RIFE - 8

Radioactivity in Food and the Environment, 2002

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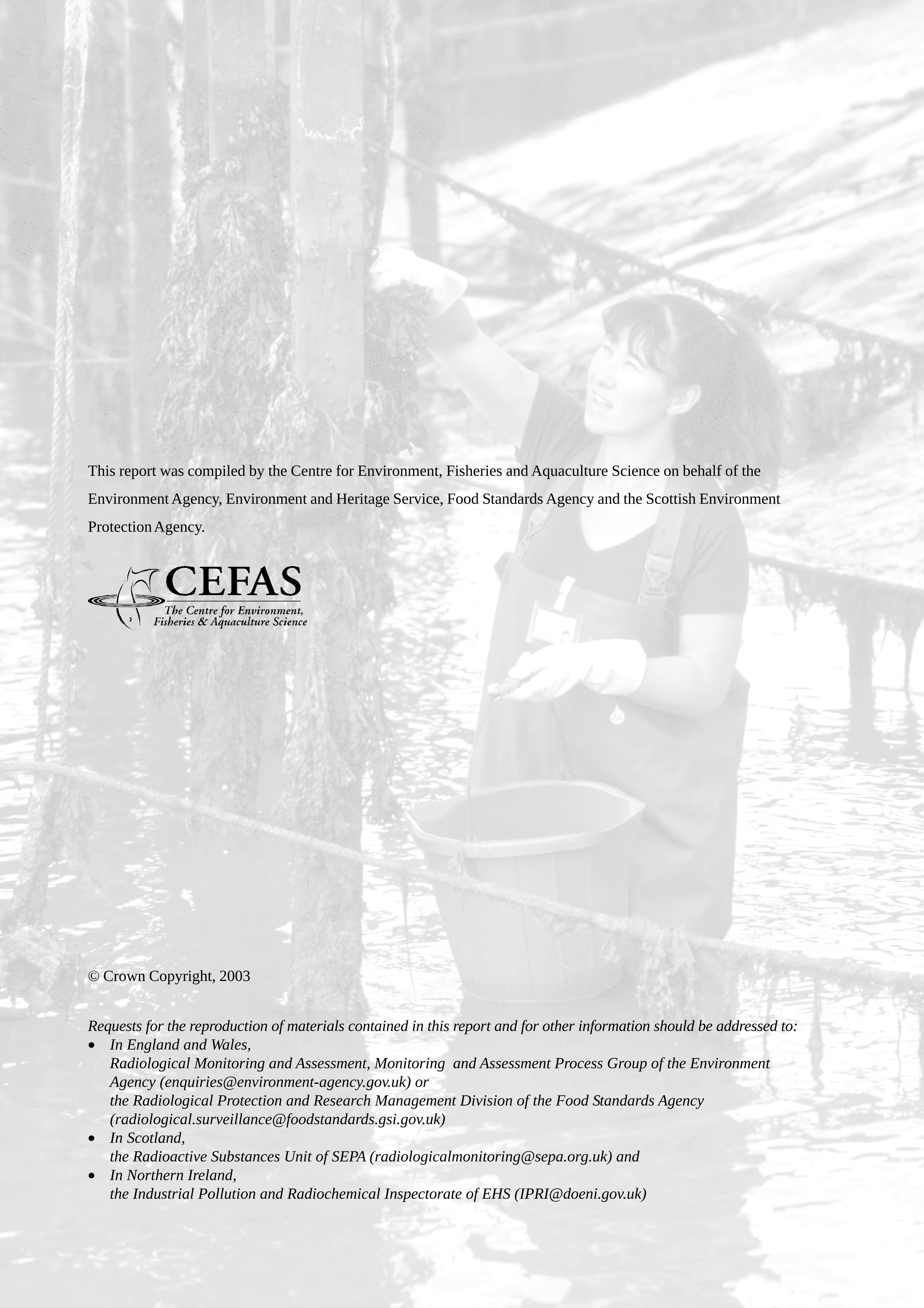
October 2003



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

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

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- *In Northern Ireland,*
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FOREWORD

We are pleased to present the 8th annual Radioactivity in Food and the Environment (RIFE) report, which contains radiological monitoring data for 2002. This report is a major step forward in the reporting of radiological monitoring. For the first time, the RIFE report contains data from monitoring of food and the environment throughout the UK.

This work is a collaboration among four Agencies: the Food Standards Agency, the Scottish Environment Protection Agency, the Environment Agency and the Environment and Heritage Service of Northern Ireland. The collaboration enables the Agencies to present a better assessment of the overall impact of radioactive discharges on food safety and the environment. The partnership also shows the commitment of the Agencies to provide a comprehensive report of monitoring data and their intention to work closely together to ensure protection of the public. The report shows that in 2002 radiation doses to the public resulting from radioactive discharges to the environment were well below national and international limits in all parts of the UK.

An essential part of assessing the impact of radiological discharges is the estimation of dose to the public. We are pleased to note that significant progress is being made on an improved method of calculating doses. The improved methodology takes account of all public exposure routes in a realistic way, leading to an improved and more reliable assessment of dose to the public from discharges to the environment. The development of this new method is being overseen by a national body, the National Dose Assessment Working Group, whose membership includes consumer representatives, officials from the Agencies, Government and the nuclear industry. We look forward to presenting assessments of doses to the public using the new method in future editions of RIFE.

We hope you will find this new format of report comprehensive and informative and we would like to take this opportunity to thank you for interest in the work of our Agencies.

John Harman

Sir John Harman
Chairman, Environment Agency

K Ledgerwood

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

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EXECUTIVE SUMMARY

Radiation Safety – Food and the Environment at Nuclear Sites

This report contains the results of radiological monitoring of food and the environment throughout the United Kingdom, the Channel Islands and the Isle of Man. The primary purpose of the monitoring programmes is to provide an independent check on the effects of discharges made by users of radioactive materials in the United Kingdom, and to ensure that any radioactivity present in food and the environment does not compromise public health. For the first time, it represents a comprehensive summary of results across the United Kingdom from programmes sponsored by the Environment Agency, the Environment and Heritage Service, the Food Standards Agency and the Scottish Environment Protection Agency.

The results of these monitoring programmes demonstrate that in 2002 even the most exposed members of the public received radiation doses from food and other pathways that were below the statutory United Kingdom annual dose limit to members of the public of 1 mSv (millisievert), European Union limits and Government targets. Assessed doses at all major sites in the United Kingdom are shown in Figure S and are detailed in the Summary Table.

The highest radiation doses were received by a group of high-rate consumers of fish and shellfish in Cumbria. The doses received by these consumers are a combination of contributions from liquid discharges from both Sellafield and from radioactivity in the environment as a result of past discharges from the Rhodia Consumer Specialties Ltd. (formerly Albright and Wilson) plant at Whitehaven. The dose to these high-rate consumers (including external doses) from Sellafield discharges was estimated to be 0.19 mSv in 2002 compared with 0.15 mSv in 2001. Concentrations in food and dose rates were largely unchanged in 2002 though there were some small increases in concentrations of tritium, carbon-14 and technetium-99 in seafood. The main reason for the increase in dose was an increase in the amount of seafood eaten. This group also received an estimated dose of 0.42 mSv from enhanced levels of natural radioactivity due to the legacy of past operations at the Rhodia Consumer Specialties Ltd. works at Whitehaven. Operations at this site ceased at the end of 2001 and the plant will be demolished in 2003. By definition, other groups will have received lower doses.

In terms of radiation exposure, the next most important group was people living in houseboats in the Ribble estuary in Lancashire. Their dose was from external radiation and was 0.12 mSv in 2002, similar to 0.14 mSv in 2001. The main source of their exposure was radioactive contamination in estuary mud arising from past Sellafield discharges. The highest exposures in Scotland were to the group of terrestrial food consumers around Chapelcross who received an annual dose of 0.055 mSv as a result of gaseous discharges including a component due to inhalation. The second highest exposure was wholly attributable to Sellafield. It relates to a group of consumers of seafood, spending time over inter-tidal areas, who were estimated to receive annual doses of 0.045 mSv. In 2001, this group was estimated to have received a similar dose of 0.040 mSv.

Doses due to gaseous discharges from Sellafield were 0.038 mSv, similar to the dose in 2001 of 0.037 mSv. The assessment included the consumption of milk, vegetables, fruit and meat and external exposure from gaseous discharges. The contribution from gaseous discharges of argon-41 reduced by about a factor of five in line with operations at Calder Hall. Most of the seafood and external exposure that can be attributed to Sellafield was from historic discharges. Recent and current discharges of technetium-99 contributed 0.030 mSv, which is around 15% of the dose to the Sellafield seafood consumers.

The next most significant site was Dungeness where gaseous discharges from the two power stations resulted in exposure of 0.12 mSv in 2002, mostly from argon-41 in external radiation pathways. At Heysham, high-rate seafood consumers were estimated to receive 0.066 mSv but most of this was attributable to Sellafield discharges. Gaseous discharges from Chapelcross and Sizewell 'A' power stations gave similar doses, about 0.054 mSv. High concentrations of tritium have been found in food and the environment near Cardiff where radiochemicals for research, medicine and industry are produced. However, doses to high-rate seafood consumers were estimated to be relatively low at 0.031 mSv in 2002, similar to 0.036 mSv in 2001. Most of the dose was due to tritium and carbon-14 in fish from the Bristol Channel.

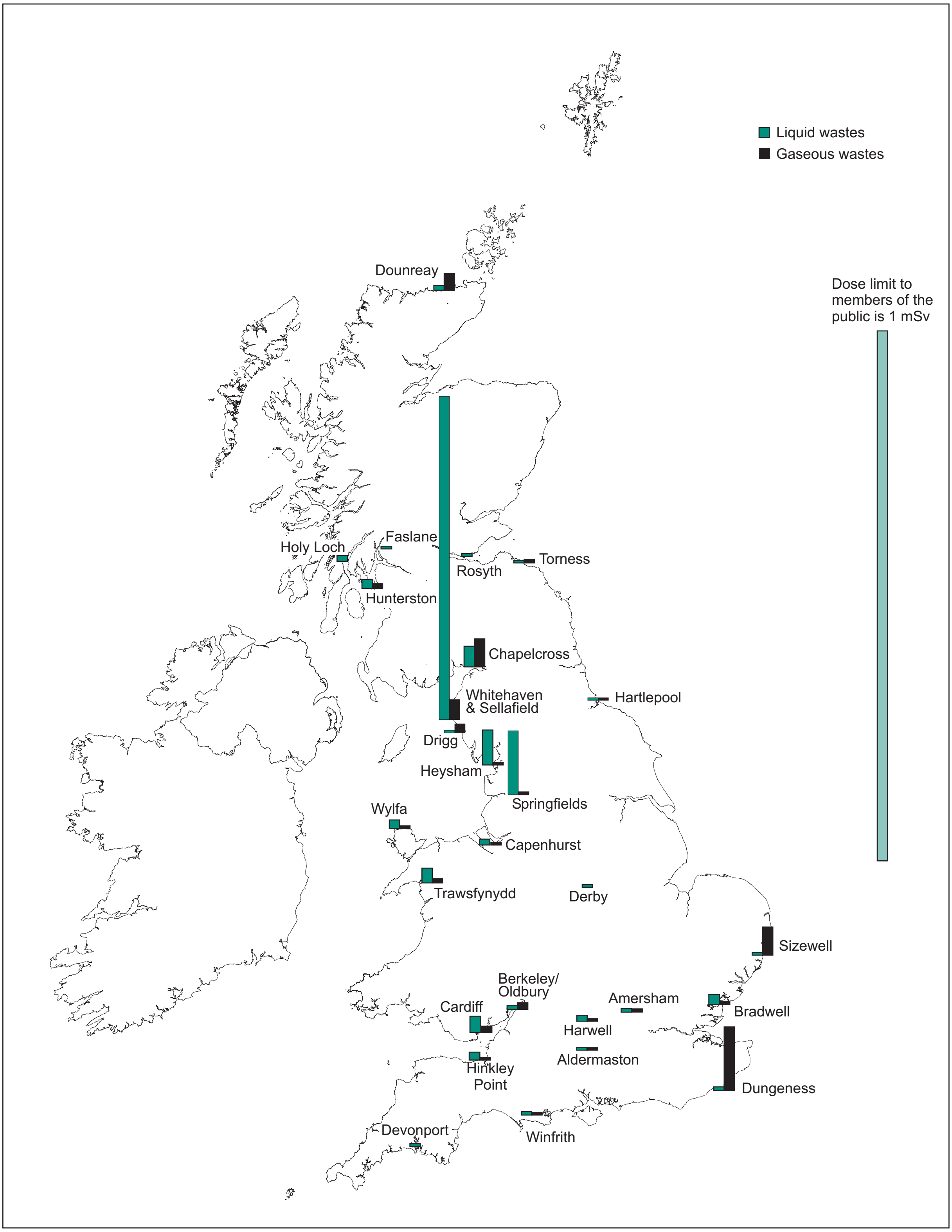

Figure S. ***Radiation exposures in the UK due to radioactive waste discharges, 2002 (Exposures at Whitehaven and Sellafield are mostly due to the legacy of enhanced natural radioactivity from the non-nuclear industry)***

Summary Table: Radiation doses due to discharges of radioactive waste in the United Kingdom, 2002

Establishment	Radiation exposure pathways	Exposure, mSv[b]	Contributors[c]
British Nuclear Fuels plc			
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (1998-2002 habits)[k]	0.19	$^{239/240}Pu$ ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (1998-2002 habits)[l]	0.61	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2002 habits)	0.24	$^{239/240}Pu$ ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	0.038	^{90}Sr ^{106}Ru
	Terrestrial foods at Ravenglass	0.020	^{60}Co ^{106}Ru
	External in intertidal areas (Ravenglass)[a]	0.038	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)[a]	0.12	Ext ^{241}Am
	External (skin) to anglers	0.22[f]	Beta
	Handling of fishing gear	0.15[f]	Beta
	Porphyra/laverbread consumption in South Wales	<0.005	^{106}Ru ^{241}Am
	Trout consumption at Sellafield	0.005	^{137}Cs ^{241}Am
	Seaweed/crops at Sellafield	0.007	^{99}Tc ^{241}Am
Drigg	Terrestrial foods[i]	0.017	^{90}Sr ^{106}Ru
	Drinking water[n]	<0.005	^{210}Po ^{241}Pu
Springfields	External (skin) to fishermen	0.37[f]	Beta
	Fish and shellfish consumption	0.017	^{137}Cs ^{241}Am
	Terrestrial foods	<0.005[h]	^{129}I ^{232}Th
	External in intertidal areas (children playing)[g,a]	<0.005	Ext ^{234}Th
	Occupancy of houseboats[a]	0.12	Ext ^{241}Am
	External in intertidal areas (anglers)	0.015	Ext
Capenhurst	Inadvertent ingestion of water and sediment and external[g]	0.011	Ext ^{241}Am
	Terrestrial foods[i]	<0.005	^{3}H U
Chapelcross	Fish and shellfish consumption and external in intertidal areas	0.039	Ext ^{241}Am
	Terrestrial foods, external and inhalation	0.055	^{41}Ar ^{137}Cs
United Kingdom Atomic Energy Authority			
Dounreay	Fish and shellfish consumption	<0.005	^{90}Sr ^{241}Am
	External in intertidal areas	0.009	Ext
	Terrestrial foods[g]	0.032	^{129}I ^{241}Am
Harwell	Fish consumption and external to anglers	0.011	Ext ^{241}Am
	Terrestrial foods[i]	<0.005	^{3}H
Winfrith	Fish and shellfish consumption and external in intertidal areas	0.007	Ext ^{241}Am
	Terrestrial foods	<0.005	^{14}C ^{137}Cs
Culham	Drinking water[n]	<0.005	^{3}H
Electricity Companies[d]			
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	0.008	Ext ^{3}H
	Terrestrial foods, external and inhalation near site	0.013	^{14}C ^{41}Ar
Bradwell	Fish and shellfish consumption and external in intertidal areas	0.019	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	0.006	^{14}C ^{41}Ar
Dungeness	Fish and shellfish consumption and external in intertidal areas	0.007	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site	0.12	^{14}C ^{41}Ar
Hartlepool	Fish and shellfish consumption and external in intertidal areas	<0.005	^{14}C ^{241}Am
	Terrestrial foods[i]	<0.005	^{14}C ^{35}S
Heysham	Fish and shellfish consumption and external in intertidal areas	0.066	Ext ^{241}Am
	Terrestrial foods[i]	<0.005	^{14}C ^{35}S
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	0.015	Ext ^{3}H
	Terrestrial foods[i]	0.005	^{14}C ^{137}Cs
Hunterston	Fish and shellfish consumption	0.005	^{99}Tc ^{137}Cs
	External in intertidal areas	0.017	Ext
	Terrestrial foods[i]	0.009	^{35}S ^{90}Sr

Summary Table: continued

Establishment	Radiation exposure pathways	Exposure, mSv[b]	Contributors[c]
Electricity Companies *continued*			
Sizewell	Fish and shellfish consumption and external in intertidal areas	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site	0.053	^{14}C ^{41}Ar
Torness	Fish and shellfish consumption and external in intertidal areas	0.005	Ext ^{241}Am
	Terrestrial foods[i]	0.007	^{35}S ^{90}Sr
Trawsfynydd	Fish consumption and external in intertidal areas	0.028	Ext ^{137}Cs
	Terrestrial foods[i]	0.008	^{14}C ^{90}Sr
Wylfa	Fish and shellfish consumption and external in intertidal areas	0.016	Ext ^{241}Am
	Terrestrial foods[i]	<0.005	^{14}C ^{35}S
Defence Establishments			
Aldermaston	Fish consumption and external to anglers	<0.005	Ext ^{137}Cs
	Terrestrial foods[i]	<0.005[h]	^{137}Cs U
Derby	Drinking water[n]	<0.005	^{60}Co
Devonport	Fish and shellfish consumption and external in intertidal areas	<0.005	Ext ^{241}Am
Faslane	Fish and shellfish consumption and external in intertidal areas	<0.005	Ext ^{137}Cs
Holy Loch	External in intertidal areas	0.011	Ext
Rosyth	External in intertidal areas	<0.005	Ext
Amersham plc			
Amersham	Fish consumption and external to anglers	0.007	Ext ^{241}Am
	Terrestrial foods[i]	0.006	^{35}S ^{75}Se
Cardiff	Fish and shellfish consumption and external in intertidal areas	0.031	Ext ^{3}H
	Terrestrial foods and inhalation near site[i]	0.013	^{3}H ^{14}C
	Inadvertent ingestion (River Taff)	<0.005	^{125}I ^{137}Cs
Rhodia Consumer Specialties Ltd			
Whitehaven	Fish and shellfish consumption[j]	0.42	^{210}Po ^{210}Pb
	Fish and shellfish consumption[m]	0.61	^{210}Po ^{241}Am

a *Includes a component due to inadvertent ingestion of water or sediment or inhalation of resuspended sediment where appropriate*
b *Unless otherwise stated represents committed effective dose calculated using methodology of ICRP-60 to be compared with the dose limit of 1 mSv (see section 3). Exposures due to marine pathways include the far-field effects of discharges of liquid waste from Sellafield. Unless stated otherwise, the critical group is represented by adults*
c *The top two contributors to the dose; either 'ext' to represent the whole body external exposure from beta or gamma radiation, 'beta' for beta radiation of skin or a radionuclide name to represent a contribution from internal exposure. Some contributions from radionuclides to internal exposure are based on concentration data at limits of detection*
d *Power stations are operated by Magnox Electric (a wholly owned subsidiary of BNFL plc), British Energy Generation Ltd. or British Energy Generation (UK) Ltd.*
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 3)*
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*

Radioactivity levels in samples collected around nuclear sites

No major changes in radioactive contamination of food, indicator materials or external dose rates were observed in 2002. Levels of technetium-99 in lobsters from the vicinity of Sellafield showed an increase over levels in 2001. However, the assessed dose to the group of seafood consumers from technetium-99 discharges was 0.030 mSv, which is 3% of the of 1 mSv dose limit for members of the public. Sea-to-land transfer of technetium-99 occurred on a small scale via the harvesting of seaweed for use as a soil conditioner and fertiliser but there was no evidence for significant transfers of technetium-99 through animals feeding on seaweed. Technetium-99 from Sellafield can be detected in the Irish Sea, in Scottish waters and the North Sea. Reductions in discharges of technetium will take place around 2006 or earlier if abatement technology can be introduced.

