	1.2	<0.0050		<0.010	0.090
Orkney Islands	Heldale Water	1	<1.0	<0.0050		<0.011	0.063
Scottish Borders	Knowsdean	12	<1.5	<0.0046	<0.01		
Stirling	Loch Katrine	10	<1.1	<0.0047	<0.01		
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0	<0.0050		<0.010	0.044

Table 9.14. Concentrations of radionuclides in sources of drinking water in England and Wales, 2004

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	0.041	<0.0010		<0.0012	<0.010
Cambridgeshire	Grafham Water	4	<4.0	0.31	0.0024		<0.0010	<0.010
Cheshire	River Dee, Chester	4	<4.0	0.24	0.0041	<0.0035	<0.0011	<0.010
Cornwall	River Fowey	4	<4.0	0.052	<0.0044	<0.0020	<0.0011	<0.017
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.059	0.0032		<0.00090	<0.010
County Durham	River Tees, Darlington	4	<4.0	<0.080	0.0033	0.0022	<0.0011	<0.010
County Durham	Honey Hill Treatment Works, Consett	3	<4.0	<0.038	0.0024		<0.0013	<0.010
Cumbria	Haweswater Reservoir	4	<4.0	<0.014	0.0024		0.0010	<0.010
Cumbria	Ennerdale Lake	4	<4.0	<0.020	0.0031		0.0013	<0.010
Derbyshire	Armfield Water Treatment Plant	4	<4.0	<0.035	0.0017		0.0010	<0.010
Derbyshire	Matlock, Groundwater	4	<4.0	<0.045	<0.0018		<0.0011	<0.010
Devon	River Exe, Exeter	4	<4.0	0.11	<0.0011	<0.0038	<0.0010	<0.010
Gloucestershire	River Severn, Tewkesbury	4	<4.0	0.17	0.0029	0.0039	<0.00090	<0.010
Greater London	River Lee, Chingford	4	<4.0	0.28	<0.0010	0.0021	<0.00090	<0.010
Hampshire	River Avon, Christchurch	4	<4.0	0.070	<0.0011	<0.0030	<0.0012	<0.010
Humberside	Littlecoates, Groundwater	3	<4.0	0.11	<0.0010		<0.0010	<0.010
Kent	Denge, Shallow Groundwater	4	<4.7	0.16	0.0020		<0.0010	<0.010
Kent	Chatham, Deep Groundwater	4	<4.0	0.057	<0.0021		<0.0015	<0.010
Lancashire	Corn Close, Groundwater	4	<4.0	0.037	<0.0010		<0.0010	<0.013
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.086	0.0023	<0.0032	<0.0010	<0.010
Northumbria	Kielder Reservoir	4	<4.0	<0.043	0.0032		<0.0015	<0.010
Oxfordshire	River Thames, Oxford	4	<4.0	0.12	0.0012	<0.0020	<0.0010	<0.010
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.063	<0.0022		<0.0010	<0.010
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.12	0.0028		<0.00090	<0.010
Surrey	River Thames, Walton	4	<4.0	0.20	<0.0015	0.0042	<0.00090	<0.010
Surrey	River Thames, Chertsey	4	<4.0	0.21	<0.0015	<0.0028	<0.0010	<0.010
Yorkshire	Eccup No.1 Works Inlet, Leeds	2	<4.0	0.12	<0.0010		0.0020	<0.010
Yorkshire	Chellow Heights, Bradford	1	<4.0	<0.17	0.0066		<0.0070	<0.010
Wales								
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.067	0.0042		0.0017	<0.010
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.032	0.0030		0.0011	<0.011
Powys	Elan Valley Reservoir	4	<4.0	<0.028	0.0045		0.0011	<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[a]	Total beta[b]
England									
Buckinghamshire	Bourne End, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.10	0.064
Cambridgeshire	Grafham Water	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.55	0.35
Cheshire	River Dee, Chester	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.26	0.16
Cornwall	River Fowey	4	<0.014	<0.010	<0.010	<0.010	0.021	0.12	0.073
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.12	0.075
County Durham	River Tees, Darlington	4	<0.010	<0.010	<0.010	<0.010	<0.022	0.11	0.067
County Durham	Honey Hill Treatment Works, Consett	3	<0.010	<0.010	<0.010	<0.010	<0.020	0.098	0.062
Cumbria	Haweswater Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.049	<0.050
Cumbria	Ennerdale Lake	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.058	0.045
Derbyshire	Armfield Water Treatment Plant	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.063	<0.050
Derbyshire	Matlock, Groundwater	4	0.012	0.037	<0.010	0.019	0.060	0.11	0.075
Devon	River Exe, Exeter	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.11	0.071
Gloucestershire	River Severn, Tewkesbury	4	<0.010	0.017	<0.010	<0.010	0.042	0.32	0.20
Greater London	River Lee, Chingford	4	<0.010	<0.010	<0.010	<0.010	0.023	0.36	0.22
Hampshire	River Avon, Christchurch	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.13	0.079
Humberside	Littlecoates, Groundwater	3	<0.010	<0.010	<0.010	<0.010	<0.020	0.19	0.12
Kent	Denge, Shallow Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.21	0.14
Kent	Chatham, Deep Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.085	0.058
Lancashire	Corn Close, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.076	0.053
Norfolk	River Drove, Stoke Ferry	4	<0.010	0.011	<0.010	<0.010	0.025	0.19	0.12
Northumbria	Kielder Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.051	<0.050
Oxfordshire	River Thames, Oxford	4	<0.010	<0.010	<0.010	<0.010	<0.022	0.24	0.16
Somerset	Ashford Reservoir, Bridgwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.13	0.082
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.010	0.011	<0.010	<0.010	0.020	0.22	0.13
Surrey	River Thames, Walton	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.35	0.23
Surrey	River Thames, Chertsey	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.31	0.19
Yorkshire	Eccup No.1 Works Inlet, Leeds	2	<0.010	<0.010	<0.010	<0.010			
Yorkshire	Chellow Heights, Bradford	1	<0.010	<0.010	<0.010	<0.010			
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	<0.020	<0.058	<0.050
Powys	Elan Valley Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.063	<0.053

[a] *Using ^{137}Cs standard*
[b] *Using ^{40}K standard*

Regional/ research

Table 9.15. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2004

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	1.1	0.0025	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.027	0.058
Co. Antrim	Lough Neagh	4	<1.0	0.0030	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.022	0.033
Co. Down	Silent Valley	4	1.1	0.0024	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.11

Table 9.16. Estimates of maximum radiation exposure from radionuclides in drinking water, 2004[a]

Country	Exposure, mSv Man-made radionuclides[b]	Natural radionculides	All radionuclides
England	<0.001	0.043	0.044
Northern Ireland	<0.001	0.026	0.027
Scotland	<0.001	[c]	0.001
Wales	<0.001	0.029	0.029

[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] *Analysis of natural radionuclides was not undertaken*