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

Concentrations of tritium associated with organic material in seafood near Cardiff remained at levels in excess of 10,000 Bq kg^{-1} (fresh weight) though some reductions were observed compared with 2001. Tritium concentrations in freshwater fish in the Thames river catchment and in seafood at various coastal locations around the UK were above an expected background tritium concentration of 1 Bq kg^{-1}. However, the degree of bioaccumulation was relatively minor.

Site incidents and non-routine surveys

During 2002, further radioactive fragments* were recovered near Dounreay. Five radioactive fragments were recovered from Sandside Bay, five from the site foreshore and 342 from the seabed near to the Dounreay site. The Dounreay Advisory Group published a detailed assessment of the situation. The fishing restrictions under the Food and Environment Protection Act 1985 (United Kingdom-Parliament, 1985) are still in force.

There were no site incidents which required off site monitoring in 2002.

An aerial survey of the Cumbrian Coastline was carried out by helicopter. Enhanced levels of natural radionuclides were identified at a few locations. More detailed sampling and survey work was carried out at three of these locations. The enhancement was found to be associated with a landfill site, a quarry and a patch of sand close to low water mark.

Surveys of consumption and occupancy by members of the public near nuclear sites at Sellafield, Aldermaston, Drigg and Hartlepool and on the Dumfries and Galloway coast were completed. The results were used to improve radiological assessments of the monitoring programmes in 2002.

Radiation doses and levels at other locations in the UK

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

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

* *Fragments are mainly fragments of irradiated nuclear fuel up to a size of a few mm in diameter*

As mentioned above there was evidence that concentrations of natural radionuclides in fish and shellfish near the (now closed) Whitehaven Works (Rhodia Consumer Specialties Ltd.) continued to be enhanced above normal levels. The dose to high-rate seafood consumers, including the effects of artificial radionuclide discharges from the Sellafield site nearby, was estimated to be 0.61 mSv for the critical group. The contributions from artificial and enhanced natural radionuclides were 0.19 and 0.42 mSv, respectively.

The programme of monitoring the effects of discharging wastes at other non-nuclear industrial sites continued. The sites included a sewage works, chemical and pharmaceutical manufacturers, a research facility and a defence equipment repair operation. There was no evidence for enhancement of radionuclides in the environmental samples tested near the sites that were studied in relation to gaseous wastes. In relation to liquid wastes, small increases in levels in pike were observed at the sewage works.

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

A small programme of monitoring of the effects of the Chernobyl accident continued in 2002. Restrictions on the movement, sale and slaughter of sheep remain in some upland areas of the United Kingdom.

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

The monitoring programmes

These monitoring programmes involved the collaboration of six specialist laboratories, each with rigorous quality assurance audits, and a wide range of sample collectors throughout the United Kingdom. They were organised independently of the industries discharging wastes by the Environment Agency, the Environment and Heritage Service, the Food Standards Agency, Scottish Environment Protection Agency and Centre for Environment, Fisheries and Aquaculture Science. The programmes include monitoring undertaken on behalf of the Scottish Executive, Channel Island States, the Department for Environment, Food and Rural Affairs, the Manx Government and the Wales Assembly Government.

In 2002, over 2600 food samples and over 1600 other samples were collected to determine levels of radioactivity in the environment. Over 21,800 analyses or dose rate measurements were completed. The programmes returned to full capacity after reductions as a result of the Foot and Mouth outbreak in 2001.

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

Research

The routine monitoring programmes were supported by a number of surveys investigating specific issues including radioactivity in cranberry products and technetium-99 in farmed salmon. Results of these surveys are reported in Section 12. The Agencies are also jointly funding work to improve the methodology for estimating public exposure including site-specific surveys of consumers' dietary habits and way of life.

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

1. INTRODUCTION

1.1 Background

This report contains the results of the radiological monitoring of food, indicator materials and dose rates in 2002 throughout the United Kingdom (UK), the Channel Islands and the Isle of Man. The report is published jointly by the Environment Agency, the Environment and Heritage Service (EHS), the Food Standards Agency and the Scottish Environment Protection Agency (SEPA).

The data in this report cover the calendar year of 2002. This is the first report in the Radioactivity in Food and the Environment (RIFE) series to include a complete coverage of programmes operated by the Environment Agency in England and Wales and the EHS in Northern Ireland. Previously the results were published separately (Environment Agency, 2002a and Environment and Heritage Service, 2002). 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 Wales Assembly Government, the Manx Government and the Channel Island States.

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

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

Where appropriate, the monitoring data for nuclear sites are supplemented by results from other projects related to the behaviour of radioactivity in the environment. The most recent summary of the scope of all radioactivity monitoring programmes as undertaken by nuclear site operators and local and central government can be found in 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 2002 are first addressed in Section 1.2. Before the results of monitoring are presented, an explanatory section gives details of methods of sampling, analysis and presentation and explains how results are interpreted in terms of public radiation exposures. In general the doses reported around each nuclear establishment are for the critical group, which receives the greatest dose from artificially produced radionuclides. The estimates exclude natural background [see Section 3.6.5 and Appendix 6] and direct radiation from nuclear facilities, which is the regulatory

* *The Environment Protection Group of DETR became part of DEFRA after June 2001*

responsibility of the Health and Safety Executive (HSE). The doses are compared with the annual limit of 1 mSv applicable for controlled releases of radioactivity from artificial sources [see Section 3.5] and would be in addition to the average UK dose of approximately 2.2 mSv received by the general public due to natural radiation (Hughes, 1999). Dose limits are based on recommendations made by the International Commission on Radiological Protection (ICRP), and embodied in European Union (EU) and UK law.

A glossary of abbreviations is provided in Appendix 3.

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from nuclear sites

Discharges of radioactive wastes as liquid or gases are made from the main nuclear sites in the UK. In addition, solid low-level wastes from nuclear sites are transferred to Drigg for disposal. These discharges and disposals are authorised by the environment agencies in the UK under the Radioactive Substances Act 1993 (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 2002 from the nuclear sites and disposals at Drigg and Dounreay are included in Appendix 1. The Environment Agency also publishes the discharge information for England and Wales on its web site as a pollution inventory.

The sites that are the principal sources of waste containing man-made radionuclides are shown in Figure 1.1. The programmes include monitoring at each of these sites. For completeness, it should be noted that discharges of radioactive waste from other sites such as hospitals, industrial sites and research establishments are also authorised under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993) but are not subject to the Nuclear Installations Act 1965 (United Kingdom - Parliament, 1965). Occasionally, the presence of radioactivity in the environment resulting from such discharges is detected within this programme. For example, iodine-131 originating from hospitals is detected in some marine samples. Small amounts of very low-level solid waste are also disposed of in specified landfill sites. As noted in Figure S and the Summary Table, there is a significant impact due to the legacy of past discharges of naturally-occurring radionuclides from the non-nuclear site at Whitehaven although discharges from non-nuclear sites are considered insignificant in general 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 recently 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 2002. The tables also list the discharge and disposal limits that are authorised or, in the case of the Ministry of Defence, administratively agreed. In some cases, the authorisations specify limits in greater detail than can be summarised in a single table: in particular, periods shorter than one year are specified at some sites. The authorised limits are usually significantly lower than discharge levels that would result in a dose equal to the dose limit. The percentages of the authorised (or agreed) limits taken up in 2002 are also stated in the tables.

Where changes in the rates of discharge in 2002 have affected the levels of radioactivity in the environment, this is addressed in the relevant part of the subsequent sections.

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”

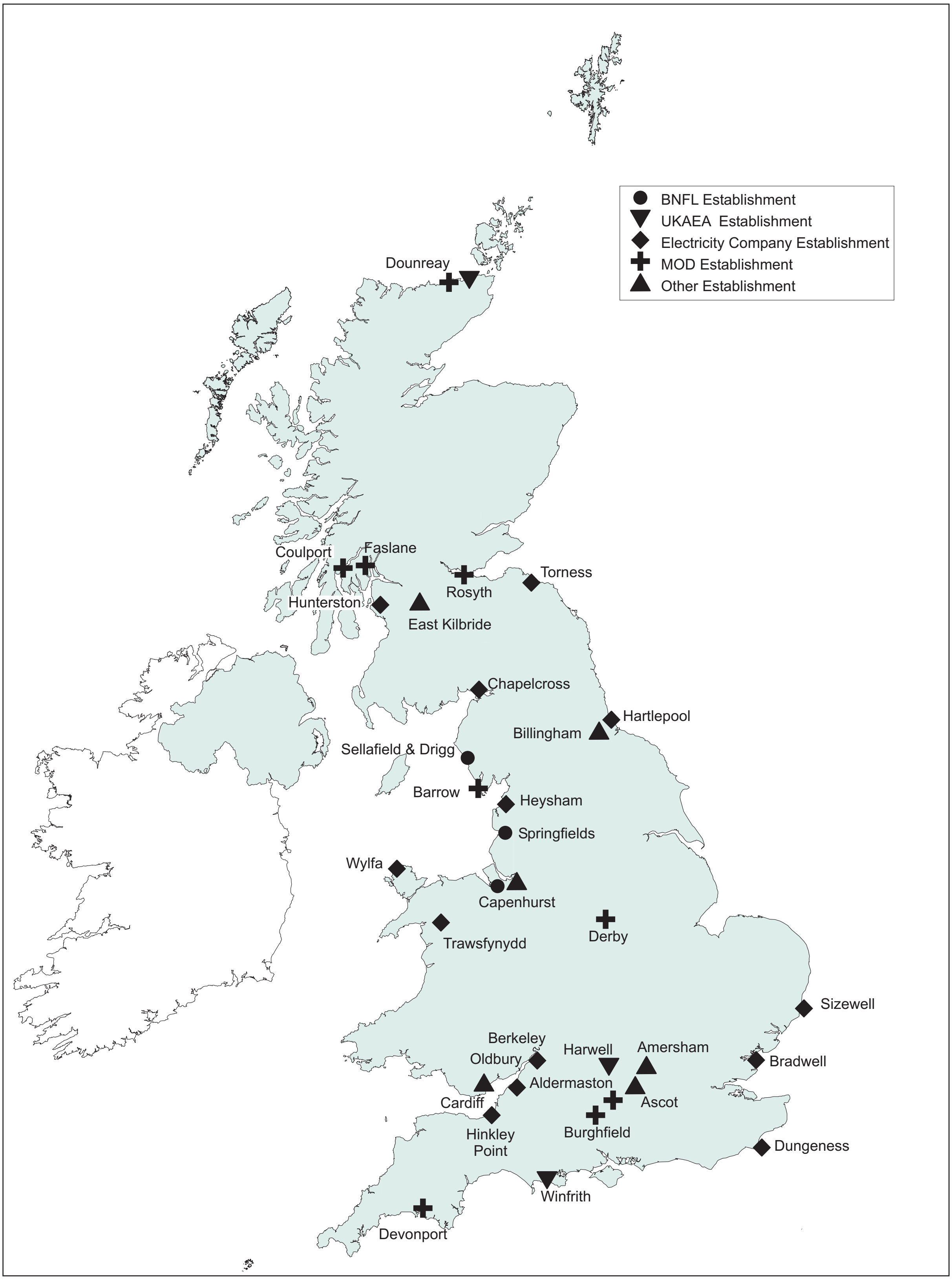

Figure 1.1 Principal sources of radioactive waste disposal in the UK

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 Assembley for Wales and Scottish Executive, 2002a). This provides a description of how the UK will implement the agreements reached at the 1998 and subsequent meetings of OSPAR (the Oslo and Paris Convention). The aims of the strategy relate to liquid wastes and not to gaseous or solid wastes. They are:

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

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

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

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

1.2.2 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 is 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 2002 are presented in Section 11.2. They confirm that the radiological impact of these disposals was insignificant.

In England and Wales, Defra issues licences to operators for the disposal of dredge material under the Food and Environment Protection Act, 1985 (United Kingdom - Parliament, 1985). The protection of the marine environment is considered before a licence is issued. Since dredge material will contain radioactivity from natural and man-made sources at varying concentrations, assessments are undertaken when appropriate for assurance that there is no significant foodchain or other risk from the disposal. In 2002, a specific assessment of the disposal of dredge material from the Heysham Approaches was carried out. The Approaches contain artificial radionuclides due to discharges from BNFL Sellafield and the nearby Heysham nuclear power station and from other widespread sources such as weapon test fallout. Samples of the material were taken and analysed and the results are given in Appendix 7. The assessment showed that the impact of the radioactivity associated with the disposal operation was very low, below 'de minimis'* levels of exposure. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 1999a).

1.2.3 Other sources of radioactivity

There are several other possible sources of radioactivity that may affect the marine food chain and the environment. These include disposals of material from offshore installations, transport incidents, satellite re-entry, releases from overseas installations and the operation of nuclear powered submarines. Submarine berths in the UK are monitored by the Ministry of Defence (DSTL, 2003). General monitoring of the British Isles is undertaken as part of the programmes described in this report. This would detect any gross effects from the sources above. No such effects were found in 2002. Low levels of radionuclides were detected in the marine environment around the Channel Islands (Section 11.2) and these may be partly due to discharges from the nuclear fuel reprocessing plant at Cap de la Hague.

1.2.4 Food irradiation

Irradiated food is food that has been exposed to radiation. It is not contaminated with radioactivity and for this reason it is not considered in detail in this report. The process has been permitted in the UK for over 10 years, and UK legislation has been amended to implement two European Directives on food irradiation (Directives 1999/2/EC and 1999/3/EC).

Food irradiation is a processing technique where food is exposed to ionising radiation in a controlled manner. The ionising radiation is either generated by machine, as is the case for electron beams or x-rays, or produced by the radioactive decay of caesium-137 or cobalt-60 (both unstable isotopes that produce gamma radiation).

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

In all there are 19 facilities that are approved to irradiate food, 15 are in Member States of the European Union, 3 are in South Africa and 1 is in Hungary. One facility in England is licensed to irradiate a range of dried herbs and spices and is inspected regularly by the Food Standards Agency.

Although few foods are irradiated in the UK, there is an increased interest in the technique in other countries, particularly in the USA. A Food Standards Agency survey identified a surprisingly high proportion of dietary supplements as irradiated and in breach of legislation (Food Standards Agency, 2002a). There were no 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".

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* *'De minimis' relates to doses of the order of 0.010 mSv or less (IAEA, 1999a)*

2. SAMPLING AND MEASUREMENT

2.1 Sampling programme

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

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

Sampling is focused on nuclear sites licensed by the HSE under the Nuclear Installations Act, 1965 (United Kingdom - Parliament, 1965). 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 spread of levels across the UK. Levels in the environment can be affected by disposals of radioactive waste from nuclear sites abroad and show the legacy of atmospheric fallout from past nuclear weapons testing and the nuclear reactor accident in 1986 at Chernobyl in the Ukraine.

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

1. Nuclear sites
2. Other industrial and landfill sites
3. Chernobyl
4. Regional monitoring

The scope of the programme in each sector is summarised in Table 2.1 and described in the following Section.

2.1.1 Nuclear sites

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

The frequency and type of measurement and the materials sampled vary from site to site. 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 levels 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.

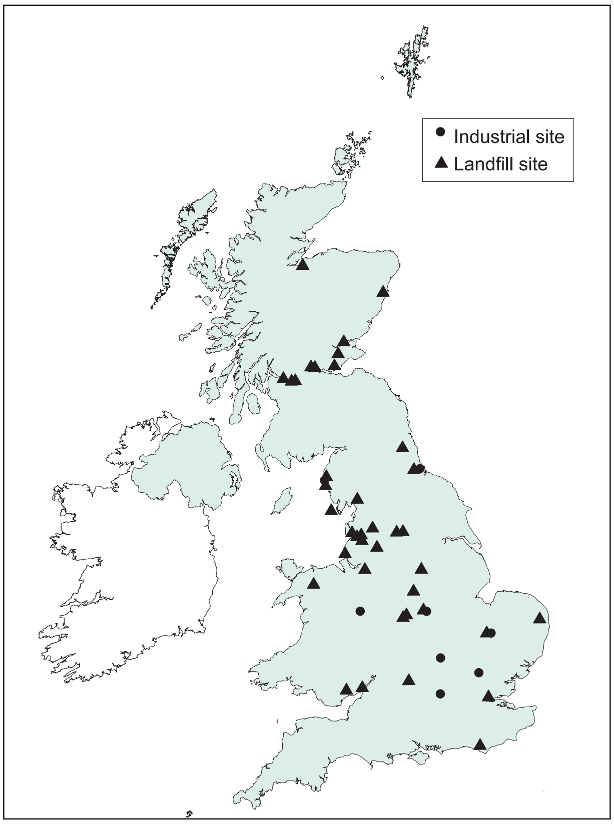

Figure 2.1 Industrial and landfill sites monitored in 2002

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. In the aquatic environment, the pathways that are the most relevant are the ingestion of seafood and freshwater fish, drinking water and external exposure from contaminated materials. In the terrestrial environment, they are 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.

The description of the work undertaken can be conveniently divided into two broad categories: aquatic and terrestrial. The first deals with contamination in or near the sea, rivers and lakes and acts as a check on disposals of liquid wastes. The second deals with contamination on land, which is dominated by gaseous disposals to the atmosphere.

The aquatic programme

The general scope of the aquatic programme in 2002 is summarised in Table 2.2. A wide range of seafood and indicator materials (see below) and direct measurements of external dose rates were taken in areas of known or suspected contamination and where public occupation occurs or is likely to occur. The frequency of measurement depends on the level of environmental impact from the source under scrutiny, with the intervals between measurements varying between one week and one year.

The types of material sampled and the locations from which samples are taken are chosen to be representative of existing exposure pathways. Knowledge of such pathways is gained from local habits surveys and other sources. As a consequence the programme varies from site to site and from year to year, according to local circumstances.

Indicator materials, such as seawater, river water, soil, tide-washed pasture, sediments, sea coal, sewage sludge and seaweeds are sampled to provide information on trends in contamination levels in the environment. These materials can concentrate particular radionuclides and offer a cost-effective means of determining levels of activity in the environment. Surface water samples are taken to investigate the drinking water pathway. In the case of sediments, there is a direct use for the measured values in dose assessments. They are used to help distinguish contributions to the overall dose rates from artificial and natural radionuclides. They form the basis for assessments of inadvertent ingestion and inhalation of resuspended material.

Data from the aquatic programme are also used to aid the development of models for assessment of future (prospective) doses from planned discharges. The models are used to help decide the acceptability of revised or new discharge authorisations.

The terrestrial programme

The general scope of the terrestrial programme in 2002 is summarised in Table 2.2. The main focus of this programme is the sampling and analysis of foodstuffs. Samples are selected that may be affected by disposals to atmosphere, although in some cases where food availability is limited, environmental indicator materials such as grass and soil are monitored. Grass and soil are also monitored in their own right as environmental samples.

The types of samples collected are chosen on a site-by-site basis to reflect local availability, and to provide information on: (i) the main components of diet such as milk, meat and cereals, and (ii) products most likely to be contaminated by disposals, such as leafy green vegetables or soft fruit. Minor foods such as mushrooms and honey, which under certain circumstances are known to accumulate radionuclides, may also be sampled when available.

Grass is a useful indicator of radioactivity as it is an efficient collector of atmospheric contaminants.

Milking cows graze significant areas of grass and many important radionuclides are passed from grass into milk. It is therefore important for monitoring purposes to ensure milk samples are collected and analysed. Milk is also a convenient product to sample regularly and analyse and is an important part of the diet, especially for young children and infants. For most analyses of milk, weekly or monthly collections are combined (bulked) to provide four quarterly samples for analysis each year, although some analyses are carried out more frequently, e.g. weekly iodine-131 analysis. The frequency of analysis of other foodstuffs is dependent upon their availability and most are collected annually. Samples are collected from locations as close to the sites as practicable as these are the best indicators of discharges.

'Dry cloth' detectors were positioned around the nuclear sites and analysed for airborne radionuclides up until 2001 (Swift, 2002) (see Section 12). This part of the programme has now ceased as the more direct measurements of foodstuffs are considered to provide a more effective method for monitoring gaseous releases. In Scotland, concentrations of some radionuclides in air are measured directly near the major nuclear sites using air samplers.

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 Drigg and Dounreay. The distribution of sites considered in 2002 is shown in Figure 2.1.

Industrial sites are chosen because either they are known from previous research to have a measurable radiological impact on people and the food chain or they represent a potential to do so. These sites do not require licensing under the Nuclear Installations Act. Examples considered in the past are hospitals, incinerators, steel works and radiochemical manufacturers. In 2002, the industrial sites studied were:

- Bracknell, Berkshire (pesticide research)
- Harlow, Essex (pharmaceuticals)
- Loughborough, Leicestershire (pharmaceuticals)
- Middlesbrough, Cleveland (chemical manufacturer)
- Milton, Cambridgeshire (sewage works)
- Milton Keynes, Buckinghamshire (biochemical research)
- Telford, Shropshire (defence equipment repair)
- Whitehaven, Cumbria (chemical manufacturer)

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

About fifty landfill sites were monitored in England, Scotland and Wales. They were studied to assess the extent, if any, of the contamination leaching from the site and re-entering the terrestrial environment in leachates collected in surface waters close to the sites.

2.1.3 Chernobyl fallout

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 Cumbria, north Wales and parts of 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.

2.1.4 Additional monitoring

In addition to the previous programmes, which address specific sources of contamination in the UK, this report also considers the levels of radionuclides in the environment in areas away from these sources as an indication of general contamination of the food supply and the environment. The component parts of this programme are:

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

Channel Islands, Isle of Man and Northern Ireland

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

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

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

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

General diet

The purpose of the general diet surveys is to provide information on radionuclides in the food supply to the whole population, rather than to those in the vicinity of particular sources of contamination such as the nuclear industry. This programme provides background information that is useful in interpreting site-related measurements and also helps ensure that all significant sources of contamination form part of the site-related programme. As part of the Total Diet Study (TDS), representative mixed diet samples are collected from towns throughout the UK [see Section 11.5]. Normal culinary techniques are used in preparing samples (e.g. removal of outer leaves if necessary) and samples are combined in amounts that reflect the relative importance of each food in the average UK diet. Some samples are analysed for a range of contaminants including radionuclides. Part of this data is also supplied to the European Commission in support of the Euratom Treaty. The EC compile data into a report of results from all Member States. At the time of writing, the last report covered data for 1996-2000 (Joint Research Council, 2003). The TDS was supplemented with a study of canteen meals in 2002. Together they account for the ‘dense’ and ‘sparse’ samples required by the EC.

Specific foods, freshwater, rain and airborne particulates

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

Milk sampling took place at dairies throughout the UK in 2002. Samples were taken monthly and some of the results are reported to the EC to allow comparison with those from other Member States (Joint Research Council, 2003).

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 11.2). Regular measurements of radioactivity in air and rain water were also made. Both programmes are partially sponsored by Defra and provide information to the EC under Article 36 of the Euratom Treaty. Similarly, in Northern Ireland EHS fund analysis of freshwater used for drinking water. These data are sent to the EC under Article 36 of the Euratom Treaty.

Seawater surveys

Seawater surveys are carried out in the seas around the UK on behalf of Defra to provide information on radionuclide levels and fluxes in the coastal seas of northern Europe. Such information is used to support international studies of the health of the seas under the aegis of the Oslo and Paris Conventions (OSPAR, 2000), 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 treatments to isolate the radionuclides under study. They are sensitive but costly. 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.

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 and the Channel Islands

- HSL Harwell 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 and Wales

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

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

- 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. It is preferred that contractors be third-party assessed for their operating procedures, i.e. be accredited by an agency such as the United Kingdom Accreditation Service. Regular calibration of detectors is undertaken and intercomparison exercises are held with participating laboratories. The quality assurance procedures and data are made available to the environment agencies and the Food Standards Agency for auditing. The methods of measurement used are summarised in Table 2.3.

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

2.2.2 Measurement of dose rates and contamination

Measurements of gamma dose in air over intertidal and other areas are normally made at 1 m above the ground using Mini Instruments* environmental radiation meters type 680 and 690 with compensated Geiger-Muller tubes type MC-71. For certain key public activities, for example for people living on houseboats or for wildfowlers lying on the ground, measurements at other distances from the ground may be made. External beta doses are measured on contact with the source, for example fishing nets, using Berthold* LB 1210B or Mini 900/EP 15* contamination monitors. These portable instruments are calibrated against recognised reference standards and the inherent instrument background is subtracted. There are two quantities that can be presented as measures of external gamma dose rate, total gamma dose rate or terrestrial gamma dose rate. Total gamma dose rate includes all sources external to the measuring instrument. Terrestrial gamma dose rate excludes cosmic sources of radiation but includes all others. In this report we have presented the total gamma dose rate. NRPB reports terrestrial gamma dose rates to SEPA. Terrestrial gamma dose rate is converted to total gamma dose rate by the addition of 0.037 $\mu Gy\ h^{-1}$ which is an approximation of the contribution made by cosmic radiation (Her Majesty's Inspectorate of Pollution, 1995).

Beta/gamma monitoring of contamination on beaches or river banks is undertaken using similar instrumentation to that for measurements of dose rates. In England and Wales, a Mini Instruments series 900 mini monitor with a beach monitoring probe is used. The aim is to cover a large area including strand-lines where radioactive debris may become deposited. Any item found with activity levels in excess of the action levels is removed for analysis. An action level of 100 counts per second (equivalent to 0.01 $mSv\ h^{-1}$) is used in England and Wales. During 2002, no items were found above the action level at any site in England and Wales. In Scotland at Dounreay, special monitoring procedures are in place due to the known presence of radioactive fragments. Further information regarding Dounreay is provided in Section 5.1.

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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.*

Table 2.1. Scope of the monitoring programmes

Programme	Sub-programme	Main purpose
Nuclear sites		Support for RSA 93, food safety assessment of waste disposal
Industrial sites	Chemical works	Support for RSA 93, food safety assessment of waste disposal
	Landfill sites	Support for RSA 93, assessment of waste disposal
Chernobyl fallout	Sheep monitoring	Support for FEPA 85, guidance on restrictions
	Freshwater fish	Support for FEPA 85, trend analysis
Regional	Channel Islands	General food safety
	Isle of Man	General food safety
	Northern Ireland	Support for RSA 93, assessment of waste disposal
	Milk	General food safety, support for EURATOM Treaty
	Crops, bread and meat	General food safety, support for EURATOM Treaty
	Diet	General food safety, support for EURATOM Treaty
	Freshwater and air particulate	Safety of drinking water and air, support for EURATOM Treaty
	Seawater	Support for OSPAR Convention

Table 2.2. Scope of the nuclear site sampling in 2002

Measurement	Routine frequency of measurement	Analyses or measurements	Types of material	Detailed species/materials
Aquatic programme				
Analysis of foods	Weekly to annually	Total alpha, beta and gamma-ray spectrometry, ^{3}H, organic ^{3}H, ^{14}C, ^{226}Ra, ^{90}Sr, ^{99}Tc, ^{147}Pm, ^{210}Po, Th, U, ^{210}Pb, transuranics	Fish, crustaceans, molluscs and edible aquatic plants	Bass, brown trout, cockles, cod, crabs, cuttlefish, dab, elvers, fish, fish oil, flounder, green crabs, grey mullet, haddock, hake, herring, *Laminaria ssp*., laverbread, lemon sole, lesser spotted dogfish, leaf beet, limpets, ling, lobsters, mackerel, mullet, mussels, native oysters, *Nephrops*, ormers, oysters, pacific oysters, perch, pike, plaice, pollack, *Porphyra*, queens, rainbow trout, ray, saithe, salmon, samphire, scallops, sea mouse, sea trout, shrimps, sole, spiny spider crabs, spurdog, squat lobsters, squid, toothed winkle, whelks, whitebait, whiting, winkles
Analysis of indicator materials and water	Monthly to annually	Total alpha, beta and gamma-ray spectrometry, ^{3}H, ^{14}C, ^{32}P, ^{90}Sr, ^{99}Tc, ^{125}I, ^{131}I, ^{210}Po, ^{226}Ra, Th, U, transuranics	Water, sediments, sewage, marsh, seaweeds, aquatic plants and coarse fish	*Ascophyllum nodosum*, clay, *Elodea canadensis*, fish meal, freshwater, *Fucus spp.*, mud, *Nuphar lutea*, *Rhodymenia spp.*, rudd, salt marsh, sand, seawater, seaweed, sediment, sewage, soil, sludge, sea coal and turf
Gamma dose rates	Monthly to annually		On beaches, harbours, marshes, riverbanks, lakesides and boats	
Beta dose rates	Quarterly to annually		On nets, pots, ropes, sediments and saltmarsh	
Contamination survey	Monthly to annually		On beaches	
Terrestrial programme				
Analysis of foods	Weekly to annually	Total alpha and gamma-ray spectrometry, ^{3}H, organic ^{3}H, ^{14}C, ^{32}P, ^{33}P, ^{35}S, ^{90}Sr, ^{99}Tc, ^{125}I, ^{129}I, ^{131}I, ^{147}Pm, Cs, ^{210}Po, ^{210}Pb, Th, U, and transuranics	Milk, crops and animals	Apples, barley, bovine meat, kidney, liver and offal, beetroot, berries, blackberries, blackcurrants, bread, broad beans, cabbage, carrots, cauliflower, chard, courgettes, cows' milk, cucumber, damsons, eggs, elderberries, goose, gooseberries, hazelnuts, honey, leaf beet, leafy green veg, leeks, lettuce, mallard, mangetout, oats, onions, parsnips, pears, peas, pheasant, plums, porcine kidney, porcine muscle, potatoes, pink potatoes, rabbit, rape oil, raspberries, rhubarb, rosehips, rowan berries, runner beans, sea kale, ovine meat and offal, sloe berries, snails, spinach, strawberries, swede, turnips, wheat, wild greens and widgeon
Analysis of indicator materials	Monthly to annually	Total alpha, beta and gamma-ray spectrometry ^{3}H, organic ^{3}H, ^{14}C, ^{32}P, ^{33}P, ^{35}S, ^{82}Br, ^{90}Sr, ^{99}Tc, ^{99m}Tc, ^{125}I, ^{131}I, ^{147}Pm, Cs, ^{210}Po, ^{210}Pb, Th, U and transuranics	Air[s], grass, soil and animal food	Air particulate, compost, grass, ground elder, hawthorn berries, herbage, lucerne, nettles, rosebay willow herb and soil

[s] *Scotland*

Table 2.3. Analytical methods

Radionuclides	Sample type	Method of measurement
^{3}H ^{3}H (organic) ^{14}C ^{32}P ^{33}P ^{35}S ^{147}Pm ^{241}Pu	All	Beta counting by liquid scintillation
^{90}Sr	High-level aquatic samples	Cerenkov counting by liquid scintillation
^{90}Sr	Terrestrial and low-level aquatic samples	Beta counting using gas proportional detectors
^{99}Tc ^{210}Pb beta	All	Beta counting using gas proportional detectors Cerenkov counting by liquid scintillation
$^{103+106}Ru$ ^{131}I ^{144}Ce $^{134+137}Cs$	Terrestrial samples	Beta counting using gas proportional detectors
^{125}I ^{129}I	Terrestrial samples$^{E/W}$	Gamma counting by solid scintillation
^{134}Cs ^{137}Cs	Seawater	Gamma counting by solid scintillation
^{7}Be ^{40}K ^{51}Cr ^{54}Mn ^{57}Co ^{58}Co ^{60}Co ^{59}Fe ^{65}Zn ^{82}Br ^{95}Nb ^{95}Zr ^{99m}Tc ^{103}Ru ^{106}Ru ^{110m}Ag ^{125}Sb ^{134}Cs ^{137}Cs ^{154}Eu ^{155}Eu ^{208}Tl ^{214}Bi ^{241}Am ^{233}Pa ^{234m}Pa ^{234}Th	All except seawater	Gamma-ray spectrometry using germanium detectors
^{129}I	Terrestrial samples^{S}	Gamma-ray spectrometry using germanium detectors
^{129}I ^{131}I ^{144}Ce	Aquatic samples	Gamma-ray spectrometry using germanium detectors
U	Terrestrial samples	Activation and delayed neutron counting
^{210}Po ^{226}Ra* ^{234}U ^{235}U $^{235+236}U$ ^{238}U ^{237}Np ^{228}Th ^{230}Th ^{238}Pu $^{239+240}Pu$ ^{241}Am ^{242}Cm $^{243+244}Cm$	All	Alpha spectrometry
^{226}Ra	Terrestrial samples	Alpha counting using thin window proportional detectors
Alpha	All^{s}	Alpha counting using gas proportional detectors

* *Determined by gamma spectrometry in sediment samples near Springfields*
E/W *England and Wales*
S *Scotland*

3. PRESENTATION AND ASSESSMENT

This Section explains how concentration and dose rate data are presented and how assessments of public dose are made for comparison with legal limits. The basis for the limits is also presented.

3.1 Temporal averaging of monitoring data

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

The method of presentation of the summarised results allows the data to be interpreted in terms of public radiation exposures for comparison with agreed safety standards. The appropriate period for comparison with recommended limits is one year. Standard practice is to combine annual rates of consumption or occupancy of the small group of people, usually living close to the site, who are expected to be the most exposed (the critical group) with the arithmetic means of observed radioactivity concentrations or dose rates, respectively, during the year at the appropriate locations. This procedure is followed for assessing the impact of contamination of seafood, air, drinking water, beaches and nets (see Section 3.6).

For milk samples, the most appropriate quantity for use in assessments is the arithmetic mean in the year at the farm where the highest concentration is observed. This is labelled ‘max’ in the tables of results to distinguish it from the values that are averaged over a range of farms. For other terrestrial foods, an alternative approach is adopted since it is recognised that the possible storage of foods harvested during a particular time of the year has to be taken into account. Greater public exposures would be observed when foods are harvested at times when levels of contamination are high. For such foods, we have presented the maximum concentration observed of each radionuclide at any time in 2002 as well as the mean value. The maximum is labelled ‘max’ in the tables and forms the basis for the assessment of dose.

3.2 Spatial averaging of monitoring data

In this report, 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. The bulking regimes are described in Section 2.1.1. 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.

3.3 Detection limits

There are two main types of result presented in the tables: (i) positively detected values above the detection limits and (ii) 'less than' values which include data at the limit of detection or minimum reporting level (MRL). There are also a few results quoted as 'not detected' (ND) by the methods used. 'Less than' values are only reported when the radionuclide is one which is likely to be discharged from the nuclear site under study, or when a positive result is detected in any other sample presented in the table in 2002.

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 limit of detection 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).

3.4 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 radiological levels 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 12.

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.

3.5 Radiation protection standards

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

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

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

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

Individual dose limits are used in situations where the effects of past routine operations have introduced radioactivity into the environment, and the effects of several sources combined with those of the present day are taken together. This is the case when assessing the results of environmental monitoring. Further 'constraints' on doses received by members of the public apply when considering the current and future operations of specific sources (United Kingdom-Parliament, 1995b).

For drinking water, the World Health Organisation (WHO) has provided screening levels to compare with the results of measurements of total alpha and beta activity (WHO, 1993). The screening levels are 0.1 and 1.0 Bq l^{-1}, respectively, and are based on consideration of the dose that would result from radium-226 (alpha) and strontium-90 (beta) intakes. These were chosen as representative of the most radiotoxic radionuclides likely to be present in significant quantities. The values represent concentrations below which water can be considered potable without any further radiological examination.

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 Food Standards Agency has publicly consulted (Food Standards Agency, 2001a) on the EC's intention to introduce legislation setting Maximum Permitted Levels for radioactivity in foodstuffs offered for sale on the common market. The findings of the consultation are available (Food Standards Agency, 2002b). The EC currently has no plans to take this matter forward. However, the Codex Alimentarius Commission has been requested by the IAEA to consider producing guideline levels for radionuclides in foods for long-term use and revise or amend the guideline levels for radionuclides in foods following accidental nuclear contamination for use in international trade. The Codex Committee on Food Additives and Contaminants is currently considering the scope of the work and obtaining further input from the IAEA.

The main focus of this report and radiological regulation and monitoring more generally is towards protection of man. Work is also under way to develop better assessment methods for radiological protection of the environment, for example, UNSCEAR (1996), IAEA (1999b) and Copplestone *et al.,* (2001). The environment agencies are leading for the UK in an EC project, FASSET, which will lead to a framework for assessment of radiation in the environment i.e. effects on flora and fauna.

3.6 Assessment methods and data

Calculations of exposures of members of the public from waste disposals are primarily based on the environmental monitoring data for 2002. These data provide information on two main pathways:

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

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

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

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

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

For external radiation pathways, the data required are:

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

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

The dose assessment in this report is for exposures that have already been received. It is a 'retrospective' dose assessment. Assessment of potential future doses is called 'prospective' dose assessment. Guidance on the principles underlying prospective assessments has been provided by a group of UK public bodies (EA, SEPA, DoENI, NRPB and Food Standards Agency, 2002). The guidance, where it is relevant to retrospective assessments, has been considered in the production of this report.

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

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

For aquatic foodstuffs, drinking water, sediments and air, the assessment is based on the mean concentration near the site in question. For milk, the mean concentration at a nearby farm with the highest individual result is used in the dose assessment. This procedure accounts for the possibility that any farm close to a site can act as the sole source of supply of milk to high-rate consumers. In the results tables, entries under the heading of number of observations refer to the number of farms from which milk is sampled. As mentioned in Section 2, the number of actual analyses performed per farm will depend on the bulking regime.

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

The tables of concentrations include 'less than' values as well as positive determinations. This is particularly evident for terrestrial foodstuffs. Where a result is presented as a 'less than' value, the dose assessment methodology treats it as if it were a positive determination in two situations: (i) when that radionuclide is specified in the relevant authorisation or (ii) when a positive determination for that radionuclide is found in another sample from the site. Although this approach may produce an overestimation of dose, particularly at sites where levels are low, it ensures that estimated exposures are unlikely to be understated. Formally, where 'less than' concentrations are included in the dose assessments, estimates of dose should be preceded with the less than (<) symbol. For reasons of clarity, we have presented estimates of dose in the text without the symbol. However, the summary table of estimates of dose does include 'less than' symbols where appropriate.

3.6.2 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 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). For foodstuffs where there is a marked variability in local availability, for example honey, or in personal preference, for example offal, diet surveys undertaken among local populations can provide additional data (Stewart *et al.*, 1990). A programme of such surveys is being undertaken around nuclear sites (Smith and Jeffs, 1999). However, it has been found that when the consumption rates for a variety of staple foodstuffs are examined, the contributions of cows' milk in the infant diet and vegetable consumption by young adults are generally the most important pathways for radionuclide intake.

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

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

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.

3.6.3 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 fetus (International Commission on Radiological Protection, 2001 and Phipps *et al*., 2001). It is reasonable to expect that a proportion of people in the critical groups assessed in this report will be women of childbearing age and that a proportion of such women will be pregnant. In the majority of cases the likelihood that a pregnant woman will be in the group is low. The average expectation of a person, randomly selected from the population, being pregnant with a child which will survive to term is about 1 in 100. The ratio of fetal to adult dose coefficients for the public is generally less than 1 (Stather *et al*., 2002). However there are some radionuclides notably tritium, carbon-14, sulphur-35 and strontium-90 where the ratio is greater, up to 2.1 for strontium-90. The implication for assessments in this report is that some doses for comparison with limits could be underestimated by excluding the fetal age group. The main group of assessments that may be affected are those for terrestrial foods. Our assessments confirm that in no case would fetal doses approach the dose limit. The NRPB is planning to issue guidance in relation to assessments of fetal doses. The assessments procedure in RIFE will be reviewed and revised as necessary when the guidance is made available.