Table 9.17. Concentrations of radionuclides in seawater, 2004

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}Ce	^{241}Am	Total alpha	Total beta
Dounreay (Sandside Bay)	4	<1.0		<0.10			<0.25	<0.10	<0.10	<0.18	<0.10		
Hartlepool (North Gare)	2			<0.41			<2.9	<0.36	<0.34	<1.3	<0.45	<2.9	15
Hartlepool (North Gare)	2[F]	2.3											
Sizewell	2			<0.41			<1.4	<0.38	<0.34	<2.3	<0.49	<3.4	17
Aldeburgh	2[F]	<1.8											
Bradwell	2			<0.40			<2.8	<0.38	<0.35	<1.4	<0.51	<3.7	14
Dungeness (inlet)	2[F]	2.9											
Dungeness south	2			<0.47			<3.4	<0.44	<0.41	<1.6	<0.61	<3.3	9.7
Winfrith (Arish Mell)	2			<0.38			<2.7	<0.36	<0.31	<1.1	<0.41	<3.3	12
Alderney	4[F]	3.4						*	0.001				
Jersey	1[F]							*	0.003				
Guernsey	3[F]							*	0.002				
Devonport (Millbrook Lake)	2	<4.0	<4.0	<0.42									
Devonport (Tor Point South)	2	<4.0	<4.0	<0.51									
Hinkley	2			<0.41			<2.7	<0.37	<0.35	<1.4	<0.56	<2.2	14
Hinkley (inlet)	1[F]	26											
Berkeley and Oldbury	2			<0.39			<2.7	<0.38	<0.33	<1.3	<0.46	<0.79	3.2
Cardiff (Orchard Ledges)[a]	2	30	<4.0										
Cardiff (Orchard Ledges East)	2[F]	5.3											
Holyhead	4[F]	<2.7						*	0.03				
Wylfa (Cemaes Bay)	2			<0.48			<3.8	<0.47	<0.41	<1.8	<0.54	<1.3	<6.8
Wylfa (Cemlyn Bay)	2			<0.48			<3.6	<0.45	<0.41	<1.6	<0.53	<2.8	16
Llandudno	1[F]							*	0.06				
Prestatyn	1[F]							*	0.08				
New Brighton	1[F]							*	0.09				
Ainsdale	1[F]							*	0.12				
Rossall	1[F]							*	0.13				
Heysham (inlet)	2			<0.43			<3.1	<0.41	<0.36	<1.5	<0.53	<2.2	14
Heysham (inlet)	2[F]	17											
Half Moon Bay	1[F]							0.002	0.16				
Walney- west shore	2[F]	16											
Silecroft	1[F]							0.003	0.14				
Seascale	2[F]							*	0.11				
Seascale (Particulate)	2			<0.06	<0.010		<0.20	<0.05	<0.05	<0.34	<0.10	<0.042	<0.07
Seascale (Filtrate)	2			<0.50	0.040	<0.82	<3.3	<0.46	<0.41	<1.6	<0.54	<2.6	12
St. Bees	10[F]	23				0.10		<0.002	0.17				
St. Bees (Particulate)	2			<0.06	<0.010		<0.44	<0.06	<0.07	<0.35	<0.09	<0.048	<0.07
St. Bees (Filtrate)	2			<0.47	<0.020	<0.16	<3.2	<0.44	<0.40	<1.5	<0.52	<1.3	6.5
Whitehaven	1[F]							0.002	0.11				
Maryport	1[F]							0.002	0.15				
Silloth	1[F]							0.002	0.19				
Seafield	4	9.1		<0.10			<0.26	<0.10	0.25	<0.17	<0.10		
Seafield (high water)	3	8.6		<0.10			<0.28	<0.10	<0.14	<0.18	<0.10		
Carsethorn	2	8.4											
Southerness[b]	4	8.9		<0.10			<0.23	<0.10	<0.13	<0.16	0.012		
Auchencairn	4	8.3											
Ross Bay	1[F]							*	0.09				
Isle of Whithorn	1[F]							*	0.07				
Drummore	1[F]							*	0.05				
Knock Bay	4	2.4		<0.10			<0.23	<0.10	<0.10	<0.15	<0.10		
Knock Bay	4[F]	2.2						*	0.02				
North of Larne	12					0.014		*	0.02				
Faslane (Carnban)	1	3.5											

** Not detected by the method used*

[a] The concentration of ^{3}H as tritiated water was 6.2 Bq l^{-1}

[b] The concentrations of ^{238}Pu, $^{239+240}$Pu, ^{242}Cm and $^{243+244}$Cm were 0.0014, 0.0066, <0.00032 and <0.00032 Bq l^{-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

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 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 2004 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 the Scottish Environment Protection Agency 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.environment-agency.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.

Uptake of tritium into animals – SC020042/SR

This study was to investigate the uptake and retention of tritium fed to animals with a view to determining the applicability of the generic ICRP dose coefficient to consumers of fish caught from Cardiff Bay.

As discussed in Section 7 of this report, fish and shellfish caught from Cardiff Bay contain relatively high levels of tritium, and these levels are believed to be organically bound as a consequence of the chemical form of the discharge of tritium from the radiochemical site at Cardiff. Rats were fed with fish caught from Cardiff Bay and the retention and uptake of tritium was determined. The results showed that if the experimental retention and uptake data were applied to a human model, the dose coefficient would change from 4.2 10^{-11} Sv Bq^{-1}, the generic value, to 6.0 10^{-11} Sv Bq^{-1} (Hodgson *et al*, 2005).

The effects of this change to dose estimates in this report is considered in Section 7.

Modelling of restricted areas of Cumbria and Wales – C05033

Restrictions concerning the movement and slaughter of sheep in the UK continue some 19 years after the initial deposition of caesium in 1986. Models have been developed using spatial information in the restricted areas of north Wales and Cumbria to help forecast the pattern of derestriction as affected by two factors: (i) the natural decay and redistribution of caesium in the environment and (ii) possible changes in the standard for radiocaesium in sheep meat, currently 1000 Bq kg^{-1}.

The work showed that if the current standard remains, few restricted areas would be likely after 2020. Harmonising the standard to the current EU Community Food Intervention Levels of 1250 Bq kg^{-1} would remove most restricted areas in Wales. The outcome of the research will be used by the Food Standards Agency in planning future derestriction exercises (Wright *et. al*., 2004).

Natural radioactivity in bottled waters – R03021

A survey was undertaken to determine the levels of natural radioactivity and uranium in bottled waters marketed in the UK. 100 brands were analysed and determinations for uranium and thorium isotopes, tritium, lead-210, radium-226, polonium-210, radon-222, total alpha and total beta were made. The results have been published by the Food Standards Agency (Food Standards Agency, 2004b).

None of the 100 brands analysed breached any legal limits. In addition, no samples contained soluble uranium at levels that would cause consumers to exceed safe levels of intake. The Agency concluded that even the samples that gave rise to the highest doses of radioactivity would not have added significantly to the average annual background dose received by people living in the UK.

Table 10.1. Extramural projects

Topic	Reference	Further details	Target completion date
RIFE Trend studies	R03011	F	Complete
Presentation of probabilistic dose estimates: Extension of stage 1 pilot study to cover uncertainty	R01058	F	Complete
Natural radioactivity in bottled waters	R03021	F	Complete
International Radionuclide Flux Database (RADFLUX)	R01051	F	Complete
Development of a regulatory framework to assess the application of best practicable means for the management of radioactive wastes	UKRSR05	S	Complete
Measurement of radioactivity in canteen meals for Euratom (2002-2005)	R03022	F	Complete
Modelling for derestriction of sheep (Chernobyl)	C05033	F	Complete
Uptake of tritium into animals	SC020042/SR	E	Complete
Assessing the suitability of controlled landfills to accept radioactive waste	UKRSR03	S	Jul-05
Assessment of organically bound tritium (OBT) in the environment	R01034	F	Nov-05
Soil and herbage survey	UKRSR01	S	Nov-05
Recovery handbook - response to nuclear incidents	C05032	F, E, S	Dec-05
Total diet studies	R03024	F	Mar-07
Measurement of radioactivity in canteen meals for Euratom (2005-2008)	R03025	F	Mar-09

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, 2004

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004	
			TBq[a]	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Rivacre Brook)	Tritium[s]	78	0.380	<1
	Uranium	0.02	$4.00\ 10^{-4}$	2.0
	Uranium daughters	0.02	$5.55\ 10^{-4}$	2.8
	Non-uranic alpha	0.003	$1.20\ 10^{-5}$	<1
	Technetium-99	0.1	$3.80\ 10^{-4}$	<1
Sellafield[c,k,t] (sea pipelines)	Alpha	1	0.291	29
	Beta	400	73.3	18
	Tritium	$2.5\ 10^{4}$	3170	13
	Carbon-14	20.8	16.3	78
	Cobalt-60	13	0.775	6.0
	Strontium-90	48	18.0	38
	Zirconium-95+Niobium-95	9	0.231	2.6
	Technetium-99	90	14.3	16
	Ruthenium-106	63	4.42	70
	Iodine-129	1.6	0.650	41
	Caesium-134	6.6	0.401	6.1
	Caesium-137	75	9.67	13
	Cerium-144	8	0.819	10
	Plutonium alpha	0.7	0.292	42
	Plutonium-241	27	8.10	30
	Americium-241	0.3	0.0372	12
	Uranium[u]	2040	436	21
Sellafield (factory sewer)[c,k]	Alpha	0.0033	$1.77\ 10^{-4}$	5.4
	Beta	0.0135	$5.10\ 10^{-4}$	3.8
	Tritium	0.132	0.0300	23
Springfields[d,k]	Alpha	4	0.24	6.0
	Beta	240	117	49
	Technetium-99	0.6	0.122	20
	Thorium-230	2	0.106	5.3
	Thorium-232	0.2	0.00106	<1
	Neptunium-237	0.04	0.0017	4.3
	Uranium	0.15	0.0461	31
Research establishments				
Dounreay[e]	Alpha[5]	0.27	$4.27\ 10^{-4}$	<1
	Beta[1]	49	0.472	<1
	Tritium	30.8	0.0984	<1
	Cobalt-60	0.46	$2.31\ 10^{-4}$	<1
	Strontium-90	7.7	0.112	1.5
	Zirconium-95+Niobium-95	0.4	$5.73\ 10^{-4}$	<1
	Ruthenium-106	4.1	0.00119	<1
	Silver-110m	0.13	$2.29\ 10^{-4}$	<1
	Caesium-137	23	0.0176	<1
	Cerium-144	0.42	0.00106	<1
	Plutonium-241	2.3	$1.18\ 10^{-4}$	<1
	Curium-242	0.04	$5.01\ 10^{-7}$	<1
Dounreay[f] PFR liquid metal disposal plant	Alpha[5]	0.02	$9.37\ 10^{-5}$	<1
	Beta[1]	0.11	0.00166	1.5
	Tritium	1.4	0.00997	<1
	Sodium-22	1.8	0.0969	5.4
	Caesium-137	0.066	0.00120	1.8
Dounreay[f] Other facilities	Alpha	0.09	$6.06\ 10^{-5}$	<1
	Beta	0.62	$3.89\ 10^{-5}$	<1
	Tritium	5.5	0.0356	<1
	Sodium-22	0.77	0.0182	2.4
	Caesium-137	1.0	0.00213	<1