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

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). Estimates of the exposures due to polonium intake have therefore been calculated using the conservative assumption that a factor of 0.8 applies to all seafood. We have retained a factor of 0.5 for other food.

Studies using adult human volunteers have suggested a gut uptake factor of 0.0002 is appropriate for the consumption of plutonium and americium in winkles from near Sellafield (Hunt *et al*., 1986, 1990). For these and other actinides in food in general, the NRPB considers a factor of 0.0005 to be a reasonable best estimate (National Radiological Protection Board, 1990) to be used when data for the specific circumstances under consideration are not available. In this report, when estimating doses to consumers of winkles from Cumbria, a gut uptake factor of 0.0002 is used for plutonium and americium and this is consistent with NRPB advice. For other foods and for winkles outside Cumbria, the factor of 0.0005 is used for these radioelements. This choice is supported by recent studies of cockle consumption (Hunt, 1998).

Volunteer studies have recently been extended to consider the transfer of technetium-99 in lobsters across the human gut (Hunt *et al.*, 2001). Although values of the gut uptake factor found in this study were lower than the ICRP value of 0.5, dose coefficients are relatively insensitive to changes in the gut uptake factor. This is because the effective dose is dominated by 'first pass' dose to the gut (Harrison and Phipps, 2001). In this report, we have therefore retained use of the standard ICRP factor and dose coefficient for technetium-99.

Harrison *et al.* (2002) has reviewed dose coefficients for tritium associated with organic material. Although there was some uncertainty associated with the dose coefficient suggesting that the best estimate would be roughly twice that of the current ICRP recommendation, there was insufficient evidence on which to base any change in value at this stage. The NRPB is planning a further study to examine whether standard biokinetic assumptions for organically bound tritium are applicable in foodstuffs in the UK context (Fry, 2002). In this report, we have therefore continued to use the value recommended by ICRP (1996a).

3.6.4 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. The 'cut-off' method described by Hunt *et al*. (Hunt *et al*., 1982) was used to define the critical group rates of occupancy and handling. This method takes the arithmetic mean of the maximum observed rate and all rates within a factor of the maximum value. It accords with the principle expressed by ICRP (International Commission on Radiological Protection, 1984) that the critical group should be small enough to be reasonably homogeneous with respect to age, diet and those aspects that affect the doses received. The factor was revised in 2002 for some sites where new surveys were undertaken and was changed from 1.5 to 3 to make the selection process consistent with that chosen for consumption pathways. The sites affected were Hartlepool and Aldermaston and the data in Appendix 4 reflect the change in factor.

3.6.5 Subtraction of 'background' levels

When assessing the man-made effect on external exposures to gamma radiation, dose rates due to background levels are subtracted. 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. 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.

* *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.*

3.6.6 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. This information can form the basis for a formal comparison with dose limits. 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 are different. An individual is unlikely to consume both aquatic and terrestrial foods at such high rates.

Schemes are being developed to consider the alternative ways to summing doses across all pathways (Camplin *et al*., 2002 and Hancox *et al*., 2000). A working group including representatives from Defra, Department of Trade and Industry, the Environment Agency, CEFAS, EHS, the Food Standards Agency, the Wales Assembly Government, Nuclear Installations Inspectorate (NII), NRPB, Radioactive Waste Management Advisory Committee and SEPA has been established to study dose assessment procedures in the UK. The group, the National Dose Assessment Working Group, will consider dose summation schemes amongst other matters relevant to retrospective dose assessment. Their views will be taken into account in future issues of the RIFE report.

3.6.7 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

Discussion of the sources of uncertainty in the components of prospective dose assessment using models has been given by Jones *et al.* (2003b). A detailed description for retrospective assessments is beyond the scope of this report. A more in depth analysis of this matter has already been undertaken in Section 3.7 of RIFE 2001 (Food Standards Agency and Scottish Environment Protection Agency, 2002). Whilst every effort is made by the contributing organizations to reduce uncertainties, the combined effect of uncertainties from each step of the monitoring process can be determined by comparing the results from independent assessments. Such comparisons take place within the framework of industry led liaison committees at many nuclear sites in the UK. In addition, comparisons can be made between industry assessments (e.g. BNFL, 2003) and those made in this report.

4. BRITISH NUCLEAR FUELS PLC

British Nuclear Fuels (BNFL) plc's main business interests in the UK are the design and production of fuel for nuclear reactors, spent fuel reprocessing, the generation of electricity and the clean-up of past nuclear site operations. The company also operates a solid waste disposal site at Drigg. Regular monitoring is carried out of the consequences of disposals of radioactive waste from all BNFL sites. For continuity with previous reports, this section comprises the results for five BNFL sites, namely Sellafield, Drigg, Springfields, Capenhurst and Chapelcross. Other power stations within BNFL are considered in Section 6 "Nuclear power stations operated by electricity generating companies".

4.1 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 defuelling prior to decommissioning. Radioactive waste discharges include a very minor contribution from the UKAEA Windscale site, which includes facilities operated by AEA Technology. The most significant discharges are made from the BNFL fuel element storage ponds and the reprocessing plants, which handle irradiated Magnox and oxide fuel from the UK nuclear power programme, and some fuel from abroad.

No changes to the limits specified in the authorisations to discharge radioactivity were made in 2002. Defra and Department of Health Ministers announced that they accepted proposals made by the Environment Agency on the future improvements to the regulation of technetium-99 discharges to sea (Environment Agency, 2001). The Environment Agency subsequently issued a Variation Notice to the Company to implement these proposals. In addition, Defra consulted on a proposal to direct the Environment Agency to consider whether it would be possible to impose a moratorium on the discharge of technetium-99 pending introduction of new tetraphenylphosphonium bromide abatement technology (Department for Environment, Food and Rural Affairs, 2002b; Environment Agency, 2002c). The outcome of the consultation is expected in 2003. A very thorough review of other authorisation requirements at BNFL Sellafield has been completed and the Environment Agency's proposed decision, including a significantly strengthened and more comprehensive authorisation was forwarded to Ministers in August 2002. The Environment Agency has also begun a review of disposals from the UKAEA Windscale site (Environment Agency, 2002d).

Current monitoring of the site reflects both historic and present day activities and, in view of its importance is considered in depth in this report.

4.1.1 The aquatic monitoring programme

Discharges from the Sellafield pipelines during 2002 are summarised in Appendix 1. Total alpha and beta discharges were 0.35 and 112 TBq, respectively (2001: 0.196 and 123 TBq, respectively). Most discharges of individual radionuclides increased in 2002 but the increases were generally small. Technetium-99 discharges increased to 85.4 TBq in 2002 (2001: 79.4 TBq) but are now much lower than the peak reached in 1995 of 192 TBq. No discharges exceeded the limits set in the authorisations.

Regular monitoring of the marine environment near Sellafield continued during 2002. 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. In 2002, 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. A review of changes in discharges and effects from the site is given by Smith *et al*. (2000a). The monitoring locations for seafood, water, indicator materials and dose rates near the Sellafield site are shown in Figures 4.1 and 4.2.

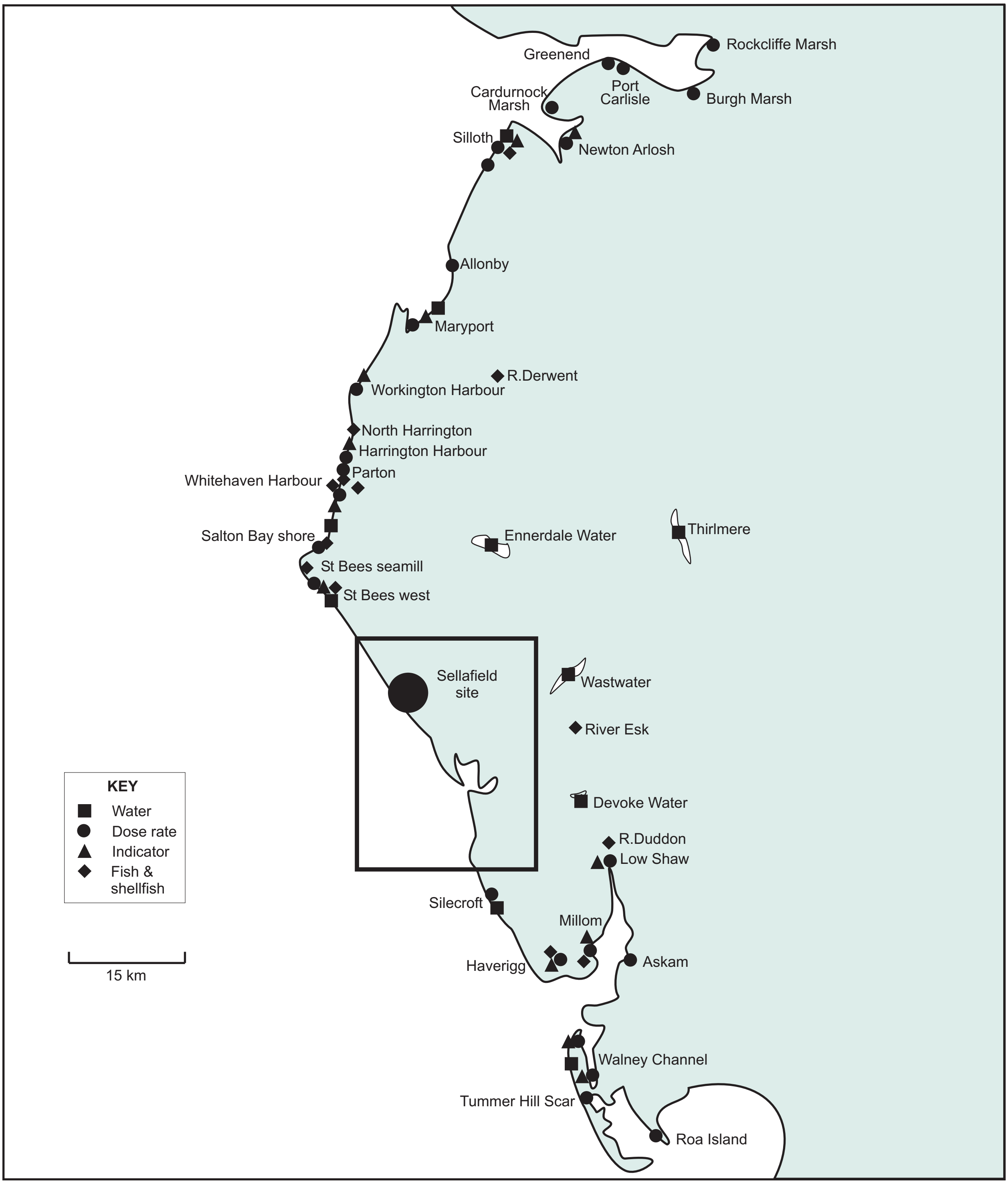

Figure 4.1 Monitoring locations in Cumbria (excluding farms)

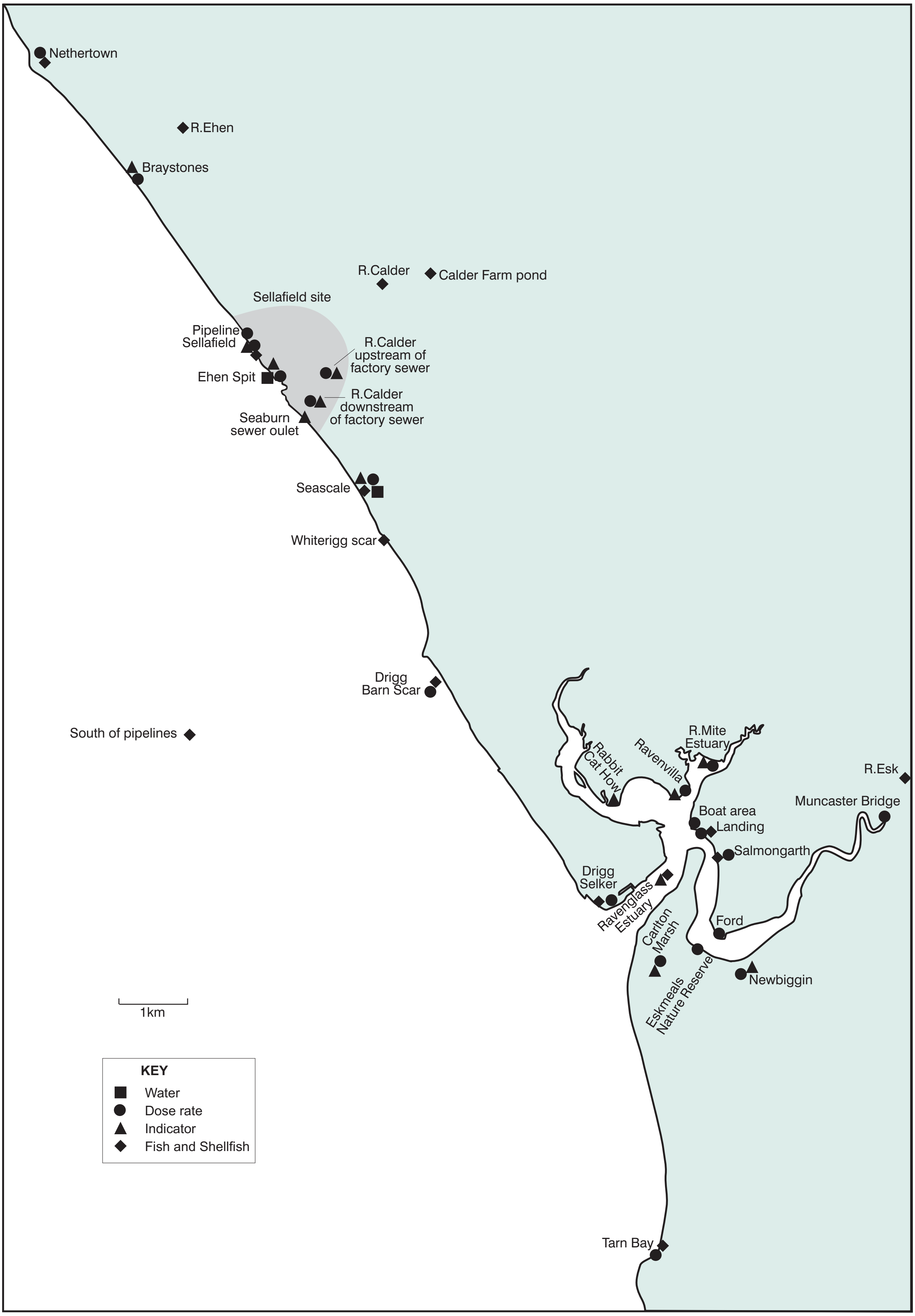

Figure 4.2 Monitoring locations at Sellafield (excluding farms)

Following international and local concerns, and given the importance of the fish farming industry in Scotland, a survey was carried out in 2003 of radioactivity in farmed salmon from Scotland and Northern Ireland (see Section 12, "Radioactivity in farmed salmon").

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 4.1. Concentrations in 2002 were generally similar to those in 2001. Small increases were observed for tritium and carbon-14. Data are listed by location of sampling or landing point, in approximate order of increasing distance from Sellafield. Samples taken near other nuclear establishments that reflect Sellafield discharges are given later in this report. The 'Sellafield Coastal Area' extends 15 km to the north and to the south of Sellafield, from St Bees Head to Selker and 11 km offshore; most of the fish and shellfish consumed by the local critical group is taken from this area. Specific surveys are carried out in the smaller 'Sellafield Offshore Area' where experience has shown that good catch rates may be obtained. This area consists of a rectangle, one nautical mile (1.8 km) wide by two nautical miles (3.6 km) long, situated south of the pipelines with the long side parallel to the shoreline; it averages about 5 km from the pipeline outlet.

The results for radiocaesium generally reflect progressive dilution with increasing distance from Sellafield. However, the rate of decline of radiocaesium concentrations with distance is not as marked, as was the case some years ago, when significant reductions in discharges were achieved. There is therefore a greater contribution from historical sources. Radiocaesium in fish from the Baltic is not due to Sellafield discharges but is substantially from the Chernobyl accident. Concentrations of radiocaesium in fish known to have been caught in Icelandic waters remained typical of those from weapon test fallout, at a value of about 0.2 Bq kg^{-1} for caesium-137 in cod. Data for the Barents Sea are similar. Data for cod from the 'Offshore Area' have been used to give a general indication of trends in fish (Figures 4.3 - 4.8) though substantial variability between species can be found.

Low concentrations of man-made radioactivity were found in fishmeal which is fed to farmed fish, poultry, pigs, cows and sheep. A study has established that any indirect onward transmission of radioactivity into human diet as a result of this pathway is of little radiological significance (Smith and Jeffs, 1999). A sample of rainbow trout from a small lake near Sellafield was again collected this year. The caesium-137 concentration in the sample, at 49 Bq kg^{-1}, was much lower than in 2000 (390 Bq kg^{-1}); however, the variability in activities in samples of freshwater fish is known to be high (Camplin *et al.*, 1989).

Concentrations of most other beta/gamma emitting radionuclides in fish tend to be lower. However, with an expected carbon-14 concentration being about 25 Bq kg^{-1} from natural sources, the data suggest there is a local enhancement of carbon-14 due to discharges from the site. The highest concentrations of radioactivity in marine fish are found for tritium at about 160 Bq kg^{-1}. Similar concentrations are found from determinations of organically associated tritium in the fish. Concentrations of tritium in local seawater at St Bees are less than 30 Bq l^{-1} (Table 11.16). This indicates that some bioaccumulation of tritium is taking place. However, the extent of bioaccumulation is much smaller than observed in the Severn Estuary near Cardiff (see Section 8.2). The radiotoxicity of tritium is very low, and the radiological importance of these concentrations, as determined later in this report, is much less than that of other radionuclides. A research project has recently been completed to obtain more information on tritium distributions in seafood in the Irish Sea and further afield (Swift and Hughes, 2003).

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 4.2 lists concentrations of beta/gamma-emitting nuclides (except plutonium-241) and total beta activity in shellfish from the Irish Sea and further afield. Crustaceans and molluscs are of particular radiological importance to the critical group near to Sellafield, as described later in this section. In addition to sampling by CEFAS, supplies of winkles, mussels and limpets were obtained from consumers who collected them in the Sellafield coastal area.