* *As reported to SEPA and the Environment Agency*

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004	
			TBq[a]	% of annual limit[b]
Harwell (pipeline)	Alpha	$5\ 10^{-5}$	$9.91\ 10^{-6}$	20
	Beta	0.0033	$2.10\ 10^{-4}$	6.4
	Tritium	0.3	0.0338	11
	Cobalt-60	$1.2\ 10^{-4}$	$9.62\ 10^{-6}$	8.0
	Caesium-137	$5.4\ 10^{-4}$	$4.51\ 10^{-5}$	8.3
Harwell (Lydebank Brook)	Alpha	10^{-4}	$1.25\ 10^{-5}$	12
	Beta	$6\ 10^{-4}$	$1.66\ 10^{-4}$	28
	Tritium	0.08	0.0162	20
Winfrith (inner pipeline)	Alpha	0.3	$3.69\ 10^{-4}$	<1
	Tritium	650	35.9	5.5
	Cobalt-60	10	0.00136	<1
	Zinc-65	6	$1.75\ 10^{-4}$	<1
	Other radionuclides	80	0.0375	<1
Winfrith (outer pipeline)	Alpha	0.004	$5.01\ 10^{-5}$	1.3
	Tritium	1	0.00766	<1
	Other radionuclides	0.01	$9.43\ 10^{-5}$	<1
Minor sites				
Imperial College Reactor Centre[g,k] Ascot	Tritium	10^{-4}	Nil	Nil
	Other radioactivity	$4\ 10^{-5}$	Nil	Nil
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	0.00144	[x]	[x]
Nuclear power stations				
Berkeley	Tritium	2	$3.00\ 10^{-4}$	<1
	Caesium-137	0.2	$1.35\ 10^{-4}$	<1
	Other radionuclides	0.4	$1.10\ 10^{-4}$	<1
Bradwell	Tritium	7	0.182	2.6
	Caesium-137	0.7	0.378	54
	Other radionuclides	0.7	0.273	39
Chapelcross	Alpha	0.1	$3.20\ 10^{-5}$	<1
	Beta[1]	25	0.0389	<1
	Tritium	5.5	0.0797	1.4
Dungeness 'A' Station	Tritium	8	0.278	3.5
	Caesium-137	1.1	0.175	16
	Other radionuclides	0.8	0.101	13
Dungeness 'B' Station	Tritium	650	407	63
	Sulphur-35	2	0.305	15
	Cobalt-60	0.03	0.00150	5.0
	Other radionuclides	0.25	0.0276	11
Hartlepool	Tritium	1200	229	19
	Sulphur-35	3	0.623	21
	Cobalt-60	0.03	0.00140	4.7
	Other radionuclides	0.3	0.0148	4.9
Heysham Station 1	Tritium	1200	224	19
	Sulphur-35	2.8	0.162	5.8
	Cobalt-60	0.03	$2.96\ 10^{-4}$	1.0
	Other radionuclides	0.3	0.0199	6.6

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004	
			TBq[a]	% of annual limit[b]
Heysham Station 2	Tritium	1200	303	25
	Sulphur-35	2.3	0.0849	3.7
	Cobalt-60	0.03	4.63 10^{-4}	1.5
	Other radionuclides	0.3	0.0253	8.4
Hinkley Point 'A' Station	Tritium	1.8	0.417	23
	Caesium-137	1	0.274	27
	Other radionuclides	0.7	0.0801	11
Hinkley Point 'B' Station	Tritium	620	416	67
	Sulphur-35	5	0.475	9.5
	Cobalt-60	0.033	2.38 10^{-4}	<1
	Other radionuclides	0.235	0.0155	6.6
Hunterston 'A' Station	Alpha	0.04	1.52 10^{-4}	<1
	Beta	0.6	0.0634	11
	Tritium	0.7	6.73 10^{-4}	<1
	Plutonium-241	1.0	2.06 10^{-4}	<1
Hunterston 'B' Station	Alpha	0.001	1.61 10^{-4}	16
	Beta[1,2,4]	0.45	0.0155	3.4
	Tritium	800	466	58
	Sulphur-35	10	0.980	9.8
	Cobalt-60	0.03	7.30 10^{-4}	2.4
Oldbury	Tritium	1	0.248	25
	Caesium-137	0.7	0.392	56
	Other radionuclides	0.7	0.214	31
Sizewell 'A' Station	Tritium	11	0.779	7.1
	Caesium-137	1	0.607	61
	Other radionuclides	0.7	0.351	50
Sizewell 'B' Station	Tritium	80	17.6	22
	Other radionuclides	0.2	0.0203	10
Torness	Alpha	0.001	2.10 10^{-5}	2.1
	Beta[1,2,4]	0.45	0.00289	<1
	Tritium	800	331	41
	Sulphur-35	10	0.0193	<1
	Cobalt-60	0.03	2.51 10^{-4}	<1
Trawsfynydd	Other radionuclides[6]	0.17	0.0106	6.2
	Tritium	0.5	0.0249	5.0
	Strontium-90	0.05	0.00337	6.7
	Caesium-137	0.03	0.00195	6.5
Wylfa[v]	Tritium	15	6.10	41
	Other radionuclides	0.11	0.0390	35
Defence establishments				
Aldermaston (River Thames)	Alpha	6 10^{-5}	9.25 10^{-6}	15
	Tritium	0.05	0.0251	50
	Plutonium-241	2.4 10^{-4}	3.70 10^{-5}	15
	Other radionuclides	6 10^{-5}	6.53 10^{-6}	11

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004	
			TBq[a]	% of annual limit[b]
Aldermaston (Silchester)	Alpha	4 10^{-5}	1.61 10^{-6}	4.0
	Beta/gamma	1.2 10^{-4}	8.99 10^{-6}	7.5
	Tritium	0.05	4.80 10^{-4}	<1
Aldermaston (to stream)	Tritium	0.01	1.33 10^{-3}	13
Barrow [h,l]	Tritium	0.012	Nil	Nil
	Other gamma emitting radionuclides	3.5 10^{-6}	Nil	Nil
Derby[m,i]	Alpha[n]	0.002	1.25 10^{-4}	6.3
	Alpha[o]	3 10^{-7}	3.00 10^{-8}	10
	Beta[o]	3 10^{-4}	9.91 10^{-7}	<1
Devonport[p,v] (sewer)	Beta		Nil	
	Tritium		Nil	
	Cobalt-60		Nil	
Devonport[q] (sewer)	Tritium	0.002	2.18 10^{-4}	11
	Cobalt-60	3.5 10^{-4}	1.34 10^{-5}	3.8
	Other radionuclides	6.5 10^{-4}	2.83 10^{-4}	44
Devonport[q] (pipeline)	Tritium	0.7	0.0857	12
	Carbon-14	0.0017	3.04 10^{-4}	18
	Cobalt-60	8 10^{-4}	8.21 10^{-5}	10
	Other radionuclides	3 10^{-4}	1.27 10^{-4}	42
Faslane	Alpha	2 10^{-4}	1.51 10^{-6}	<1
	Beta[1,3]	5 10^{-4}	5.38 10^{-6}	1.1
	Tritium	1	0.0479	4.8
	Cobalt-60	5 10^{-4}	7.19 10^{-6}	1.4
Rosyth[r]	Alpha	10^{-6}	1.60 10^{-8}	1.6
	Beta[1,3]	5 10^{-4}	3.00 10^{-5}	6.0
	Tritium	0.04	7.23 10^{-4}	1.8
	Cobalt-60	0.005	7.81 10^{-5}	1.6
Radiochemical production				
Amersham[j]	Alpha	3 10^{-4}	1.09 10^{-5}	3.6
	Beta >0.4 MeV	0.06	4.83 10^{-4}	<1
	Tritium	0.141	0.00107	<1
	Iodine-125	0.004	8.30 10^{-5}	2.1
	Caesium-137	0.005	1.40 10^{-6}	<1
	Other radionuclides	0.215	0.00948	4.4
Cardiff (Amersham plc)[j]	Tritium	130	44.4	34
	Carbon-14	0.91	0.210	23
	Phosphorus-32/33	8.5 10^{-5}	4.19 10^{-6}	4.9
	Iodine-125	3 10^{-4}	2.11 10^{-5}	7.0
	Others	1.2 10^{-4}	Nil	Nil

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004	
			TBq[a]	% of annual limit[b]
Industrial and landfill sites				
Drigg (sea pipeline)	Alpha	0.1	7.27 10^{-5}	<1
	Beta	0.3	0.00114	<1
	Tritium	120	0.217	<1
Drigg (stream[w])	Alpha	9 10^{4}	53.9	<1
	Beta	1.2 10^{6}	458	<1
	Tritium	6 10^{8}	2.35 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] *Discharge authorisations at Sellafield were revised with effect from 1st October 2004*
[d] *Discharge authorisations at Springfields were revised with effect from 1st November 2004*
[e] *Discharge authorisations at Dounreay were revised with effect from 1st October 2004, discharges are quoted for 1st January-31 October 2004. Limits quoted are old limits*
[f] *Discharge authorisations at Dounreay were revised with effect from 1st October 2004, discharges are quoted for 1st November- 31 December. Limits quoted are new limits*
[g] *Discharge authorisations at Ascot were revised with effect from 1st December 2004*
[h] *Discharge authorisations at Barrow were revised with effect from 1st June 2004, discharges are quoted for the full calendar year. Limits quoted are new limits*
[i] *Discharge authorisations at Derby were revised with effect from 1st July 2004, discharges are quoted for the full calendar year. Limits quoted are new limits*
[j] *Discharge authorisations at Amersham and Cardiff were revised with effect from 1st April 2004. Discharges are quoted for 1st April to 31st December multiplied by 1.3 to correct for discharges made between 1st January and 31st March 2004. Limits quoted are new limits*
[k] *Discharges are quoted for the full calendar year, limits quoted are old limits valid prior to the re-authorisation*
[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 Rolls Royce Marine Power Operations Ltd*
[n] *Discharge limit is for Nuclear Fuel Production Plant*
[o] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[p] *Discharges were made by the Ministry of Defence*
[q] *Discharges were made by Devonport Royal Dockyard Ltd*
[r] *Discharges were made by Rosyth Royal Dockyard Ltd*
[s] *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}*
[t] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[u] *The limit and discharge data are expressed in kg*
[v] *The current limits are expressed as an activity concentration of 2 MBq m^{-3} with no more than 800 m^3 discharged per year*
[w] *Discharges and limits are expressed in terms of concentrations of activity in Bq m^{-3} (discharges are expressed as the annual mean)*
[x] *Not available*
[1] *Excluding tritium*
[2] *Excluding sulphur-35*
[3] *Excluding cobalt-60*
[4] *Excluding plutonium-241*
[5] *Excluding curium-242*
[6] *Including strontium*

Table A1.2 Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2004

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004	
			TBq	% of annual limit[b]
Nuclear fuels production and reprocessing				
Capenhurst (BNFL)	Tritium	1600	$4.30\ 10^{-6}$	<1
	Uranium[q]		$5.60\ 10^{-6}$	
Capenhurst (Urenco)	Uranium	$2.5\ 10^{-6}$	$5.70\ 10^{-7}$	23
Sellafield[c,r,j]	Alpha	0.00246	$1.24\ 10^{-4}$	5.0
	Beta	0.341	0.00146	<1
	Tritium	1440	320	22
	Carbon-14	7.3	0.849	12
	Sulphur-35	0.21	$2.63\ 10^{-5}$	<1
	Argon-41	3700	Nil	Nil
	Cobalt-60	$9.2\ 10^{-4}$	$3.20\ 10^{-7}$	<1
	Krypton-85	$4.7\ 10^{5}$	$1.20\ 10^{5}$	26
	Strontium-90	0.0094	$5.47\ 10^{-5}$	<1
	Ruthenium-106	0.056	0.00162	2.9
	Antimony-125	0.005	$4.59\ 10^{-4}$	9.2
	Iodine-129	0.069	0.0158	23
	Iodine-131	0.055	$6.81\ 10^{-4}$	1.2
	Caesium-137	0.0183	$4.33\ 10^{-4}$	2.4
	Plutonium (alpha)	0.00122	$5.19\ 10^{-5}$	4.3
	Plutonium-241	0.0174	$3.18\ 10^{-4}$	1.8
	Americium-241 and curium-242	$7.40\ 10^{-4}$	$3.71\ 10^{-5}$	5.0
Springfields[d,j]	Uranium	0.006	$1.2\ 10^{-3}$	20
Research establishments				
Dounreay (Fuel Cycle Area)	Alpha[y]	$9.8\ 10^{-4}$	$9.77\ 10^{-6}$	<1
	Beta[v,w]	0.045	$2.11\ 10^{-4}$	<1
	Tritium	2	0.491	25
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	$4.69\ 10^{-5}$	1.1
	Ruthenium-106	0.0039	$5.41\ 10^{-6}$	<1
	Iodine-129	0.0011	$8.10\ 10^{-5}$	7.4
	Iodine-131	$1.5\ 10^{-4}$	$3.86\ 10^{-5}$	26
	Caesium-134	$8.4\ 10^{-4}$	$6.62\ 10^{-7}$	<1
	Caesium-137	0.007	$2.51\ 10^{-5}$	<1
	Cerium-144	0.007	$4.33\ 10^{-6}$	<1
	Plutonium-241	0.0033	$7.58\ 10^{-6}$	<1
	Curium-242	$2.7\ 10^{-4}$	$6.40\ 10^{-8}$	<1
	Curium-244[z]	$5.4\ 10^{-5}$	$1.60\ 10^{-7}$	<1
Dounreay (Fast Reactor)	Alpha[x]	10^{-5}	$2.47\ 10^{-9}$	<1
	Beta[v,w]	0.0015	$1.15\ 10^{-8}$	<1
	Tritium	4.5	$9.20\ 10^{-4}$	<1
	Krypton-85	$4\ 10^{-4}$	$1.91\ 10^{-6}$	<1
Dounreay (Prototype Fast Reactor)	Alpha[x]	$6\ 10^{-6}$	$3.40\ 10^{-8}$	<1
	Beta[v,w]	$5.1\ 10^{-5}$	$4.30\ 10^{-7}$	<1
	Tritium	10.5	0.365	3.5
	Krypton-85	4	Nil	Nil
Dounreay (PFR minor sources)	Alpha[x]	$6\ 10^{-8}$	Nil	Nil
	Beta[v,w]	$5\ 10^{-7}$	Nil	Nil
	Tritium	0.2	0.0100	5.0

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004 TBq	Discharges during 2004 % of annual limit[b]
Dounreay (East minor sources)	Alpha[x]	$1.37\ 10^{-5}$	$9.30\ 10^{-8}$	<1
	Beta[w]	$3.71\ 10^{-4}$	$4.84\ 10^{-7}$	<1
	Krypton-85	1	Nil	Nil
Dounreay (West minor sources)	Alpha[x]	$3\ 10^{-7}$	$1.16\ 10^{-9}$	<1
	Beta[v]	$7.5\ 10^{-5}$	$7.50\ 10^{-9}$	<1
	Tritium	0.01	$4.85\ 10^{-4}$	4.9
Harwell (AEA Technology)				
	Alpha	$7\ 10^{-7}$	Nil	Nil
	Beta	$3\ 10^{-5}$	Nil	Nil
	Tritium	$2\ 10^{-4}$	Nil	Nil
Harwell (UKAEA)				
	Alpha	$8\ 10^{-7}$	$4.39\ 10^{-8}$	5.5
	Beta	$2\ 10^{-5}$	$1.02\ 10^{-6}$	5.1
	Tritium	15	0.550	3.7
	Krypton-85	2	Nil	Nil
	Radon-220	100	10.1	10
	Radon-222	3	0.330	11
	Iodines	0.01	Nil	Nil
	Other radionuclides	0.1	Nil	Nil
Windscale	Alpha	$1.2\ 10^{-5}$	$1.65\ 10^{-7}$	1.4
	Beta	$5\ 10^{-4}$	$2.38\ 10^{-6}$	<1
	Tritium	2.3	0.00196	<1
	Krypton-85	14	0.138	<1
	Iodine-131	0.0012	$2.04\ 10^{-6}$	<1
Winfrith (AEA Technology)	Alpha	$2\ 10^{-7}$	Nil	Nil
	Beta	$2.5\ 10^{-5}$	$8.31\ 10^{-6}$	33
	Tritium	10	3.89	39
Winfrith (UKAEA)	Alpha	$2\ 10^{-6}$	Nil	Nil
	Beta	$2.5\ 10^{-5}$	$7.88\ 10^{-8}$	<1
	Tritium	5	0.0829	1.7
	Carbon-14	0.3	$4.09\ 10^{-4}$	<1
	Krypton-85	150	Nil	Nil
Minor sites				
Imperial College Reactor Centre[e,j] Ascot	Tritium	$5\ 10^{-4}$	$7.67\ 10^{-5}$	15
	Argon-41	2.5	0.261	10
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	$5\ 10^{-7}$	[t]	[t]
	Tritium	0.05	[t]	[t]
Nuclear power stations				
Berkeley[k]	Beta	$3\ 10^{-5}$	$6.39\ 10^{-7}$	2.1
	Tritium	0.0754	0.00492	6.5
	Carbon-14	0.011	$2.11\ 10^{-4}$	1.9