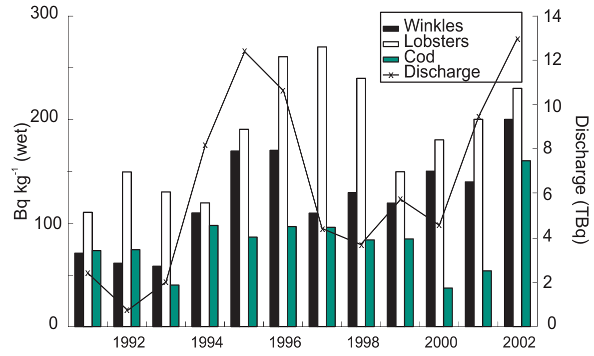

Figure 4.3 Carbon-14 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

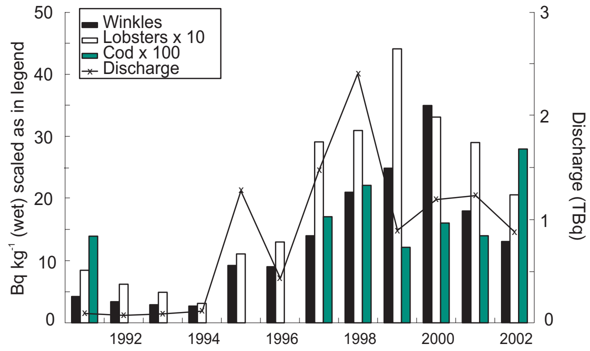

Figure 4.4 Cobalt-60 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

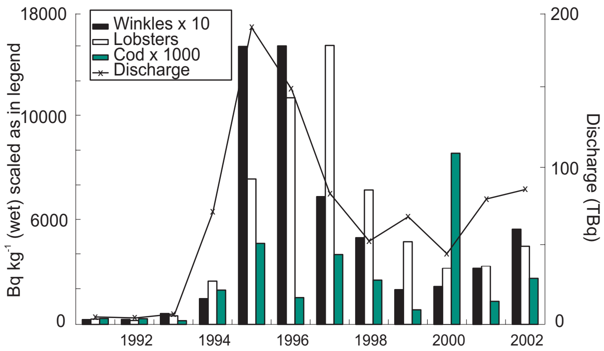

Figure 4.5 Technetium-99 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

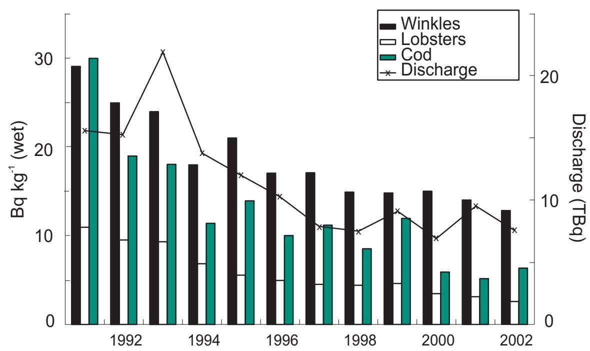

Figure 4.6 Caesium-137 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

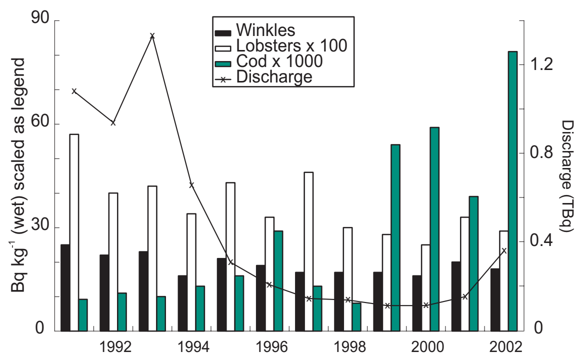

Figure 4.7 Plutonium-239/240 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

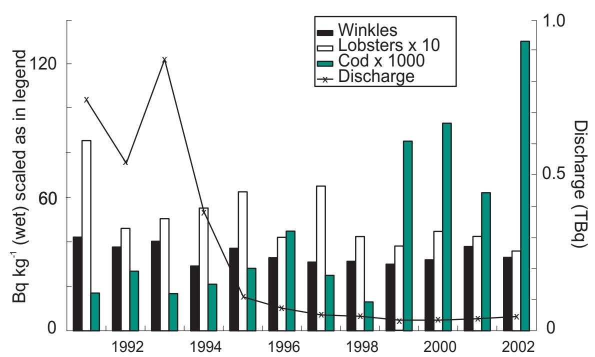

Figure 4.8 Americium-241 liquid discharge from Sellafield and concentrations in cod, lobsters and winkles near Sellafield

Concentrations of artificial radionuclides in shellfish, as with fish, generally diminish with increasing distance from Sellafield. There can be substantial variations between species: for example, lobsters tend to concentrate more technetium-99 in comparison with crabs (see also Knowles *et al.*, 1998; Swift and Nicholson, 2001). However, as a general rule, molluscs tend to contain higher levels of radionuclides than crustaceans, which in turn tend to contain more than fish. The highest concentrations due to Sellafield discharges are found for tritium, carbon-14 and technetium-99. When comparing 2001 and 2002 data across a wide range of sampling locations and shellfish species, few significant changes in concentrations were found. Some increases in carbon-14 and ruthenium-106 were detected. Technetium-99 levels generally increased in local samples but by small amounts. Further information about technetium-99 trends is given for seaweeds around the UK later in this report.

Analyses for transuranic radionuclides are costly and labour-intensive; as in previous years, a selection of samples of fish and shellfish, chosen mainly on the basis of potential radiological significance, were analysed for transuranic nuclides. The data for 2002 are presented in Table 4.3. Transuranics are less mobile than radiocaesium in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranics in shellfish compared with fish and a rapid reduction with distance from Sellafield in concentrations of transuranics, particularly in shellfish. Concentrations in shellfish in 2002 were generally similar to those in 2001 (Figures 4.7 and 4.8). Those in samples from the northeastern Irish Sea remain the highest levels of such nuclides to be found in foodstuffs in the UK. The concentrations in cod caught offshore of Sellafield increased in 2002. However, this observation is not supported by other transuranic analyses and relative to shellfish, fish species contain very low concentrations of transuranic radionuclides.

The longer term changes in concentrations in seafood are shown in Figures 4.3 - 4.8 with the corresponding discharge profiles. In general, concentrations have increased and decreased in response to changes in discharges. However, there have been irregular results, particularly for fish and this is probably due to their migratory nature.

Concentrations of natural radionuclides in fish and shellfish in the Sellafield area are presented in Section 10.

Individual dose

Table 4.4 summarises doses in 2002 from artificial radionuclides in fish and shellfish.

The dose to the local critical group of high-rate consumers was 0.19 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 2002 and increases were found in the consumption of fish and molluscs. The increase in dose from 0.15 mSv reported for 2001 (based on a five year average of habits surveys data 1997 – 2001) (Food Standards Agency and SEPA, 2002) is largely due to increases in the consumption rates of the local critical group. Most of the dose from the ingestion of seafood and external irradiation due to Sellafield was from historic discharges. Recent and current discharges of technetium-99 contributed about 15% of the dose to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose were plutonium-239/240 and americium-241.

The dose estimates are based on a five-year average of critical group habits in order 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, 2001c). The period of averaging chosen for the 2002 dose assessment was 1998-2002 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 2002 is provided in Table 4.4 for comparison with the same group using the five year average habit survey data.

Data for natural radionuclides in fish and shellfish are discussed in Section 10. However, the effects on the Sellafield critical group from controlled discharges of natural radionuclides from another west Cumbrian source, Rhodia Consumer Specialties Ltd., Whitehaven, are also considered here. The increase in natural radionuclide concentrations is difficult to determine above a variable background (see Appendix 6). However, using maximising assumptions for the dose coefficients, the dose to the local group of seafood consumers due to the enhancement of concentrations of natural radionuclides in the Sellafield area in 2002 was estimated to be 0.42 mSv using a gut uptake factor for polonium of 0.8. Most of this was due to the polonium-210 and lead-210 content of shellfish. Taken with the 0.19 mSv dose from artificial radionuclides this gives a total dose to the critical group of 0.61 mSv. These doses may be compared with an average dose of approximately 2.2 mSv y^{-1} to members of the UK public from all natural sources of radiation (Hughes, 1999).

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 4.4). 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 2001 (see following text table). It is expected that there will be fluctuations in concentrations due to normal sampling variability. All doses were well within the dose limit for members of the public of 1 mSv.

The dose from artificial radionuclides, appropriate to a consumption rate of 15 kg $year^{-1}$ of fish from landings at Whitehaven and Fleetwood, is also given in Table 4.4. This consumption rate represents an average for typical fish-eating members of the public. Their dose was very low, around 0.001 mSv in 2002.

Doses from artificial radionuclides in the Irish Sea		
Group	Dose, mSv	
	2001	2002
Northern Ireland	0.015	0.012
Dumfries and Galloway	0.040	0.045
Whitehaven	0.031	0.026
Sellafield	0.15	0.19
Isle of Man	0.007	0.007
Morecambe Bay	0.059	0.066
Fleetwood	0.019	0.018
North Wales	0.008	0.014

No consumption of uncommon seafood, such as sea mice, caught as by-catch of fishing in the Sellafield area was reported in 2002, though this practice has been observed in the past (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999) and the pathway will be kept under review. Further information of concentrations in, and doses from, uncommon seafood has been reported (Swift, 2002a).

The exposure of potential consumers of trout from a tarn at a local farm was also considered in 2002. Their dose was 0.005 mSv which was 0.5% of the dose limit to members of the public of 1 mSv. This includes a contribution due to Chernobyl and weapons test fallout.

External exposure from gamma emitting radionuclides

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

A range of coastal locations is regularly monitored, both in the Sellafield vicinity and further afield, using environmental radiation meters. Table 4.5 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 rate measured above mud and salt marsh fluctuate quite markedly, disguising the general decrease with increasing distance from Sellafield (see Figure 4.9). Dose rates over intertidal areas throughout the Irish Sea in 2002 were similar to those data for the same locations in 2001 (Environment Agency, 2002a and Food Standards Agency and Scottish Environment Protection Agency, 2002). The longer term reduction of gamma dose rates since the 1980s can be seen in Figure 4.10; this has occurred primarily as a result of the reduction of gamma emitting radionuclides from Sellafield.

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

Concentrations of radionuclides in surface sediments are also regularly monitored, both because of relevance to dose rates and in order to keep under review distributions of adsorbed radioactivity. Concentrations of beta/gamma emitting radionuclides and transuranics, taken mostly at the same locations as the dose rate measurements, are given in Table 4.6.

The trends over the last two decades of discharges from Sellafield and concentrations in mud from Ravenglass are shown in Figures 4.11 - 4.14. 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 quite similar but there has been more variability in the concentrations of caesium-137, plutonium isotopes and americium-241. This is probably due to either remobilisation of historical sediments containing higher activity concentrations or increased presence of finer-grained sediments with higher activity concentrations. For americium-241 there is also an additional contribution due to ingrowth from plutonium-241 in the environment. Overall concentrations in sediments in 2002 were similar to those in 2001 (Environment Agency, 2002a and Food Standards Agency and Scottish Environment Protection Agency, 2002).

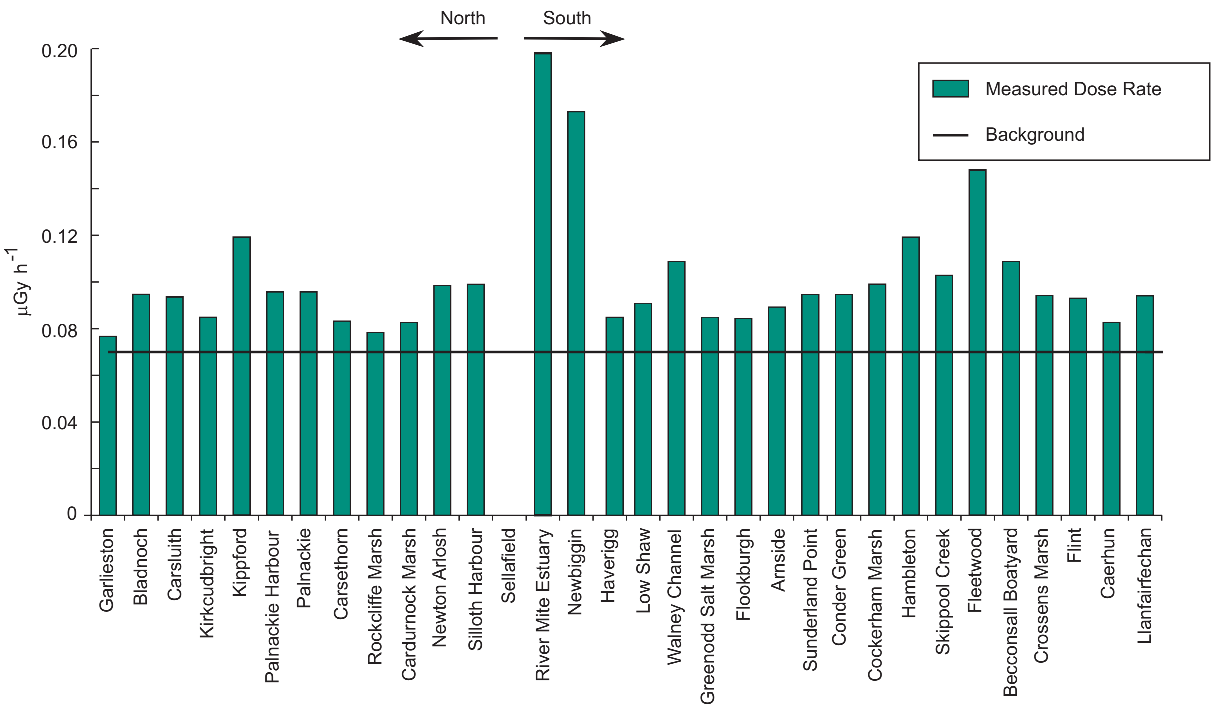

Figure 4.9 Gamma dose rate above mud and salt marsh with distance from Sellafield

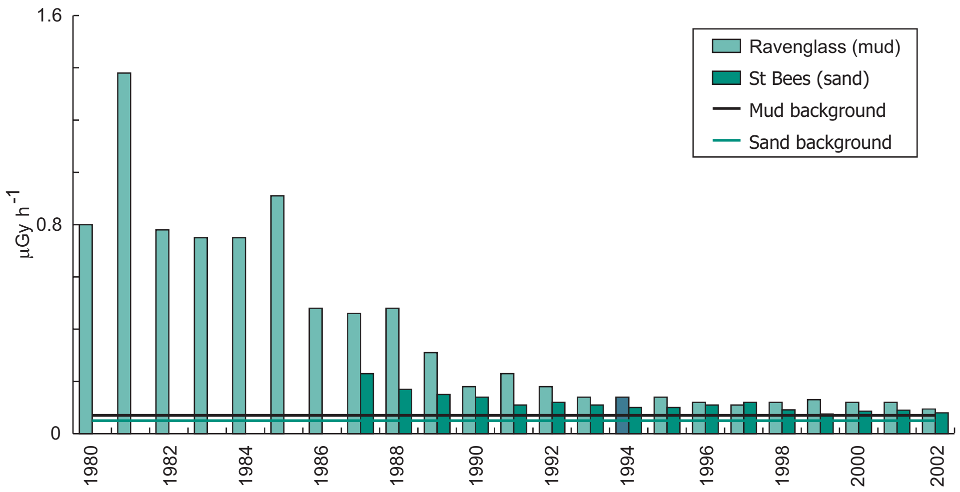

Figure 4.10 Gamma dose rate at Ravenglass and St Bees (data prior to 1988 are from BNFL surveys)

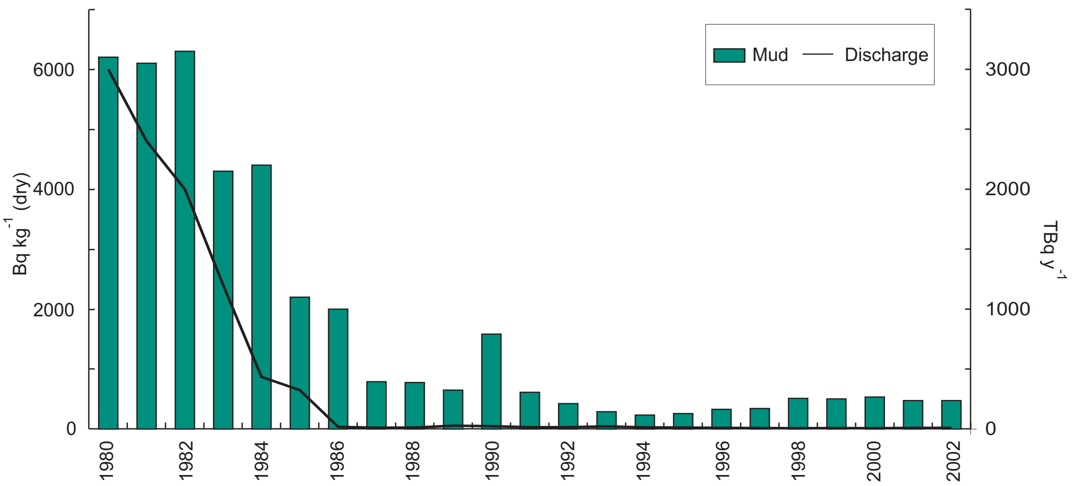

Figure 4.11 Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)

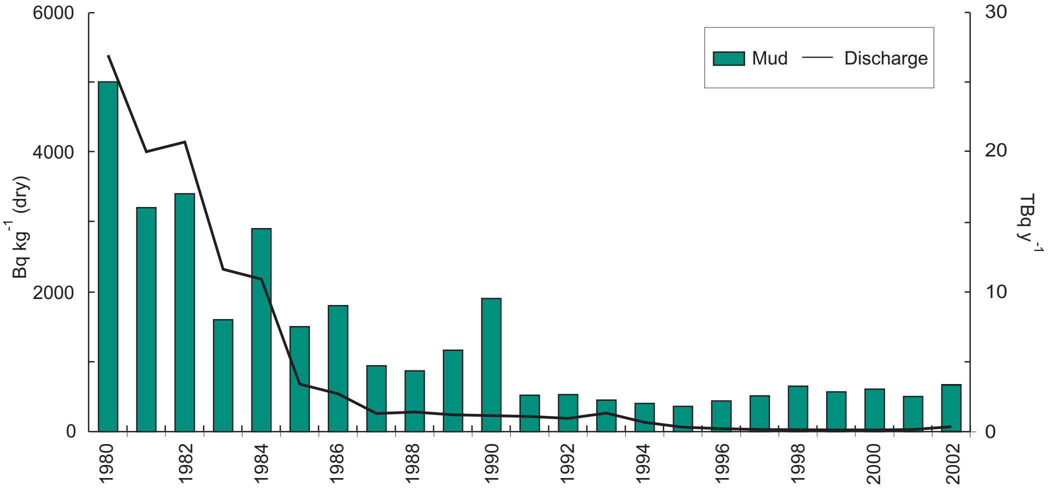

Figure 4.12 ***Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)***

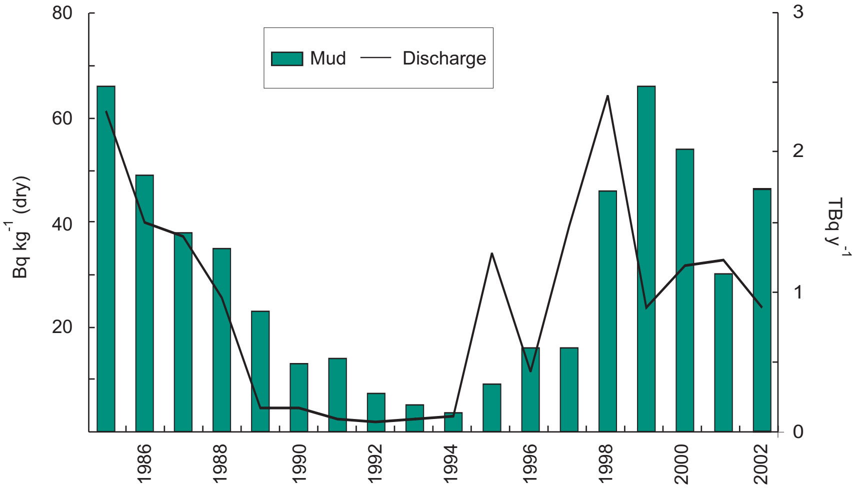

Figure 4.13 ***Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)***

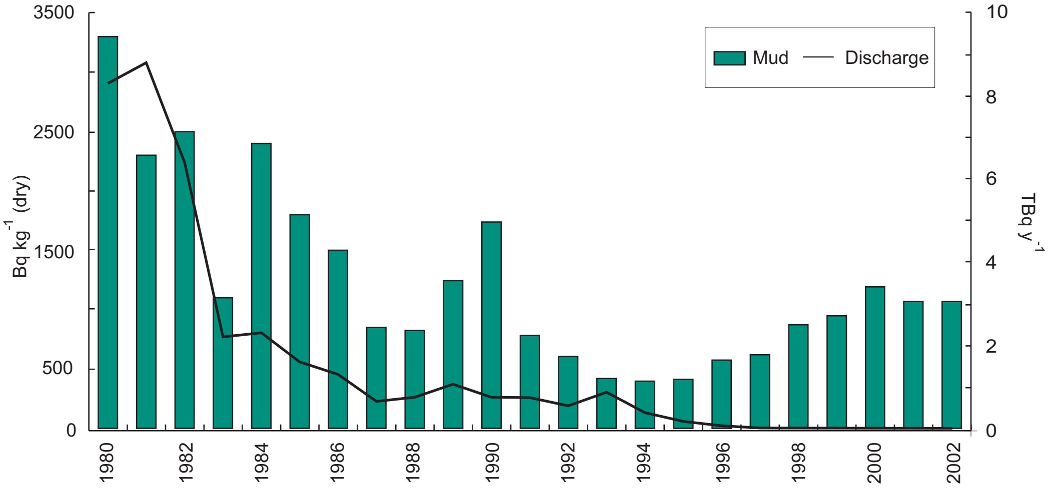

Figure 4.14 ***Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)***

The results of the assessment of external exposure pathways are shown in Table 4.7. 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 2002, their dose was 0.12 mSv or about 12% of the dose limit for members of the public. This was similar to the value of 0.14 mSv in 2001 (Environment Agency, 2002a). A small contribution due to inadvertent ingestion of sediments and inhalation of resuspended sediments is included. Their dose dominates those due to external exposure because of the long times spent over muddy areas. Other groups received lower doses in 2002. 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 to the public 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 2002 are presented in Table 4.8. Measured dose rates were generally similar to those for 2001. 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 1200 h year^{-1} was appropriate. The skin dose from handling of fishing gear in 2002, including a component due to natural radiation, was 0.15 mSv, which was less than 1% of the appropriate dose limit of 50 mSv. 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 2002 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 4.9. The skin dose to anglers who dig bait, based on a time handling sediment of 950 h year^{-1}, was 0.22 mSv in 2002 which was less than 1% of the skin dose limit.

In addition, more general beta/gamma monitoring of contamination on beaches continued in 2002. 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. The far-field monitoring was at Maryport, Parton and Walney in 2002. No material was found in excess of the action levels equivalent to 0.01 mSv h^{-1} in 2002 and no material was therefore removed. Monitoring is continuing in 2003 with special emphasis being placed near Sellafield in view of operations to recover redundant pipelines.

Aerial surveys

An aerial survey of the Cumbrian coastline was carried out by helicopter (Sanderson *et al*., 2001). Aerial surveys can be good methods for surveying large areas quickly. Enhanced levels of natural radionuclides were identified at a few locations. More detailed sampling and survey work was carried out at three of these locations in 2002. The enhancement was found to be associated with a landfill site, a quarry and a patch of sand close to low water mark. In addition, sampling was carried out at the Eskmeals firing range (see section 7.5).

Water

Table 4.10 shows the results of the analysis of samples of surface water taken from Ehen Spit (see Figure 4.2) near Sellafield where water issues from the ground at low tide. 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 2002 were similar to those reported in 2001. The dose from inadvertent consumption of water from Ehen Spit has been shown to be insignificant (Environment Agency, 2002a).

There was some evidence of tritium from Sellafield at the factory sewer outfall on the River Calder (see Figure 4.2). However the waters are not potable and the low concentrations are of no radiological significance. The concentrations of tritium in the River Calder downstream of Sellafield were below the limit of detection.

The levels of tritium in rivers and lakes in West Cumbria, some of which are sources of public drinking water, were below the limit of detection. The levels of total beta activity were below the WHO recommended value of 1.0 Bq l^{-1}.

Research and monitoring of the distribution of radionuclides in seawater is considered in Section 11.

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 feral pigeons contaminated with radionuclides at a bird sanctuary at Seascale (see Section 4.1.2). Gully pots in road drains collect sediments washed off road surfaces. Samples were taken from one drain at Whitehaven and five drains in Seascale village, two near the bird sanctuary. The results of analyses in 2002 are shown in Table 4.11. Levels of caesium-137 and plutonium isotopes were enhanced in the drains nearest the bird sanctuary, but are now about one hundred times lower than they were in 1998 when remedial measures were taken.

Seaweeds and related pathways

Seaweeds are useful indicator materials; they may concentrate certain radionuclides, so they greatly facilitate measurement and assist in the tracing of these radionuclides in the environment. Table 4.12 presents the results of measurements in 2002 of seaweeds from shorelines of the Cumbrian coast and further afield. Although small quantities of samphire 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 increases in discharges of technetium-99 from Sellafield, however, whilst there was a small increase in 2002 the highest concentrations which are found near Sellafield are now much less than those in the mid 1990s (Figure 4.15). Although the spatial extent of the technetium-99 from Sellafield is clearly evident in this figure, so is the large reduction in levels as the effect of Sellafield becomes less pronounced in moving from the eastern Irish Sea, to the rest of the Irish Sea, to Scottish Waters and on to the North Sea. Movement southwards from Sellafield into the English Channel is insignificant (Hunt *et al*., 2002).

Seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a continuing research study in 2002. The results are shown in Table 4.13. 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 2002, 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

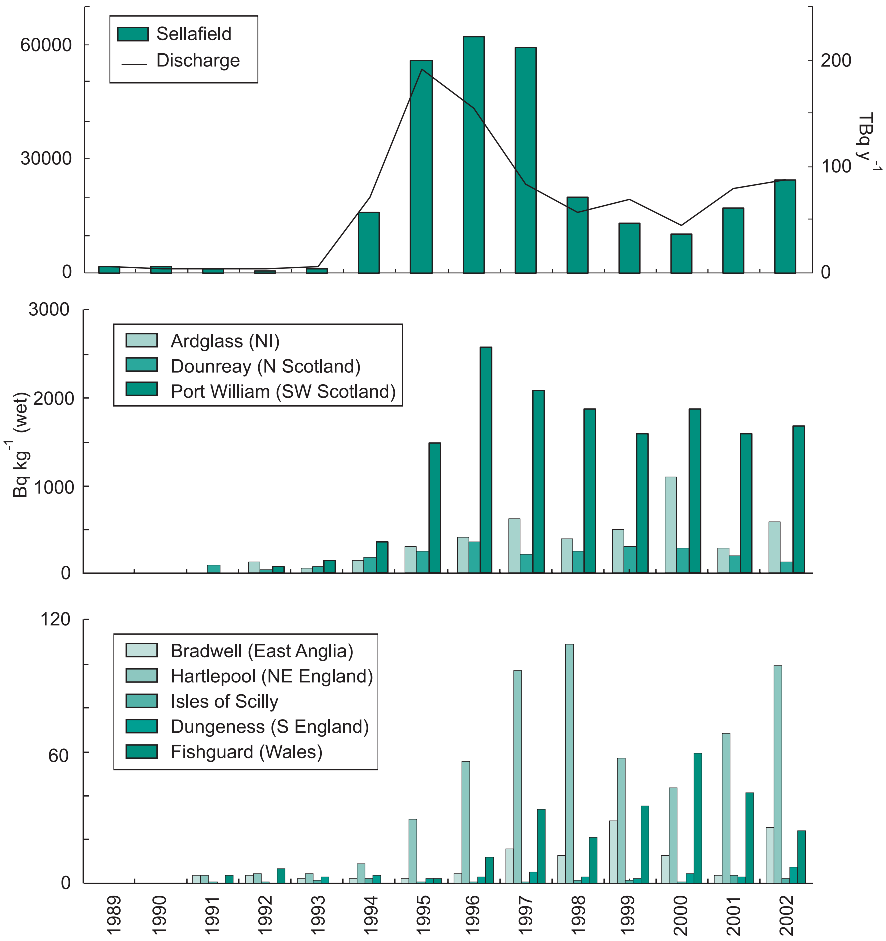

***Figure 4.15** Technetium-99 liquid discharge from Sellafield and concentration in seaweed,* **Fucus vesiculosus**

and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Various vegetable samples that had been grown in the soils from these plots were obtained. The technetium-99 concentrations in vegetables ranged from 1 to 36 Bq kg^{-1} in the edible parts. Small concentrations of gamma-emitting radionuclides were found in some vegetables.

Consumption rates of people who were supplied with vegetables from the plots were investigated. Based on pessimistic assumptions, the maximum annual dose received by the local consumers from radioactivity in vegetables was estimated to be 0.007 mSv. The highest annual dose due to technetium-99 was 0.006 mSv. Exposures of consumers further afield in Northern Ireland, Scotland and north Wales will be less. Whilst the doses due to consumption of seafood and external radiation from sediments remain more important, the seaweed/vegetable pathway will be kept under review.

The potential transfer of technetium-99 to milk, meat and offal from animals grazing tide-washed pasture was considered using a modelling approach in the report for 1997 (Ministry of Agriculture, Fisheries and 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 2002 suggests that this dose estimate remains valid (Table 4.13). In the Scottish islands, seaweed may be eaten directly by sheep grazing on the foreshore. However, 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. It was assumed that sheep obtain all their fodder from seaweed, which contained the highest observed levels of technetium-99, at a rate of 30 kg a day and that consumers obtain all their sheep meat and offal from this source. The latest available data for technetium-99 in seaweed from the Shetlands and the Orkneys were from 1998, and were 130 Bq kg^{-1} and 410 Bq kg^{-1}, respectively (Food Standards Agency and Scottish

Environment Protection Agency, 1999). The annual dose calculated for high-rate sheep meat and offal consumers was 0.047 mSv for the Shetlands and 0.15 mSv for the Orkneys. Both doses were for infants, with other age groups being significantly lower.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2002; 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 indicator material. Samples of *Porphyra* are regularly collected from selected locations along UK shorelines of the Irish Sea. Results of analyses for 2002 are presented in Table 4.12. Samples of laverbread from the major manufacturers are regularly collected from markets in south Wales and analysed. Results for 2002 are also presented in Table 4.12. The dose to critical laverbread consumers in south Wales was much less than 0.005 mSv, confirming the low radiological significance of this exposure pathway.

4.1.2 The terrestrial monitoring programme

Environmental monitoring of the terrestrial environment at Sellafield and Ravenglass are considered together in this Section. The programme around the Ravenglass estuary approximately 10 km south of the Sellafield site is included here because it is used to investigate contamination of sea-washed land resulting from discharges of liquid waste from Sellafield.

Sellafield

Discharges of gaseous wastes from Sellafield are summarised in Appendix 1. There were significant reductions for some radionuclides when compared with 2001, notably sulphur-35, argon-41, cobalt-60 and iodine-131. These were largely due to changes in operations at Calder Hall. Discharges from the Calder Hall power station further reduced in March 2003 when power generation ceased prior to defuelling and decommissioning.

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 indicator materials such as grass and soil. Samples were obtained from different locations around the site in order to encompass the possible variations in activity levels due to the influence of meteorological conditions on the dispersal of gaseous discharges. The analyses undertaken included gamma-ray spectrometry and specific measurements for tritium, carbon-14, sulphur-35, strontium-90, technetium-99, iodine-129, radiocaesium, uranium and transuranics.

The results of routine monitoring in 2002 are presented in Table 4.14. The concentrations of all radionuclides were low and there was no indication of widespread contamination from the site. Concentrations in terrestrial foodstuffs were generally similar to those in 2001 (Food Standards Agency and Scottish Environment Protection Agency, 2002).

Levels of activity in bovine and ovine meat and offal continued to be analysed in 2002. Concentrations of radionuclides were low, with limited evidence of the effects of Sellafield derived activity in data for tritium, carbon-14 and sulphur-35. Plutonium concentrations were much lower than those found in seafood.

The fruit and vegetables that were sampled in 2002 included apples, blackberries, broad beans, cabbage, carrots, cauliflower, leeks, potatoes, runner beans, sloes, swede and turnips. The results were similar to those in previous years. In common with meat and offal samples, limited evidence for the effects of Sellafield discharges was found in data for tritium, carbon-14 and sulphur-35. Concentrations of transuranic radionuclides were very low.

The dose received by the critical group who consume terrestrial food and are exposed to external and inhalation pathways from gaseous releases was calculated using the methods and data presented in Section 3 and Appendix 2. The results are presented in Table 4.15. 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 0.038 mSv (Adult: 0.024; 10y: 0.024). The most significant contributions to the 1-year-olds dose were from argon-41, strontium-90 and ruthenium-106. The most important foodstuff was milk which accounted for more than 50% of the dose. The exposure is very likely to be an upper estimate of the effects of Sellafield discharges because: (i) it is based on the assumption that a radionuclide which is not detected in a sample is present at a concentration equivalent to the limit of detection; (ii) the effects of the background of artificial radionuclides in the area from Chernobyl and weapon test fallout are included; and (iii) it is assumed that most food consumed is locally produced.

The assessed dose due to high-rate food consumption by infants in 2002 (0.033 mSv) was similar to the corresponding dose in 2001 (0.037 mSv). Doses as a result of environmental non-food pathways were lower in 2002 due to the reduced discharges of argon-41 from Calder Hall.

Previous reports in this series have dealt with the issue of contamination associated with pigeons in the vicinity of Sellafield. Internal contamination, mainly of caesium-137, in birds sampled by 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 prevented access to the loft spaces in buildings on the Sellafield site. In view of the limited numbers of pigeons now on the site, the Food Standards Agency is reviewing the need for the precautionary advice to continue. In addition, a random selection of ten feral pigeons have been caught and analysed and the Food Standards Agency is consulting on the need for continued precautionary advice. The results will be made available on www.food.gov.uk

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 indicator materials were collected and analysed for radionuclides which were released in liquid effluent discharges from Sellafield. In addition, analyses for sulphur-35, from gaseous releases, were also undertaken to compare with results for the immediate area around Sellafield.

The results of measurements in 2002 are presented in Table 4.16. In general, the data are similar to those for 2001 (Food Standards Agency and Scottish Environment Protection Agency, 2002) and show lower concentrations than are found in the direct vicinity of Sellafield. The evidence for sea-to-land transfer is limited. Very little technetium-99 was detected but some promethium-147 was present in grass samples from Ravenglass. Concentrations of transuranic radionuclides were generally very low but the observed ratio of $^{239+240}Pu$:^{238}Pu of 3:1 in bovine liver is characteristic of the Sellafield signal. A ratio of $^{239+240}Pu$:^{238}Pu of about 40:1 would be expected for fallout. The only other indication of the effects of Sellafield discharges is the detection of sulphur-35 in some samples. These may have been due to gaseous discharges from the site.

The exposure due to consumption of terrestrial foods from Ravenglass in 2002 is given in Table 4.15. The 1-year-old age group received the highest exposures. Their dose, including contributions from Chernobyl and weapon test fallout, was calculated to be 0.020 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv. This compares with 0.017 mSv for 2001 (Food Standards Agency and Scottish Environment Protection Agency, 2002). Sea-to-land transfer therefore, does not have a major effect on the terrestrial food chain in the Ravenglass area.

4.2 Drigg, Cumbria

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

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

The current disposal authorisation allows for the discharge of leachate from the trenches through a marine pipeline. The limits for activity to be discharged through the marine pipeline and for concentrations of residual activity in the Drigg Stream are given in Appendix 1. These discharges are small compared with those discharged from the nearby Sellafield site. Marine monitoring of the Drigg site is therefore subsumed within the Sellafield programme that is described in Section 4.1. The contribution to exposures due to Drigg discharges is negligible compared with that attributable to Sellafield and any effects of Drigg discharges in the marine environment could not be detected in 2002 above those due to Sellafield.

The results of analyses of spot samples of water and sediment taken from the Drigg stream are given in Table 4.17. The concentrations of total alpha and beta activity were significantly below the limits specified in the authorisation. The total beta concentrations were less than 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 increased in 2002. For example, caesium-137 increased from <100 (2001) to 440 Bq kg^{-1} and plutonium-239/240 from <10 (2001) to 75 Bq kg^{-1}. The current levels are not exceptional. They reflect the legacy of direct discharges of leachate from the disposal site into the stream (BNFL, 2002). This practice stopped in 1991.

In the past, groundwater from some of the trenches on the Drigg site moved eastwards towards a Network Rail-owned drain along the perimeter of the site. Radioactivity from Drigg was detected in the drain water. BNFL took steps in the early 1990s to reduce ingress of water into the trenches and built a “curtain wall” to reduce lateral migration of leachate into the drain. The results of monitoring in the drain show that levels of radioactivity are now very low and have reduced significantly since the curtain wall was constructed. The concentrations of total alpha and total beta activity were less than the WHO screening values.

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

Results for 2002 are given in Table 4.17. Evidence in support of the proposition that radioactivity in Drigg leachate might be transferring to foods was very limited. In general, concentrations of radionuclides detected were similar to or lower than those found near Sellafield. 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 4.15). This compares with 0.016 mSv in 2001.

4.3 Springfields, Lancashire

This establishment is mainly concerned with the manufacture of fuel elements for nuclear reactors and the production of uranium hexafluoride. Radioactive liquid waste arisings consist mainly of thorium and uranium and their decay products; liquid discharges are made by pipeline to the Ribble estuary. Discharges of beta-emitting radionuclides, which result in the greatest contribution to the radiological impact due to Springfields, increased from 85 TBq (2001) to 106 TBq in 2002 (see Appendix 1). Discharges of gaseous effluents remained very low at a similar level to those for 2001.

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 targetted 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. Indicator materials including grass and soil were also sampled. Water was sampled from the vicinity of Ulnes Walton where low-level solid wastes from Springfields used to be disposed of in landfill. Disposal ceased in 1993. The local monitoring locations are shown in Figure 4.16.

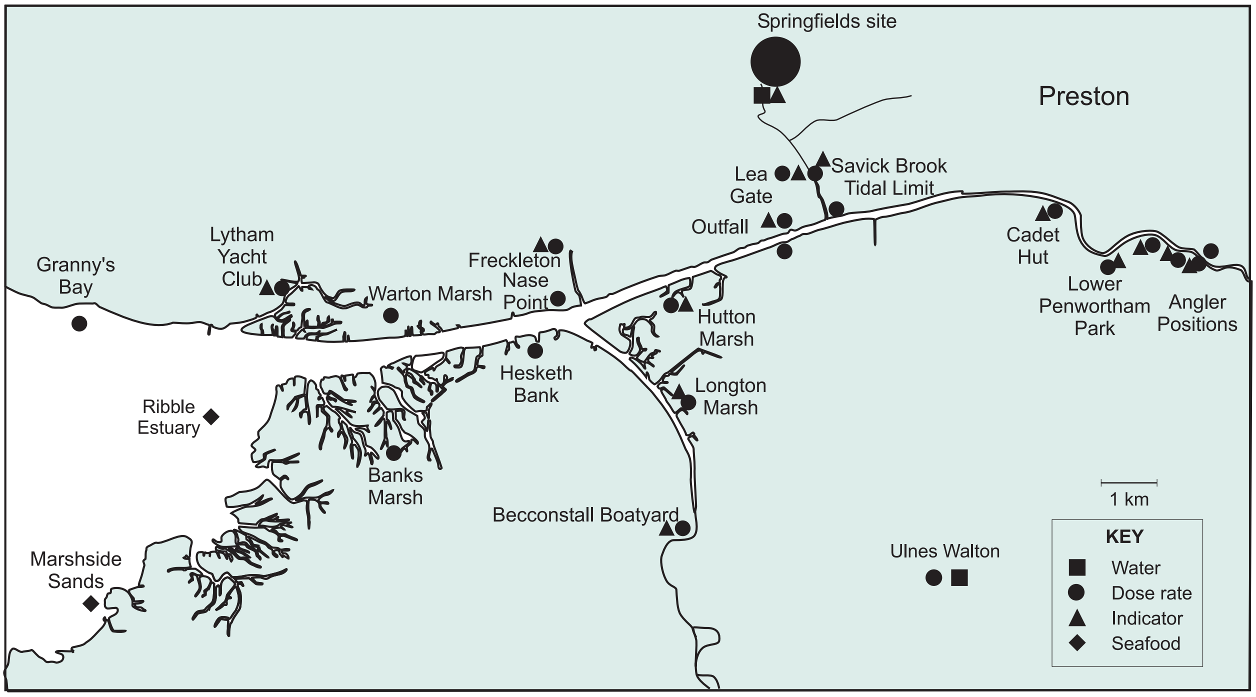

Figure 4.16 Monitoring locations at Springfields (excluding farms)

Results for 2002 are shown in Tables 4.18(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 4.17). 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.