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004	
			TBq	% of annual limit[b]
Bradwell	Beta	6 10^{-4}	1.75 10^{-5}	2.9
	Tritium	1.5	0.0243	1.6
	Carbon-14	0.6	0.00260	<1
	Sulphur-35	0.02	2.48 10^{-5}	<1
Chapelcross	Tritium	5000	594	12
	Sulphur-35	0.05	7.60 10^{-4}	1.5
	Argon-41	4500	68.7	1.5
Dungeness 'A' Station	Beta[u]	5.5 10^{-4}	1.80 10^{-4}	33
	Tritium	2.6	0.401	15
	Carbon-14	5	3.05	61
	Sulphur-35	0.15	0.0381	25
	Argon-41	1700	1040	61
Dungeness 'B' Station	Beta[u]	0.001	5.29 10^{-6}	<1
	Tritium	15	7.47	50
	Carbon-14	5	0.669	13
	Sulphur-35	0.45	0.0419	9.3
	Argon-41	150	14.2	9.5
	Iodine-131	0.005	1.67 10^{-6}	<1
Hartlepool	Beta[u]	0.001	4.43 10^{-6}	<1
	Tritium	6	3.43	57
	Carbon-14	5	1.42	28
	Sulphur-35	0.16	0.0707	44
	Argon-41	60	8.63	14
	Iodine-131	0.005	2.68 10^{-5}	<1
Heysham Station 1	Beta[u]	0.001	7.67 10^{-6}	<1
	Tritium	6	0.724	12
	Carbon-14	4	0.680	17
	Sulphur-35	0.12	0.0164	14
	Argon-41	60	3.06	5.1
	Iodine-131	0.005	1.11 10^{-4}	2.2
Heysham Station 2	Beta[j,u]	0.001	1.19 10^{-5}	1.2
	Tritium	15	1.30	8.7
	Carbon-14	3	1.39	46
	Sulphur-35	0.3	0.0189	6.3
	Argon-41	85	20.4	24
	Iodine-131	0.005	4.34 10^{-5}	<1
Hinkley Point 'A' Station	Beta	1.5 10^{-4}	2.65 10^{-6}	1.8
	Tritium	1.5	0.0616	4.1
	Carbon-14	0.6	0.00150	<1
Hinkley Point 'B' Station	Beta[u]	0.001	3.11 10^{-5}	3.1
	Tritium	30	3.01	10
	Carbon-14	8	1.31	16
	Sulphur-35	0.4	0.158	40
	Argon-41	300	13.9	4.6
	Iodine-131	0.005	4.18 10^{-6}	<1
Hunterston 'A' Station	Beta[u]	6 10^{-5}	2.9 10^{-7}	<1
	Tritium	0.02	0.00136	6.8
	Carbon-14	0.002	1.34 10^{-4}	6.7

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004	
			TBq	% of annual limit[b]
Hunterston 'B' Station	Beta[u]	0.002	$2.86\ 10^{-5}$	1.4
	Tritium	20	5.75	29
	Carbon-14	3	1.97	66
	Sulphur-35	0.8	0.0494	6.2
	Argon-41	220	24.5	11
Oldbury	Beta	$1\ \ 10^{-4}$	$3.72\ 10^{-5}$	37
	Tritium	9	2.93	33
	Carbon-14	4	1.51	38
	Sulphur-35	0.45	0.109	24
	Argon-41	500	37.7	7.5
Sizewell 'A' Station	Beta	$8.5\ 10^{-4}$	$1.61\ 10^{-4}$	19
	Tritium	3.5	1.39	40
	Carbon-14	2	1.08	54
	Sulphur-35	0.35	0.118	34
	Argon-41	3000	1370	46
Sizewell 'B' Station[a]	Noble gases	300	3.08	1.0
	Halogens	0.003	$1.20\ 10^{-4}$	4.0
	Beta[u]	0.01	$3.86\ \ 10^{-6}$	<1
	Tritium	8	0.651	8.1
	Carbon-14	0.6	0.199	33
Torness	Beta[u]	0.002	$5.28\ 10^{-6}$	<1
	Tritium	20	1.81	9.0
	Carbon-14	3	0.582	19
	Sulphur-35	0.8	0.0193	2.4
	Argon-41	220	4.37	2.0
Trawsfynydd	Beta	$5\ 10^{-5}$	$3.25\ 10^{-7}$	<1
	Tritium	0.75	0.0518	6.9
	Carbon-14	0.01	0.00116	12
Wylfa	Beta	$7\ 10^{-4}$	$3.50\ 10^{-5}$	5.0
	Tritium	18	3.05	17
	Carbon-14	2.3	1.34	58
	Sulphur-35	0.45	0.191	42
	Argon-41	100	34.0	34
Defence establishments				
Aldermaston[a,m]	Alpha	$4.5\ 10^{-7}$	$6.39\ 10^{-8}$	14
	Tritium	170	19.4	11
	Krypton-85	1	0.00355	<1
	Plutonium-241	$1.68\ 10^{-6}$	$2.12\ 10^{-7}$	13
	Other beta and gamma emitters	$5\ 10^{-6}$	$1.35\ 10^{-7}$	2.7
Barrow[f,l]	Tritium	$3.2\ \ 10^{-6}$	Nil	Nil
	Argon-41	0.048	"	"
Burghfield[a,m]	Tritium	0.05	Nil	Nil
	Uranium	$2\ 10^{-8}$	$8.00\ 10^{-10}$	4.0
Coulport	Tritium	0.05	0.00320	6.4
Derby[g,n,s]	Uranium	$5\ 10^{-6}$	$1.26\ 10^{-6}$	25
Derby (Neptune)	Alpha[u]	$2.4\ 10^{-8}$	$7.80\ 10^{-11}$	<1
	Beta[u]	$1.8\ 10^{-6}$	$2.23\ 10^{-9}$	<1
Devonport[o]	Beta/gamma[u]	$3\ 10^{-7}$	$2.92\ 10^{-8}$	9.7
	Tritium	0.004	$1.49\ 10^{-4}$	3.7
	Carbon-14	0.043	$2.99\ 10^{-5}$	<1
	Argon-41	0.015	$9.61\ 10^{-5}$	<1

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2004 TBq	% of annual limit[b]
Dounreay				
(Vulcan)	Alpha[u]	10^{-6}	4.68 10^{-8}	4.7
	Beta[u]	10^{-4}	1.20 10^{-6}	1.2
	Noble gases	0.027	4.72 10^{-4}	1.7
	Iodine-131	3.7 10^{-4}	2.60 10^{-5}	7.0
Rosyth[p]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	Nil	Nil
Radiochemical production				
Amersham - Grove Centre[h]	Alpha	2.25 10^{-6}	2.72 10^{-7}	12
(Amersham plc)	Beta >0.4 MeV	0.0202	1.29 10^{-4}	<1
	Radionuclides T½<2hr	0.01	3.35 10^{-4}	3.4
	Tritium	2	1.50 10^{-6}	<1
	Sulphur-35	0.035	0.00273	7.8
	Selenium-75	0.0015	2.09 10^{-4}	14
	Iodine-125	0.02	0.00137	6.9
	Iodine-131	0.001	6.69 10^{-4}	67
	Radon-222	10	2.92	29
	Other noble gases	50	8.51	17
	Other	0.016	0.00127	7.9
Cardiff - Maynard Centre[h]	Soluble tritium	156	83.5	54
(Amersham plc)	Insoluble tritium	600	338	57
	Carbon-14	2.38	1.47	62
	Phosphorus-32/33	5 10^{-6}	2.62 10^{-6}	52
	Iodine-125	1.8 10^{-4}	9.11 10^{-5}	51
	Other activity	0.001	Nil	Nil
Cardiff				
(Ortho-Clinical Diagnostics Ltd)[i]	Iodine-125	0.0150	Nil	Nil
	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] *Data quoted to 2 significant figures except when values are less than 1%*
[c] *Discharge authorisations at Sellafield were revised with effect from 1st October 2004*
[d] *Discharge authorisations at Springfields were revised with effect from 1st November 2004*
[e] *Discharge authorisations at Ascot were revised with effect from 1st October 2004*
[f] *Discharge authorisations at Barrow were revised with effect from 1st June 2004. Discharges are quoted for the full calendar year, limits quoted are new limits*
[g] *Discharge authorisations at Derby were raised with effect from 1st July 2004. Discharges are quoted for the full calendar year, limits quoted are new limits*
[h] *Discharge authorisations at Amersham and Cardiff were revised with effect from 1st April 2004. Discharges are quoted for 1st April to 31st December multiplied by 1.3 to account for discharges made between 1st January and 31st March 2004. Limits quoted are new limits*
[i] *Discharge authorisations at Ortho Clinical Diagnostics Ltd (Cardiff) were revoked from 1st April 2004. Discharges are quoted for 1st January -31 March 2004. Limits quoted are old limits*
[j] *Discharges are quoted for the full calendar year, limits quoted are old limits valid prior to the re-authorisation*
[k] *Combined data for Berkeley Power Station and Berkeley Technology Centre*
[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 AWE plc*
[n] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[o] *Discharges were made by Devonport Royal Dockyard Ltd*
[p] *Discharges were made by Rosyth Royal Dockyard Ltd*
[q] *There are no numerical limits for this discharge. However, the authorisation stipulates that the Best Practicable Means should be used to control the discharge*
[r] *Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP*
[s] *Annual limits on beta and alpha derived from monthly and weekly notification levels*
[t] *Not available*
[u] *Particulate activity*
[v] *Excluding tritium*
[w] *Excluding krypton-85*
[x] *Excluding radon and daughter products*
[y] *Excluding curium-242 and 244*
[z] *Data includes any curium-243 present*

Table A1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2004

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 2004	
			TBq	% of limit
Drigg	Tritium	10	1.10	11
	Carbon-14	0.05	0.0110	22
	Cobalt-60	2	0.240	12
	Iodine-129	0.05	$4.50\ 10^{-4}$	<1
	Radium-226 plus thorium-232	0.03	0.00540	18
	Uranium	0.3	0.0830	28
	Other alpha[a]	0.3	0.0860	29
	Others[a,b]	15	5.5	37
Dounreay[c]	Alpha		$3.32\ 10^{-4}$	
	Beta/gamma		0.00662	

[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:

$$C_m = F_m Ca\, Q_f \qquad \text{and}$$

$$C_f = F_f\, Ca\, Q_f \qquad \text{where}$$

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	^{241}Pu
Milk	Sellafield	a	$2.15\ 10^{-4}$	$4.39\ 10^{-6}$
	Ravenglass	a	$5.20\ 10^{-4}$	$1.06\ 10^{-5}$
	Drigg	a	$5.00\ 10^{-4}$	$1.56\ 10^{-5}$
	Isle of Man	a	$4.85\ 10^{-4}$	$1.27\ 10^{-5}$
Beef	Sellafield	$2.15\ 10^{-2}$	$2.15\ 10^{-1}$	$4.39\ 10^{-4}$
	Ravenglass	a	$5.20\ 10^{-1}$	$1.06\ 10^{-3}$
Lamb	Sellafield	a	$2.48\ 10^{-1}$	$2.03\ 10^{-4}$
	Ravenglass	a	$6.00\ 10^{-1}$	$4.87\ 10^{-4}$
	Drigg	a	$5.50\ 10^{-1}$	$7.20\ 10^{-4}$
Beef offal	Sellafield	a	$2.15\ 10^{-1}$	a
	Ravenglass	a	$5.20\ 10^{-1}$	a
Lamb offal	Sellafield	a	$2.48\ 10^{-1}$	a
	Ravenglass	a	$6.00\ 10^{-1}$	a
	Drigg	a	$5.50\ 10^{-1}$	$5.40\ 10^{-2}$

[a] *Positive result used, or LoD result used because modelling result greater than LoD*

A2.2 Air

For some sites, discharges to air can lead to significant doses. Doses may arise from radionuclides transferred from the plume to food crops and animal products, inhalation of radionuclides in the plume itself and external doses from radionuclides in the plume.

An assessment of doses from non-food pathways arising from discharges to air has been made around the operating Magnox power stations Chapelcross, Dungeness A, Oldbury, Sizewell A and Wylfa, from Sellafield and GE Health Care at Amersham and at Cardiff. For the 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. Inhalation of other radionuclides downwind of the discharge point has also been assessed.

Average annual concentrations of radionuclides in the air at nearest habitations were calculated using a Gaussian plume model, PC CREAM (Mayall *et al.*, 1997), and the reported discharges of radionuclides to air. Site-specific meteorological data were used in the assessments. The key modelling assumptions (i.e. discharge height, habitations) are shown in Table A2.3.

External radiation doses from radionuclides in the plume and from deposited activity were calculated taking into account occupancy indoors and outdoors and location factors to allow for building shielding. 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 (i.e. shielding factor of 0.2) has been made. Internal radiation doses from inhalation of discharged radionuclides was assessed using breathing rates. Doses were assessed for three age groups: infants (1 y), children (10 y) and adults. Adults and infants are assumed to have year-round occupancy at the nearest habitation, whilst children are assumed to spend time away at school. The inhalation and occupancy rates assumed in this assessment are shown in Table A2.4. 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
Amersham	20	Dwelling	250	
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	93	Farm	1200	900°
Wylfa	17	Farm	500	110°

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
Amersham, 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, Sellafield and Wylfa (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	11	0.14	$2.5\ 10^{-7}$				$8.5\ 10^{-6}$
Chapelcross	12			$1.5\ 10^{-5}$	1.3		
Dungeness A	$7.6\ 10^{-2}$	0.58		$7.2\ 10^{-3}$	$1.9\ 10^{2}$	$3.4\ 10^{-5}$	
Oldbury	0.17	$8.9\ 10^{-2}$		$6.4\ 10^{-3}$	2.2	$2.2\ 10^{-6}$	
Sizewell A	$9.0\ 10^{-2}$	$7.0\ 10^{-2}$		$7.6\ 10^{-3}$	$8.8\ 10^{1}$	$1.0\ 10^{-5}$	
Wylfa	0.11	$4.9\ 10^{-2}$		$7.0\ 10^{-3}$	1.2	$1.3\ 10^{-6}$	

Table A2.6 Predicted concentrations of radionuclides in air at most exposed location in vicinity of Amersham and Sellafield

Radionuclide	Radioactivity concentration in air, Bq m^{-3}	
	Amersham	Sellafield
Tritium	$1.0\ 10^{-7}$	0.65
Carbon-14		$1.7\ 10^{-3}$
Sulphur-35	$1.9\ 10^{-4}$	$5.4\ 10^{-8}$
Cobalt-60		$6.5\ 10^{-10}$
Selenium-75	$1.4\ 10^{-5}$	
Krypton-85		$2.4\ 10^{2}$
Strontium-90	$8.8\ 10^{-6}$	$1.1\ 10^{-7}$
Ruthenium-106		$3.3\ 10^{-6}$
Antimony-125		$9.3\ 10^{-7}$
Iodine-125	$9.2\ 10^{-5}$	
Iodine-129		$3.2\ 10^{-5}$
Xenon-133	0.58	
Iodine-131	$4.5\ 10^{-5}$	$1.4\ 10^{-6}$
Caesium-137	$8.6\ 10^{-5}$	$8.8\ 10^{-7}$
Radon-222	0.20	
Plutonium-239		$1.1\ 10^{-7}$
Plutonium-241		$6.5\ 10^{-7}$
Americium-241	$6.9\ 10^{-17}$	$7.6\ 10^{-8}$

APPENDIX 3. ABBREVIATIONS AND GLOSSARY

AEA	Atomic Energy Authority
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BNFL	British Nuclear Fuels plc
BNG	British Nuclear Group
BNGSL	British Nuclear Group Sellafield Ltd
CCFAC	The Codex Committee on Food Additives and Contaminants
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
DRDL	Devonport Royal Dockyard Ltd
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
HMSO	Her Majesty's Staionery Office
HPA	Health Protection Agency
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IC	Imperial College
ICRP	International Commission on Radiological Protection
IRPA	International Radiation Protection Association
LLWR	Low-Level Waste Repository
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
NII	Nuclear Installations Inspectorate
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NRTE	Naval reactor test establishment
OBT	Organically bound tritium
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Convention
PFR	Prototype fast reactor
QNL	Quarterly Notification Level
RIFE	Radioactivity in Food and the Environment
RRMPOL	Rolls Royce Marine Power Operations Ltd

RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
SFL	Springfields Fuels Ltd
SL	Scientifics Ltd
SRP	Society for Radiological Protection
TDS	Total Diet Study
THORP	Thermal Oxide Reprocessing Plant
TNORM	Technologically enhanced Naturally Occurring Radioactive Material
TPP	Tetraphenylphosphonium bromide
TRAMP	Terrestrial Radioactive Monitoring Programme
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
USA	United States of America
VLA	Veterinary Laboratories Agency
WELL	Winfrith Environmental Level Laboratory
WFD	Water Framework Directive
WHO	World Health Organisation
YP	Ystradyfodwg and Pontpridd

Absorbed dose	The ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent to J/kg.
Becquerel	One radioactive transformation per second
Committed effective dose	The sum of the committed equivalent doses for all organs and tissues in the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the Sievert (Sv).
Critical group	Those who receive the largest dose from artificially-produced radionuclides due to their habits, diet and where they spend their time.
Direct shine	Ionising radiation which arises directly from processes or operations on premises using radioactive substances and not as a result of discharges of those substances to the environment
Dose	Shortened form of ‘effective dose’ or ‘absorbed dose’
Dose limits	Maximum permissible dose resulting from ionising radiation from practices covered by the Euratom Basic Safety Standards Directive, excluding medical exposures. It applies to the sum of the relevant doses from external exposures in the specified period and the 50 year committed doses (up to age 70 for children) from intakes in the same period. Currently, the limit has been defined as 1 mSv/y for the UK.
Dose rates	The radiation dose delivered per unit of time.
Effective dose	The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the Sievert (Sv).
Environmental materials	Include freshwater, grass, seawater, seaweed, sediment, soil and various species of plants.
Equivalent dose	The absorbed dose in a tissue or organ weighted for the type and quality of the radiation by a radiation-weighting factor. The unit of equivalent dose is the Sievert (Sv).