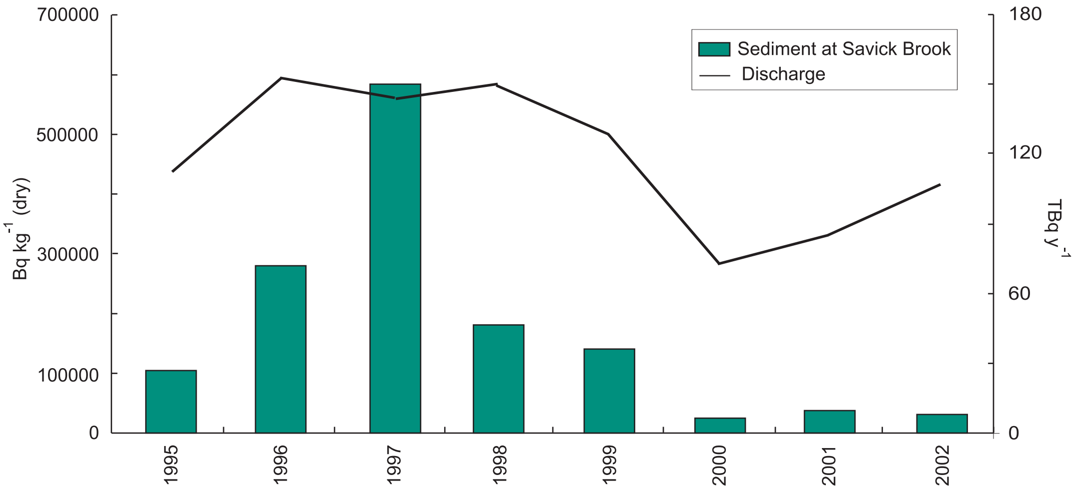

Figure 4.17 Total beta liquid discharge from Springfields and concentration in sediment at Savick Brook

Gamma dose rates throughout the estuary are enhanced above levels expected due to natural background. This is largely due to the historic effects of discharges from Sellafield. The results in 2002 were similar to those for 2001. 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 2002, the dose to houseboat dwellers was 0.12 mSv including a small contribution from inhalation of resuspended sediments and inadvertent ingestion of sediments. In 2001, it was similar (0.14 mSv).

The exposures of anglers and children playing were of lesser importance. Their doses were 0.015 mSv and <0.005 mSv, respectively, in 2002, similar to the values for 2001.

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 0.37 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 2001. The dose for the seafood consumption group was 0.017 mSv or less than 2% of the 1 mSv dose limit. The majority of the dose is attributable to Sellafield discharges transferred to the Springfields area with only a small percentage resulting from releases from the Springfields site itself.

In 2002, 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 2001 were detected. Concentrations in fresh water and sediment in Deepdale Brook, a small stream that passes through the site, were also unchanged. Freshwater from the vicinity of Ulnes Walton showed similar levels of uranium isotopes to those found in Deepdale Brook.

4.4 Capenhurst, Cheshire

The main functions undertaken on the Capenhurst site are enrichment of uranium and dismantling of redundant plant. The enrichment facility is operated by Urenco (Capenhurst) Ltd. Radioactive waste arisings consist of tritium, uranium plus its daughter products, technetium-99 and neptunium-237 (from recycled fuel). In 2002, BNFL had authorisations to dispose of small amounts of radioactivity in gaseous wastes via stacks and in liquid wastes to the Rivacre Brook. 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.

Results for 2002 are presented in Table 4.19(a) and (b). Concentrations of radionuclides in samples from the land and from the Rivacre Brook were generally similar to those for 2001. 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 0.011 mSv in 2002. The dose to high-rate seafood consumers would be less than the dose to children ingesting Rivacre Brook water and sediment. The dose to the critical group of terrestrial food consumers was less than 0.005 mSv in 2002.

4.5 Chapelcross, Dumfries and Galloway

BNFL operates four Magnox-type reactors at Chapelcross. Since 1980, the Chapelcross Processing Plant, which produces tritium, has also operated on this site. Gaseous wastes from the site are discharged to the local environment and liquid waste is discharged to the Solway Firth under authorisation from SEPA. Habits surveys have been used to investigate aquatic exposure pathways. The most recent survey was completed in 2000 and 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 now only of minor importance. Nevertheless, this situation could change and will be kept under review. Samples of seawater and *Fucus vesiculosus*, as useful 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 2002 are presented in Tables 4.20(a), (b) and (c). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to the effects of Sellafield discharges and are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides and gamma dose rates in intertidal areas remained at similar levels to those detected in recent years.

The dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.039 mSv in 2002 which was less than 4% of the dose limit for members of the public of 1 mSv. This is a small reduction on the level in 2001 (0.044mSv). Measurements of the contact beta dose-rate on fishing nets were below the limit of detection. A consideration of the discharges from Chapelcross indicates that they contribute a very small fraction of the total dose to the local population; the greater proportion of the dose can be attributed to the emissions from Sellafield.

Since 1992, a number of particles have been found at the end of the discharge outfall. Most of these particles are limescale and originate from deposits within the pipeline. Monitoring of this area continues, although work carried out by the operator in recent years has led to a progressive decline in the number of these particles being found in the environment. During 2002, three particles of limescale were found compared with 1 in 2001, 3 in 2000 and 10 in 1999.

Concentrations of radionuclides in milk and grass were generally similar to those observed in 2001. 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 presence of caesium-137 in geese is probably a result of grazing on salt marsh and is therefore marine-derived. 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 0.055 mSv, which was less than 6% of the dose limit for members of the public of 1 mSv. The annual dose contribution from argon-41, calculated from an atmospheric transport model (see Appendix 2) was 0.032 mSv, the remaining 0.023 mSv was from the consumption of terrestrial foods. In 2001, the annual dose from the consumption of terrestrial foods was 0.041 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 4.20(c)). The annual dose from inhaling air containing caesium-137 at these concentrations was estimated to be much less than 0.005 mSv.

Table 4.1. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2002

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}												
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Sellafield coastal area	Cod	6				0.29		<0.21	<0.19		<0.80	<0.26	10	<0.42	210
Sellafield coastal area	Plaice[a]	4	150	160		<0.16		<0.28	<0.33		<0.82	<0.10	4.2	<0.44	150
Sellafield coastal area	Bass	1				<0.09		<0.35	<0.46		<0.96	0.22	13	<0.61	
Sellafield coastal area	Mullet	1				0.13		<0.22	<0.22		<0.74	<0.08	7.5	<0.39	
Sellafield offshore area	Cod	2			160	<0.28	0.15	<0.28	<0.22	2.6	<1.2	<0.15	6.3	<0.46	
Sellafield offshore area	Plaice[b]	2			100	0.22	0.080	<0.09	<0.07	22	<0.40	0.06	6.8	<0.20	
Sellafield offshore area	Flounder	1				<0.36		<0.76	<0.60		<3.1	<0.34	12	<1.1	
Sellafield offshore area	Dab	2				0.36		<0.24	<0.20		<0.91	<0.12	9.3	<0.42	
Sellafield offshore area	Whiting	1				<0.15		<0.30	<0.27		<1.4	<0.15	9.1	<0.68	
Sellafield offshore area	Spurdog	1				<0.11		<0.31	<0.29		<1.1	<0.12	2.3	<0.70	
Sellafield offshore area	Lesser spotted dogfish	1				<0.07		<0.12	<0.10		<0.55	<0.06	9.2	<0.27	
Ravenglass	Cod	5				<0.18		<0.19	<0.17		<0.71	<0.18	8.6	<0.38	
Ravenglass	Plaice	4	140	160		<0.15		<0.22	<0.21		<0.81	<0.10	4.7	<0.41	
Ravenglass	Pollack	1				<0.11		<0.24	<0.21		<0.95	<0.11	12	<0.48	
Whitehaven	Cod	4			37	<0.07	0.058	<0.15	<0.11		<0.60	<0.07	4.6	<0.34	
Whitehaven	Plaice	4				<0.09	0.064	<0.22	<0.19		<0.78	<0.09	4.0	<0.40	
Whitehaven	Ray	4				<0.11		<0.30	<0.32		<1.0	<0.11	5.4	<0.46	
Parton	Cod	4				<0.14		<0.23	<0.22		<0.81	<0.10	9.8	<0.49	
Morecambe Bay (Flookburgh)	Flounder	4			97	<0.12		<0.44	<0.66		<1.3	<0.13	11	<0.83	
Morecambe Bay (Morecambe)	Plaice	4	32	32		<0.09	0.030	<0.28	<0.33	7.4	<0.84	<0.09	5.1	<0.49	
Morecambe Bay (Morecambe)	Bass	2				<0.10		<0.25	<0.25		<0.90	<0.10	14	<0.45	
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.07	0.17	<0.18	<0.20		<0.54	<0.07	4.5	<0.28	
River Calder	Brown trout	1				<0.13		<0.48	<0.57		<1.3	<0.14	4.9	<0.63	
Calder Farm	Rainbow trout	2				<0.09		<0.23	<0.23		<1.0	0.71	49	<0.53	
Local fish farm	Rainbow trout	1				<0.05		<0.11	<0.09		<0.45	<0.05	0.15	<0.21	
River Duddon	Sea trout	1				<0.10		<0.32	<0.36		<0.96	<0.10	6.6	<0.63	
River Kent	Sea trout	1				<0.07		<0.23	<0.26		<0.69	<0.07	1.1	<0.46	
River Derwent	Sea trout	1				<0.08		<0.35	<0.57		<0.73	<0.08	2.2	<0.47	
River Ehen	Sea trout	1				<0.07		<0.24	<0.26		<0.79	0.30	6.9	<0.49	
River Esk	Salmon	1				<0.15		<0.39	<0.42		<1.3	<0.13	0.50	<0.51	
Fleetwood	Cod	4			61	<0.09	0.023	<0.23	<0.22	0.44	<0.81	<0.09	4.4	<0.43	
Fleetwood	Plaice	4				<0.09		<0.22	<0.22		<0.79	<0.09	3.6	<0.41	
Isle of Man	Cod	4				<0.06		<0.17	<0.15		<0.56	<0.06	1.5	<0.33	
Isle of Man	Herring	4				<0.08		<0.42	<0.23		<0.79	<0.09	0.86	<0.45	
Inner Solway	Plaice	3				<0.11		<0.24	<0.21		<0.59	<0.11	2.0	<0.55	
Inner Solway	Mullet	2				<0.10		<0.30	<0.50		<0.54	<0.10	3.7	<0.35	
Inner Solway	Flounder	4		13	66	<0.10	0.76	<0.19	<0.19	32	<0.64	<0.10	13	<0.42	
Inner Solway	Lemon sole	2				<0.11		<0.37	<0.32		<0.87	<0.11	1.2	<0.55	
Inner Solway	Salmon	1		6.8		<0.10		<0.15	<0.16		<0.46	<0.10	0.24	<0.32	
Inner Solway	Sea trout	1		13		<0.10		<0.21	<0.19		<0.71	<0.10	4.1	<0.44	
North Solway	Cod	1	<25	<25	66	<0.05	0.022	<0.14	<0.15	0.58	<0.45	<0.05	2.7	<0.23	
Kirkcudbright	Plaice	3				<0.09		<0.28	<0.25		<0.85	<0.10	1.7	<0.49	
North Anglesey	Ray	4				<0.11		<0.27	<0.27		<1.1	<0.11	1.5	<0.45	
North Anglesey	Plaice	2	<25	<25	34	<0.05		<0.14	<0.13		<0.51	<0.06	1.6	<0.31	
Ribble Estuary	Flounder	1				<0.07		<0.29	<0.43		<0.71	<0.07	5.2	<0.37	
Ribble Estuary	Salmon	1				<0.15		<0.33	<0.28		<1.2	<0.16	0.26	<0.78	
Ribble Estuary	Bass	1				<0.13		<0.51	<0.87		<1.2	<0.12	6.8	<0.58	
Ribble Estuary	Sea trout	1				<0.09		<0.19	<0.16		<0.92	<0.10	3.5	<0.51	

Table 4.1. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Northern Ireland	Cod	8	36	<0.06		<0.19	<0.22	<0.58	<0.06	1.9	<0.32
Northern Ireland	Haddock	4		<0.06		<0.26	<0.43	<0.55	<0.06	1.2	<0.30
Northern Ireland	Whiting	7		<0.06		<0.27	<0.21	<0.56	<0.06	2.5	<0.29
Northern Ireland	Herring	4		<0.08		<0.25	<0.30	<0.72	<0.08	0.77	<0.38
Northern Ireland	Spurdog	8		<0.08		<0.28	<0.36	<0.79	<0.08	2.1	<0.42
West of Scotland	Mackerel	2		<0.09		<0.27	<0.29	<0.89	<0.10	<0.13	<0.51
Sound of Mull	Salmon	1		<0.05		<0.18	<0.18	<0.56	<0.06	0.31	<0.36
Minch	Cod	3	13	<0.04		<0.12	<0.13	<0.37	<0.04	0.51	<0.23
Minch	Plaice	3		<0.05		<0.15	<0.17	<0.43	<0.05	0.36	<0.25
Minch	Haddock	3		<0.05		<0.15	<0.15	<0.50	<0.06	0.47	<0.29
Minch	Herring	1		<0.08		<0.27	<0.31	<0.73	<0.09	0.30	<0.30
Minch	Mackerel	1	56	<0.12	<0.035	<0.22	<0.17	<1.1	<0.12	<0.13	<0.54
Shetland	Fish meal	4		<0.19	0.034	<0.46	<0.44	<1.7	<0.19	0.53	<0.83
Shetland	Fish oil	4		<0.10		<0.29	<0.31	<0.98	<0.11	<0.10	<0.55
Northern North Sea	Cod	4	23	<0.05	<0.027	<0.14	<0.15	<0.46	<0.05	0.54	<0.25
Northern North Sea	Plaice	4		<0.05		<0.16	<0.19	<0.49	<0.05	0.29	<0.23
Northern North Sea	Herring	3		<0.07		<0.25	<0.34	<0.67	<0.07	0.32	<0.36
Northern North Sea	Haddock	4	32	<0.05		<0.16	<0.17	<0.48	<0.05	0.31	<0.26
Mid North Sea	Cod	4	18	<0.06	<0.029	<0.17	<0.19	<0.49	<0.06	0.43	<0.23
Mid North Sea	Plaice	4	18	<0.05	<0.027	<0.15	<0.17	<0.46	<0.05	0.22	<0.24
Southern North Sea	Cod	1		<0.06	<0.027	<0.12	<0.09	<0.47	<0.06	0.42	<0.21
Southern North Sea	Plaice	2		<0.05	<0.029	<0.11	<0.09	<0.43	<0.05	0.22	<0.20
Southern North Sea	Herring	2		<0.08		<0.18	<0.17	<0.68	<0.08	0.39	<0.36
English Channel-East	Cod	4		<0.05	<0.028	<0.13	<0.12	<0.46	<0.05	0.20	<0.22
English Channel-East	Plaice	4		<0.05	<0.026	<0.12	<0.11	<0.45	<0.05	<0.14	<0.24
English Channel-West	Mackerel	4		<0.08		<0.23	<0.24	<0.74	<0.08	0.19	<0.38
English Channel-West	Plaice	4	23	<0.05	<0.034	<0.14	<0.14	<0.48	<0.05	<0.11	<0.27
English Channel-West	Whiting	4		<0.04	<0.027	<0.10	<0.09	<0.35	<0.04	0.31	<0.20
Gt Yarmouth (retail shop)	Cod	4		<0.05		<0.12	<0.11	<0.47	<0.05	0.21	<0.26
Gt Yarmouth (retail shop)	Plaice	4		<0.06		<0.13	<0.12	<0.48	<0.05	0.30	<0.23
Skagerrak	Cod	3		<0.05		<0.21	<0.27	<0.52	<0.06	0.41	<0.31
Skagerrak	Herring	3		<0.06		<0.24	<0.33	<0.62	<0.06	0.41	<0.35
Iceland area	Cod	2		<0.05		<0.12	<0.11	<0.47	<0.06	0.18	<0.21
Iceland processed	Cod	2	32	<0.05		<0.09	<0.07	<0.37	<0.04	0.20	<0.18
Barents Sea	Cod	4		<0.05		<0.28	<0.51	<0.50	<0.05	0.25	<0.27
Baltic Sea	Cod	3		<0.10		<0.34	<0.53	<0.91	<0.10	9.2	<0.45
Baltic Sea	Herring	3		<0.10		<0.38	<0.57	<0.95	<0.10	6.9	<0.48
Norwegian Sea	Cod	1		<0.04		<0.15	<0.19	<0.40	<0.04	0.25	<0.24
Norwegian Sea	Herring	1		<0.22		<0.79	<1.0	<2.1	<0.22	0.33	<0.74
Norwegian Sea	Saithe	1		<0.06		<0.23	<0.31	<0.59	<0.07	0.34	<0.25
Norwegian Sea	Mackerel	1		<0.13		<0.46	<0.57	<1.2	<0.12	0.12	<0.50
Celtic Sea	Cod	4	36	<0.05	<0.028	<0.13	<0.12	<0.46	<0.05	0.37	<0.25
Celtic Sea	Haddock	1		<0.07		<0.17	<0.16	<0.59	<0.07	0.11	<0.31
Celtic Sea	Whiting	1		<0.06		<0.18	<0.23	<0.50	<0.06	0.29	<0.21
Celtic Sea	Plaice	2		<0.05		<0.15	<0.16	<0.49	<0.05	<0.12	<0.28

[a] *The concentration of ^{147}Pm was 0.044 Bq kg^{-1}*
[b] *The concentration of ^{129}I was <0.31 Bq kg^{-1}*

Table 4.2. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2002

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Sellafield coastal area	Crabs[a]	8	71	78	160	<0.07	2.9	<0.20	1.2	<0.20	<0.24	47
Sellafield coastal area	Lobsters	8	120	120	230	<0.07	2.1	<0.23	0.57	<0.22	<0.28	4400
Sellafield coastal area[b]	Winkles	4			130	<0.14	9.4	<0.34	1.4	<0.41	<0.48	580
Sellafield coastal area[b]	Mussels	4				<0.10	6.7	<0.40	0.86	<0.30	<0.34	
Sellafield coastal area[b]	Limpets	4			99	<0.11	3.0	<0.29	6.1	<0.28	<0.28	650
Sellafield coastal area	Whelks	2			130	<0.10	2.5	<0.28	0.18	<0.39	<0.63	140
Sellafield offshore area	Whelks	2				<0.25	5.8	<0.71		<0.53	<0.44	
St Bees	Winkles[c]	4	<26	<29	180	<0.12	14	<0.29	13	<0.46	<0.96	980
St Bees	Mussels	4				<0.09	6.6	<0.44		<0.30	<0.38	
St Bees	Limpets	4				<0.12	4.4	<0.32		<0.40	<0.42	
Nethertown	Winkles	12	<25	<25	200	<0.16	13	<0.46	7.9	<0.51	<0.52	540
Nethertown	Mussels	4	130	130	240	<0.12	10	<0.66		<0.27	<0.25	1800
Seascale	Sea mouse[d]	1				<0.38	61	<0.87	4.0	<0.64	<0.48	290
Whitriggs	Shrimps	1				<0.20	0.59	<0.52		<0.68	<0.77	
Drigg	Winkles	4			260	<0.15	13	<0.38		<0.32	<0.31	590
Ravenglass	Crabs	4				<0.08	1.2	<0.20	0.56	<0.27	<0.34	24
Ravenglass	Lobsters	6				<0.07	1.4	<0.19	0.26	<0.21	<0.27	2600
Ravenglass	Winkles	2				<0.11	6.0	<0.27		<0.26	<0.26	
Ravenglass	Cockles	4			190	<0.10	16	<0.27	2.0	<0.27	<0.27	64
Ravenglass	Mussels	4		100		<0.09	5.6	<0.36		<0.22	<0.21	1800
Tarn Bay	Winkles	2				<0.15	7.3	<0.38		<0.35	<0.31	
Saltom Bay	Winkles	4				<0.12	5.3	<0.31		<0.30	<0.32	
Whitehaven	*Nephrops*	4	28	29	79	<0.09	<0.11	<0.24	0.11	<0.25	<0.26	590
Whitehaven	Whelks	2			110	<0.09	1.7	<0.25	0.10	<0.23	<0.23	
Silloth	Mussels	4		<25		<0.07	1.1	<0.19		<0.23	<0.28	
Parton	Crabs	4			120	<0.15	1.6	<0.38		<0.43	<0.43	
Parton	Lobsters	4				<0.08	0.89	<0.21		<0.25	<0.36	
Parton	Winkles	4	<25	<25		<0.13	5.5	<0.32		<0.28	<0.25	
Parton	Mussels	2	38	56								
Haverigg	Cockles	2				<0.07	5.1	<0.18		<0.54	<0.60	
Millom	Mussels	2				<0.06	1.2	<0.16		<0.16	<0.17	
Red Nab Point	Winkles	4				<0.16	0.91	<0.15		<0.15	<0.14	
Morecambe Bay (Flookburgh)	Shrimps	4			110	<0.07	<0.07	<17		<0.20	<0.23	6.6
Morecambe Bay (Morecambe)	Mussels	4	<35	53	77	<0.07	0.57	<0.17		<0.18	<0.17	710
Morecambe Bay (Flookburgh)	Cockles	4			100	<0.06	1.4	<0.15	0.31	<0.19	<0.24	87
Morecambe Bay (Middleton Sands)	Cockles	2				<0.06	2.0	<0.15		<0.18	<0.19	