External dose	Doses to humans from sources that do not involve ingestion or inhalation of the radionuclides.
Fragments	'Fragments' are considered to be fragments of irradiated fuel, which are up to a few millimetres in diameter.
Indicator materials	Environmental materials may be sampled for the purpose of indicating trends in environmental performance or likely impacts on the foodchain. These include seaweed, soil and grass.
In-growth	Additional activity produced as a result of radioactive decay of parent radionuclides.
Kerma air rate	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.
Radiation exposure	Being exposed to radiation from which a dose can be received
Radiation Weighting Factor	Factor used to weight the tissue or organ absorbed dose to take account of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the disintegration of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
TNORM	Naturally occurring radioactive materials that may have been technologically enhanced in some way. The enhancement has occurred when a naturally occurring radioactive material has its composition, concentration, availability, or proximity to people altered by human activity. The term is usually applied when the naturally occurring radionuclide is present in sufficient quantities or concentrations to require control for purposes of radiological protection of the public or the environment.
Tissue Weighting Factors	Factor used to weight the equivalent dose in a tissue or organ to take account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung = 0.12; bone marrow = 0.12; skin = 0.01.
Total dose	An assessment of dose that takes into account all exposure pathways such as radionuclides in food and the environment and direct radiation.

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 (2004)		1 kg y^{-1} pike
		630 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

Table A4.2. continued

Site	Group[a]	Rates
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
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 (2004)	A	32 kg y^{-1} fish
		3.5 kg y^{-1} crustaceans
		1.7 kg y^{-1} molluscs
		980 h y^{-1} over sediment and shale
	B	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

Table A4.2. continued

Site	Group[a]	Rates
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
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) (2004)	41 kg y^{-1} cod (60%) and other fish (40%)
		25 kg y^{-1} crab (50%), lobster (40%) and *Nephrops* (10%)
		34 kg y^{-1} winkles (50%) and other molluscs (50%)
		1000 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 2000-2004) (2004)	39 kg y^{-1} fish
		12 kg y^{-1} crabs
		6.7 kg y^{-1} lobsters
		3.3 kg y^{-1} Nephrops
		13 kg y^{-1} winkles
		13 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

Table A4.2. continued

Site	Group[a]	Rates
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
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) (NA)	2100 h y^{-1} over mud
		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 (2004)		22 kg y^{-1} fish
		6.5 kg y^{-1} crabs and lobsters
		1.5 kg y^{-1} molluscs
		270 h y^{-1} over sand and stones

[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 and cockles suggested a factor in the range 0.30 to 0.61 and 0.15 to 0.57 respectively, close to the ICRP value of 0.5 (Hunt and Rumney, 2004 and 2005). 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 molluscs 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 (now part of HPA) 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 HPA 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) reviewed dose coefficients for tritium associated with organic material. They gave estimates of uncertainty on central estimates of dose coefficients but did not suggest revision of the current ICRP value for organically-bound tritium. The HPA has recently published a study of the uptake and retention of tritium in rats fed with fish from Cardiff Bay (Hodgson *et al*., 2005). This suggests that an increase in the dose coefficient from the ICRP value of 4.2 10^{-11} Sv Bq^{-1} (adults) (ICRP, 1996a) to 6.0 10^{-11} Sv Bq^{-1} may be warranted in some circumstances. The effect of applying the higher value is considered in the assessment of seafood consumption at the Cardiff site (Section 7).

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 to the public near nuclear sites from all exposure pathways. The approach uses dietary and occupancy data collected from integrated habit surveys carried out around nuclear sites. The habit surveys are targeted at those most likely to be exposed around the site and gathers data on people's occupancy close to each site and local food intake rates. The sites for which integrated habit survey data are currently available are: Aldermaston and Burghfield, Amersham, Cardiff, Devonport, Dounreay, Hartlepool, Hunterston, Sellafield, Winfrith and Wylfa. Further sites will be added in future RIFE reports as new integrated surveys are undertaken.

7.2 Objectives

The Environment Agencies are required to ensure that doses to the public do not exceed 1 mSv/y from all routine man made sources, except certain medical ones. Doses to the public are assessed and compared with the dose limit. For nuclear sites the dose assessment takes into account exposure to radionuclides in food and the environment and direct radiation. The assessment makes use of the monitoring results reported elsewhere in this report.

7.3 Methods and data

The calculation method relies on the application of data from site-specific habits surveys (Camplin *et al*., 2005). This is possible because recent surveys have considered the habits of individuals in an integrated way, i.e. information for each individual has been recorded for all of the pathways of interest. 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. Doses to the public from direct radiation are included in the assessment of total dose using information provided by the HSE who are responsible for assessing dose from direct radiation to the public.

The methodology may be summarised in four steps;

1) Starting with the first pathway, individuals are selected from the habit data based on the 'cut-off' method whereby all those who have habits within a factor of three of the maximum observed for the pathway are selected as members of the potential critical group for that pathway (Hunt *et al*., 1982; Preston *et al*., 1974).

2) Habit profiles for a particular pathway (for example fish consumers) are calculated for adults by averaging the habit data selected by the cut-off method. The profile includes averages of all the other habits identified in the integrated habit survey. Habit profiles for children and infants are derived from the adult profiles using scaling factors.

3) Steps 1) and 2) are repeated for each pathway, thereby deriving a profile for each pathway and a series of potential critical groups.

4) Once all pathway profiles have been determined, doses are calculated for each profile using the environmental and food data. Doses from direct radiation are added to those profiled groups who spend time near to the nuclear site (Stephen, 2005). The group with the highest dose near each site becomes the critical group.

The habit profiles that gave rise to the highest doses in this assessment of RIFE 2004 data are given in Table A7.1. Care should be taken in using these data in other circumstances because the profiles leading to the highest doses may change if the measured or forecast concentrations and dose rates change. Doses are calculated for each potential critical group using the same concentration and dose rate information used in the routine assessments earlier in this report. Pathways related to gaseous discharges, which are not included in the routine monitoring programmes (in particular inhalation and plume shine), were assessed using dispersion modelling made with the PC CREAM assessment code (Mayall *et al*., 1997). 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, 2004

Site	Critical Group[a]	Consumption ($kg\ y^{-1}$, $l\ y^{-1}$), occupancy rate ($h\ y^{-1}$) or direct radiation fraction[b]												
		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	0.13	1.6	0	0	2.5	0	-	0	0	0.9	0	0
Amersham	Local adult inhabitants (0 - 0.25km)	0	1	1.1	0	0	1.6	0.1	-	0	0	0.8	0.3	0
Cardiff	Milk consumers aged 1 y	0	0	0	0	0	1	0.1	-	0	0	7	0	0
Devonport	Local adult inhabitants (0 - 0.25km)	0	1	0	0	0	0	0	-	0	0	0	0	0
Dounreay	Local adult inhabitants (0.5 - 1km)	0.6	1	0	0	3.7	0	0	-	20	0	0	0	0
Hartlepool	Local adult inhabitants (0.5 - 1km)	0	1	0	0	0	0	0	-	0	0	0	0	0
Hunterston	Adult mushroom consumers	0	1	0	0	0	5.7	0	-	0	0	0	0	0
Sellafield	Milk consumers aged 1 y	0	0.37	2.9	0	0	0.8	0	-	0	0	2.8	0	0
Winfrith	Adult green vegetable consumers	0	0.5	5.6	0	0.9	36.7	1.7	10	0	6.7	0	0	0
Wylfa	Local adult inhabitants (0 - 0.25km)	0.3	1	0	0	2.2	0	0	-	0	0	0	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
Amersham	Adult occupants over river bank	0	0	0	0	0	0	0	-	640	0	0	0	0
Cardiff	Adult fish consumers	0.1	0	0	0	24.3	0	0	-	50	0	0	0	0
Devonport	Adult occupants over sediments	0	0	0	0	0	0	0	-	2260	0	0	0	0
Dounreay	Adult occupants over sediment	0	0	0	0	2.7	7.2	0	-	420	0	0	0	0
Hartlepool	Adult occupants over sediment	0.5	0.43	0	0	2.7	0	0	-	910	0	0	0	0
Hunterston	Adult crustacean consumers	22.1	0	0	0.1	29.0	0.3	0.9	-	50	0.6	0.5	0	0
Sellafield	Adult mollusc consumers	6.0	0	0	0	19.4	0	0	360	0	0	0	0	0
Winfrith	Adult fish consumers	4.1	0.2	1.4	0	40.4	3.3	0	-	0	0	0	0	0
Wylfa	Adult occupants over sediment	0.2	0.08	1.5	0	2.1	0.4	0.2	-	300	0	0	0	0
C Combined releases from the site														
Aldermaston and Burghfield	Milk consumers aged 1 y	0	0.13	1.6	0	0	2.5	0	-	0	0	0.9	0	0
Amersham	Local adult inhabitants (0 - 0.25km)	0	1	1.1	0	0	1.6	0.1	-	0	0	0.8	0.3	0
Cardiff	Adult fish consumers	0.1	0	0	0	24.3	0	0	-	50	0	0	0	0
Devonport	Adult occupants over sediments	0	0	0	0	0	0	0	-	2260	0	0	0	0
Dounreay	Local adult inhabitants (0.5 - 1km)	0.6	1	0	0	3.7	0	0	-	20	0	0	0	0
Hartlepool	Local adult inhabitants (0 - 0.25km)	0	1	0	0	0	0	0	-	230	0	0	0	0
Hunterston	Adult mushroom consumers	0	1	0	0	0	5.7	0	-	0	0	0	0	0
Sellafield	Adult mollusc consumers	6.0	0	0	0	19.4	0	0	360	0	0	0	0	0
Winfrith	Adult fish consumers	4.1	0.2	1.4	0	40.4	3.3	0	-	0	0	0	0	0
Wylfa	Local adult inhabitants (0 - 0.25km)	0.3	1	0	0	2.2	0	0	-	0	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)[c]	Plume pathways (0.25-0.5 km)[c]	Plume pathways (0.5-1km)[c]	Vegetables - Green	Vegetables - Other Domestic	Vegetables - Potatoes	Vegetables - RootS
		Consumption (kg y^{-1}, l y^{-1}), occupancy rate (h y^{-1}) or direct radiation fraction[b]												
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	970	1.4	0.5	3.2	2.4
Amersham	Local adult inhabitants (0 - 0.25km)	0	0.5	0	0	0	0	6630	0	0	0.7	3.1	1.7	0.4
Cardiff	Milk consumers aged 1 y	0	0	0.3	225	0	0	0	0	0	1.6	2.8	2.4	6.2
Devonport	Local adult inhabitants (0 - 0.25km)	0	0	0	0	0	0	6720	0	0	0	0	0	0
Dounreay	Local adult inhabitants (0.5 - 1km)	0	0.6	0	0	0	0.1	0	0	7180	0	2.9	16.7	1.1
Hartlepool	Local adult inhabitants (0.5 - 1km)	0	0	0	0	0	0	0	0	2090	0	0	0	0
Hunterston	Adult mushroom consumers	0	0	17.0	0	0	3.8	0	0	8090	39.8	49.6	136.2	106.5
Sellafield	Milk consumers aged 1 y	0	0.2	0.2	338	0	0	1130	850	390	0.2	0	4.8	1.4
Winfrith	Adult green vegetable consumers	13.4	4.6	0.5	64.1	0	0	720	650	1700	30.7	15.7	26.2	11.6
Wylfa	Local adult inhabitants (0 - 0.25km)	0	0	0	0	0	0	7900	0	0	0	0	0	0
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
Amersham	Adult occupants over 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
Devonport	Adult occupants over sediments	0	0	0	0	0	0	0	0	0	0	0	0	0
Dounreay	Adult occupants over sediment	0	0	0	0	0	0	0	0	0	7.4	3.2	15.5	8.1
Hartlepool	Adult occupants over sediment	0	0	0	0	1.7	0.8	80	390	0	0	0	0	0
Hunterston	Adult crustacean consumers	0	0	0.9	0	0.4	0	0	0	0	2.0	1.2	1.4	1.1
Sellafield	Adult mollusc consumers	0	0	0	0	33.9	0	0	0	0	0	0	0	0
Winfrith	Adult fish consumers	0	0	0	0	0.3	0	0	1650	0	2.6	11.4	3.6	12.6
Wylfa	Adult occupants over sediment	0	0.1	0.5	0	0.1	0.1	0	0	0	0	0.1	0	0
C Combined releases from the site														
Aldermaston and Burghfield	Milk consumers aged 1 y	0	0	0	302.9	0	0	0	0	970	1.4	0.5	3.2	2.4
Amersham	Local adult inhabitants (0 - 0.25km)	0	0.5	0	0	0	0	6630	0	0	0.7	3.1	1.7	0.4
Cardiff	Adult fish consumers	0	0	0	0	0	0	0	0	0	1.1	3.7	4.7	3.8
Devonport	Adult occupants over sediments	0	0	0	0	0	0	0	0	0	0	0	0	0
Dounreay	Local adult inhabitants (0.5 - 1km)	0	0.6	0	0	0	0.1	0	0	7180	0	2.9	16.7	1.1
Hartlepool	Local adult inhabitants (0 - 0.25km)	0	0	0	0	3.8	1.9	1300	0	0	0	0	0	0
Hunterston	Adult mushroom consumers	0	0	17.0	0	0	3.8	0	0	8090	39.8	49.6	136.2	106.5
Sellafield	Adult mollusc consumers	0	0	0	0	33.9	0	0	0	0	0	0	0	0
Winfrith	Adult fish consumers	0	0	0	0	0.3	0	0	1650	0	2.6	11.4	3.6	12.6
Wylfa	Local adult inhabitants (0 - 0.25km)	0	0	0	0	0	0	7900	0	0	0	0	0	0

[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] *For direct radiation, the fraction is a representation of proportion of the critical group who are subject to the estimated direct radiation dose, and not their occupancy, whereas the occupancies quoted are the estimates of the average occupancy of the critical group who are subjected to plume pathway exposures*

[c] *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 2004 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 or local adult inhabitants. Direct radiation was important at Amersham, Dounreay, Hartlepool, Hunterston and Wylfa. However it should be noted that the direct radiation dose estimates were ‘less than’ values for some sites. The highest dose was at Amersham and was due to direct radiation.

The most important groups for liquid discharges were adult seafood consumers or occupants over contaminated substrates. The highest dose was at Sellafield though 60% was 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, 2004

Site	Critical group[a]	Exposure, mSv	
		Total	Dominant contributions[b]
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Milk consumers aged 1 y	<0.005	Milk, ^{137}Cs
Amersham	Local adult inhabitants (0 - 0.25km)	0.24	Direct radiation
Cardiff	Milk consumers aged 1 y	0.009	Milk, ^{14}C, ^{32}P, ^{137}Cs
Devonport	Local adult inhabitants (0 - 0.25km)	<0.005	Plume related pathways
Dounreay	Local adult inhabitants (0.5 - 1km)	0.011	Direct radiation
Hartlepool	Local adult inhabitants (0.5 - 1km)	0.020	Direct radiation
Hunterston	Adult mushroom consumers	0.10	Direct radation
Sellafield	Milk consumers aged 1 y	0.024	Milk, ^{90}Sr, ^{137}Cs, ^{129}I
Winfrith	Adult green vegetable consumers	<0.005	Domestic fruit, milk, green vegetables, honey, ^{14}C, ^{137}Cs
Wylfa	Local adult inhabitants (0 - 0.25km)	0.011	Direct radiation
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants of river bank	<0.005	External dose rate from river bank
Amersham	Adult occupants over river bank	<0.005	Gamma dose rate over sediment
Cardiff	Adult fish consumers	0.012	Fish, ^{3}H
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult occupants over sediment	0.008	Gamma dose rate over sediment
Hartlepool	Adult occupants over sediment	0.010	Direct radiation
Hunterston	Adult crustacean consumers	<0.005	Crustaceans, fish, ^{99}Tc, ^{137}Cs, ^{241}Am
Sellafield	Adult mollusc consumers	0.60[b]	Crustaceans, molluscs, ^{210}Po, ^{241}Am
Winfrith	Adult fish consumers	<0.005	Fish, ^{14}C, ^{137}Cs, ^{241}Am
Wylfa	Adult occupants over sediment	<0.005	Direct radiation, gamma dose rate over sediment
C Combined releases from the site			
Aldermaston and Burghfield	Milk consumers aged 1 y	<0.005	Milk, ^{137}Cs
Amersham	Local adult inhabitants (0 - 0.25km)	0.24	Direct radiation
Cardiff	Adult fish consumers	0.012	Fish, ^{3}H
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Local adult inhabitants (0.5 - 1km)	0.011	Direct radiation
Hartlepool	Local adult inhabitants (0 - 0.25km)	0.021	Direct radiation
Hunterston	Adult mushroom consumers	0.10	Direct radiation
Sellafield	Adult mollusc consumers	0.60[c]	Crustaceans, molluscs, ^{210}Po, ^{241}Am
Winfrith	Adult fish consumers	<0.005	Fish, ^{14}C, ^{137}Cs, ^{241}Am
Wylfa	Local adult inhabitants (0 - 0.25km)	0.011	Direct radiation

[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] Pathways and radionuclides that contribute more than 10% of the total dose. Some radionuclides are reported as being at the limits of detection
[c] The doses from man-made and natural radionuclides were 0.23 and 0.37 mSv respectively. The source of natural radionuclides was a chemical works near Sellafield at Whitehaven