Table 4.2. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	Total beta
Sellafield coastal area	Crabs[a]	8	<2.2	0.96	<0.47	<0.07	1.8	<0.44	0.81	<0.19	<0.13	130
Sellafield coastal area	Lobsters	8	<1.2	1.8	<0.31	<0.08	2.7	<0.44	0.41	<0.22	<0.21	2800
Sellafield coastal area[b]	Winkles	4	21	1.9	2.2	<0.14	3.6	<1.5	1.7	<0.36	<0.39	
Sellafield coastal area[b]	Mussels	4	13	<0.20	1.7	<0.10	2.5	<0.97		<0.22	<0.24	
Sellafield coastal area[b]	Limpets	4	<9.4	<1.0	6.1	<0.12	5.8	<0.67		<0.35	<0.19	
Sellafield coastal area	Whelks	2	4.1	1.8	0.63	<0.10	1.1	<0.59		<0.25	<0.26	
Sellafield offshore area	Whelks	2	<11	3.0	<0.86	<0.27	1.9	<1.1		<0.76	<0.50	
St Bees	Winkles[c]	4	51	5.2	3.8	<0.11	16	6.7	8.5	<6.4	<0.41	
St Bees	Mussels	4	24	<0.19	2.0	<0.10	2.9	2.5		<0.28	<0.28	
St Bees	Limpets	4	21	2.8	6.1	<0.14	10	3.0		<0.43	<0.38	
Nethertown	Winkles	12	44	6.8	3.5	<0.18	13	<4.0	20	<0.48	<0.44	650
Nethertown	Mussels	4	24	<0.30	3.0	<0.12	3.6	1.6		<0.34	<0.25	1300
Seascale	Sea mouse[d]	1	24	<0.63	24	<0.38	19	6.6		<0.90	1.3	
Whitriggs	Shrimps	1	<2.2	<0.38	<0.51	<0.22	2.8	<1.1		<0.53	<0.47	
Drigg	Winkles	4	32	5.0	2.7	<0.16	7.4	1.9	1.8	<0.41	<0.30	720
Ravenglass	Crabs	4	<0.75	<0.31	<0.20	<0.08	1.4	<0.47		<0.21	<0.22	110
Ravenglass	Lobsters	6	<1.2	1.4	<0.24	<0.08	2.1	<0.55		<0.22	<0.20	2100
Ravenglass	Winkles	2	11	2.2	1.9	<0.12	5.7	0.62		<0.30	<0.24	
Ravenglass	Cockles	4	12	<0.22	0.89	<0.11	5.0	1.8		<0.35	<0.22	200
Ravenglass	Mussels	4	12	<0.18	1.7	<0.10	2.2	<0.96		<0.26	<0.24	
Tarn Bay	Winkles	2	9.8	1.9	1.5	<0.17	6.1	<0.84		<0.43	<0.45	
Saltom Bay	Winkles	4	12	2.2	4.2	<0.14	8.0	<0.65		<0.37	<0.31	
Whitehaven	*Nephrops*	4	<0.90	<0.17	<0.24	<0.10	3.9	<0.40		<0.29	<0.18	520
Whitehaven	Whelks	2	1.8	0.53	<0.43	<0.09	1.4	<0.40		<0.29	<0.19	210
Silloth	Mussels	4	2.6	<0.14	0.63	<0.08	4.6	<0.39		<0.22	<0.18	
Parton	Crabs	4	<1.9	<0.50	<0.43	<0.16	1.9	<0.79		<0.43	<0.38	
Parton	Lobsters	4	<0.83	<0.53	<0.23	<0.09	2.6	<0.40		<0.24	<0.18	
Parton	Winkles	4	11	<1.2	1.7	<0.15	11	<1.1		<0.38	<0.30	
Parton	Mussels	2										
Haverigg	Cockles	2	2.9	<0.14	0.40	<0.08	3.7	<0.27		<0.17	<0.13	
Millom	Mussels	2	3.5	<0.12	0.73	<0.06	2.1	<0.30		<0.18	<0.14	
Red Nab Point	Winkles	4	2.2	<0.14	0.97	<0.07	5.0	<0.30		<0.18	<0.15	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.67	<0.12	<0.19	<0.07	4.5	<0.40		<0.20	<0.19	
Morecambe Bay (Morecambe)	Mussels	4	1.7	<0.13	0.60	<0.07	3.5	<0.36		<0.20	<0.18	
Morecambe Bay (Flookburgh)	Cockles	4	<1.1	<0.11	0.46	<0.07	3.7	<0.31		<0.17	<0.15	
Morecambe Bay (Middleton Sands)	Cockles	2	2.1	<0.11	0.40	<0.07	4.0	<0.26		<0.17	<0.15	

Table 4.2. 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
Fleetwood	Lobsters	2				<0.07	0.40	<0.19		<0.30	<0.55	990
Fleetwood	Squid	1				<0.05	<0.05	<0.14		<0.14	<0.13	
Fleetwood	Whelks	4			78	<0.07	<0.17	<0.17	<0.044	<0.17	<0.16	9.2
Isle of Man	Lobsters	4				<0.04	<0.05	<0.11		<0.10	<0.08	180
Isle of Man	Scallops	4				<0.04	<0.08	<0.12		<0.11	<0.10	
Inner Solway	Shrimps	4	<24	9.9		<0.11	<0.12	<0.24	0.88	<0.29	<0.31	<23
Southerness	Winkles	4	<6.1	<9.4		<0.13	2.2	<0.33	1.7	<0.38	<0.46	<1.6
Kirkcudbright	Scallops	7				<0.08	<0.08	<0.12		<0.12	<0.12	
Kirkcudbright	Queens	8				<0.06	<0.08	<0.11		<0.11	<0.10	
North Solway coast	Crabs	8	<25	<27	83	<0.10	0.67	<0.23	0.60	<0.24	<0.26	34
North Solway coast	Lobsters	8			73	<0.13	<0.31	<0.33	0.56	<0.36	<0.34	1100
North Solway coast	Winkles	8				<0.09	1.6	<0.17	1.8	<0.16	<0.16	580
North Solway coast	Cockles	5		<5.0	72	<0.07	2.1	<0.18	0.75	<0.17	<0.15	25
North Solway coast	Mussels	8		14	91	<0.08	0.79	<0.13	0.47	<0.13	<0.13	270
North Solway coast	Razor shells	1				<0.04	0.26	<0.11		<0.11	<0.13	
Wirral	Shrimps	2		<25		<0.04	<0.05	<0.12		<0.13	<0.13	16
Wirral	Cockles	4				<0.04	0.14	<0.09		<0.10	<0.09	16
Liverpool Bay	Mussels	2		<25								
Mersey Estuary	Mussels	2		<25								
Ribble Estuary	Shrimps	2			56	<0.06	<0.07	<0.15		<0.13	<0.11	3.2
Ribble Estuary	Cockles	2				<0.09	0.51	<0.23		<0.26	<0.28	
Ribble Estuary	Mussels	1				<0.06	0.25	<0.13		<0.15	<0.16	
Knott End	Cockles	1				<0.04	1.8	<0.09		<0.09	<0.08	
North Anglesey	Crabs	2				<0.05	<0.06	<0.12		<0.13	<0.11	9.1
North Anglesey	Lobsters	2				<0.07	<0.07	<0.17		<0.16	<0.13	33
Conwy	Mussels	2			35	<0.05	<0.05	<0.11		<0.12	<0.11	
Northern Ireland	Crabs	3				<0.11	<0.11	<0.28		<0.34	<0.39	
Northern Ireland	Lobsters	8			27	<0.12	<0.13	<0.32		<0.44	<0.62	120
Northern Ireland	*Nephrops*	8			25	<0.12	<0.11	<0.29		<0.38	<0.47	39
Northern Ireland	Winkles	4				<0.08	<0.10	<0.18		<0.24	<0.29	
Northern Ireland	Mussels	2			20	<0.11	<0.12	<0.27		<0.39	<0.46	37
Skye	Lobsters	1				<0.10	<0.10	<0.23		<0.23	<0.18	
Skye	Mussels	1				<0.10	<0.10	<0.26		<0.27	<0.26	
Islay	Crabs	1				<0.10	<0.10	<0.10		<0.10	<0.10	
Islay	Scallops	1				<0.10	<0.10	<0.13		<0.12	<0.10	
Minch	*Nephrops*	3				<0.10	<0.10	<0.28		<0.33	<0.39	8.0
Northern North Sea	*Nephrops*	3				<0.13	<0.14	<0.34		<0.40	<0.46	8.1
Southern North Sea	Cockles	2				<0.03	<0.12	<0.08		<0.09	<0.08	
Southern North Sea	Mussels	4			30	<0.03	<0.03	<0.07		<0.09	<0.09	1.7
Southern North Sea	Cockles[e]	2				<0.09	<0.11	<0.22		<0.21	<0.17	0.12
Southern North Sea	Mussels[e]	2				<0.04	<0.04	<0.10		<0.11	<0.09	
Cromer	Crabs	1				<0.07	<0.07	<0.17		<0.23	<0.25	
English Channel-East	Scallops	4			27	<0.08	<0.10	<0.21		<0.23	<0.23	
English Channel-West	Crabs	4			25	<0.11	<0.11	<0.26		<0.40	<0.58	
English Channel-West	Lobsters	4				<0.11	<0.12	<0.28		<0.31	<0.32	0.19
English Channel-West	Scallops	4			20	<0.11	<0.12	<0.30		<0.29	<0.27	

Table 4.2. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	Total beta
Fleetwood	Lobsters	2	<0.67	0.43	<0.16	<0.07	1.7	<0.34	<0.21	<0.15	860
Fleetwood	Squid	1	<0.45	<0.09	<0.11	<0.05	0.60	<0.20	<0.17	<0.09	
Fleetwood	Whelks	4	<0.65	<0.12	<0.18	<0.07	0.81	<0.38	<0.20	<0.19	
Isle of Man	Lobsters	4	<0.43	<0.08	<0.12	<0.05	0.37	<0.28	<0.14	<0.14	200
Isle of Man	Scallops	4	<0.38	<0.08	<0.10	<0.05	0.31	<0.19	<0.16	<0.09	
Inner Solway	Shrimps	4	<0.68	<0.15	<0.35	<0.10	4.6	<0.56	<0.13	<0.25	
Southerness	Winkles	4	<3.0	<0.56	1.1	<0.12	1.7	<0.65	<0.15	<0.28	
Kirkcudbright	Scallops	7	<0.36	<0.09	<0.11	<0.08	<0.19	<0.23	<0.11	<0.12	
Kirkcudbright	Queens	8	<0.37	<0.08	<0.10	<0.06	0.22	<0.23	<0.10	<0.11	
North Solway coast	Crabs	8	<0.85	<0.15	<0.22	<0.10	1.3	0.44	<0.20	<0.19	
North Solway coast	Lobsters	8	<1.3	<0.21	<0.33	<0.13	1.9	<0.66	<0.29	<0.29	
North Solway coast	Winkles	8	<1.4	<0.19	<0.75	<0.09	1.7	<0.36	<0.18	<0.17	
North Solway coast	Cockles	5	<1.1	<0.12	<0.32	<0.07	4.0	<0.35	<0.16	<0.17	
North Solway coast	Mussels	8	<1.1	<0.15	0.41	<0.08	2.0	<0.22	<0.14	<0.12	
North Solway coast	Razor shells	1	<0.34	<0.07	<0.09	<0.04	0.91	<0.17	<0.13	<0.07	
Wirral	Shrimps	2	<0.43	<0.08	<0.12	<0.05	2.2	<0.21	<0.14	<0.09	
Wirral	Cockles	4	<0.42	<0.07	<0.12	<0.05	1.5	<0.23	<0.12	<0.12	
Liverpool Bay	Mussels	2									
Mersey Estuary	Mussels	2									
Ribble Estuary	Shrimps	2	<0.58	<0.11	<0.16	<0.07	2.5	<0.32	<0.19	<0.17	
Ribble Estuary	Cockles	2	<0.88	<0.16	<0.22	<0.10	2.4	<0.39	<0.25	<0.19	
Ribble Estuary	Mussels	1	<0.59	<0.10	0.25	<0.06	2.5	<0.36	<0.17	<0.19	
Knott End	Cockles	1	1.2	<0.07	0.35	<0.04	2.9	<0.25	<0.11	<0.12	
North Anglesey	Crabs	2	<0.51	<0.10	<0.14	<0.06	0.48	<0.31	<0.16	<0.15	
North Anglesey	Lobsters	2	<0.64	<0.12	<0.17	<0.08	0.17	<0.41	<0.20	<0.22	100
Conwy	Mussels	2	<0.46	<0.08	<0.12	<0.05	0.24	<0.27	<0.14	<0.13	
Northern Ireland	Crabs	3	<1.1	<0.20	<0.27	<0.11	0.27	<0.54	<0.30	<0.23	
Northern Ireland	Lobsters	8	<1.3	<0.22	<0.29	<0.12	0.34	<0.53	<0.37	<0.21	
Northern Ireland	*Nephrops*	8	<1.1	<0.21	<0.26	<0.11	0.97	<0.51	<0.34	<0.22	
Northern Ireland	Winkles	4	<0.74	<0.14	<0.19	<0.08	<0.30	<0.37	<0.22	<0.18	
Northern Ireland	Mussels	2	<1.2	<0.21	<0.28	<0.12	0.46	<0.58	<0.30	<0.26	
Skye	Lobsters	1	<0.77	<0.10	<0.22	<0.10	0.26	<0.49	<0.11	<0.21	
Skye	Mussels	1	<0.88	<0.10	<0.24	<0.10	<0.10	<0.51	<0.12	<0.22	
Islay	Crabs	1	<0.23	<0.10	<0.10	<0.10	0.26	<0.15	<0.10	<0.10	
Islay	Scallops	1	<0.40	<0.10	<0.11	<0.10	0.27	<0.27	<0.10	<0.13	
Minch	*Nephrops*	3	<1.0	<0.19	<0.23	<0.10	0.29	<0.41	<0.32	<0.16	
Northern North Sea	*Nephrops*	3	<1.4	<0.23	<0.30	<0.13	<0.17	<0.52	<0.40	<0.21	
Southern North Sea	Cockles	2	<0.32	<0.06	<0.09	<0.04	0.18	<0.19	<0.10	<0.09	
Southern North Sea	Mussels	4	<0.30	<0.05	<0.08	<0.03	0.11	<0.17	<0.08	<0.07	
Southern North Sea	Cockles[e]	2	<0.90	<0.16	<0.21	<0.10	<0.16	<0.36	<0.26	<0.17	
Southern North Sea	Mussels[e]	2	<0.41	<0.07	<0.11	<0.04	<0.04	<0.24	<0.12	<0.11	41
Cromer	Crabs	1	<0.70	<0.13	<0.18	<0.08	0.23	<0.47	<0.22	<0.24	
English Channel-East	Scallops	4	<0.83	<0.15	<0.19	<0.09	<0.08	<0.34	<0.26	<0.15	
English Channel-West	Crabs	4	<1.1	<0.20	<0.25	<0.11	<0.09	<0.53	<0.30	<0.23	
English Channel-West	Lobsters	4	<1.2	<0.20	<0.27	<0.12	<0.11	<0.50	<0.34	<0.22	
English Channel-West	Scallops	4	<1.1	<0.19	<0.24	<0.11	<0.10	<0.43	<0.36	<0.20	

[a] *The concentration of ^{129}I was <0.37 Bq kg^{-1}*
[b] *Samples collected by Consumers 116 and 971*
[c] *The concentration of ^{129}I was <0.87 Bq kg^{-1}*
[d] *Aphrodite aculeata, an annelid worm. No evidence of consumption was found in 2002*
[e] *Landed in Holland*

Table 4.3. Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2002

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Sellafield coastal area	Cod	2		0.0015	0.0070		0.013	0.000090	0.000026
Sellafield coastal area	Plaice	1		0.0022	0.011		0.022	0.000059	0.000030
Sellafield coastal area	Bass	1					<0.26		
Sellafield coastal area	Mullet	1					<0.10		
Sellafield coastal area	Crabs	2	0.0031	0.073	0.33	3.7	1.5	<0.0010	<0.0023
Sellafield coastal area	Lobsters	2	0.019	0.059	0.29	3.6	3.6	<0.0021	0.0077
Sellafield coastal area	Winkles[a]	1	0.011	0.93	4.4	50	9.3	*	0.015
Sellafield coastal area	Mussels[a]	1		1.5	7.4	80	16	0.030	0.039
Sellafield coastal area	Limpets[a]	1		1.4	6.3	72	11	0.029	0.011
Sellafield coastal area	Whelks	1		0.38	2.0	20	4.5	*	0.0060
Sellafield offshore area	Cod	1		0.017	0.081		0.13	0.00039	0.00024
Sellafield offshore area	Plaice	1	0.00019	0.0029	0.015		0.035	0.00016	0.000082
Sellafield offshore area	Flounder	1					<0.27		
Sellafield offshore area	Dab	2					<0.31		
Sellafield offshore area	Whiting	1					<0.33		
Sellafield offshore area	Spurdog	1					<0.50		
Sellafield offshore area	Lesser spotted dogfish	1					0.16		
Sellafield offshore area	Whelks	1		0.47	2.3	25	7.4	*	0.021
St Bees	Winkles	1	0.040	4.8	22	260	39	0.17	0.078
St Bees	Mussels	2		1.5	7.0	82	15	0.062	0.039
St Bees	Limpets	1		2.4	12		24	0.065	0.036
Nethertown	Winkles	4	0.070	3.8	18	210	33	<0.077	0.079
Nethertown	Mussels	4		2.2	10		21	<0.038	0.038
River Ehen	Sea trout	1					<0.21		
River Calder	Brown trout	1					<0.35		
Calder Farm	Rainbow trout	2					<0.21		
Local fish farm	Rainbow trout	1					<0.05		
Seascale	Sea mouse[b]	1		10	52		140	0.12	0.21
Whitriggs	Shrimps	1					<0.42		
Drigg	Winkles	1	0.020	2.1	10	100	20	0.039	0.031
Ravenglass	Cod	1		0.00037	0.0017		0.0038	*	0.0000092
Ravenglass	Plaice	1		0.0032	0.016		0.033	0.000070	0.000064
Ravenglass	Pollack	1					<0.30		
Ravenglass	Crabs	1		0.024	0.14	1.3	1.0	*	0.0015
Ravenglass	Lobsters	1		0.060	0.29	2.9	5.4	*	0.0092
Ravenglass	Winkles	2					17		
Ravenglass	Cockles	1		2.1	9.7	100	28	0.063	0.088
Ravenglass	Mussels	1		1.1	5.8	61	13	0.047	0.016
River Esk	Salmon	1					<0.13		
Tarn Bay	Winkles	1		2.0	9.7	93	20	*	0.028
Saltom Bay	Winkles	4					15		
Whitehaven	Cod	1		0.00031	0.0015		0.0028	0.000014	0.000023
Whitehaven	Plaice	1		0.00075	0.0040		0.013	*	0.000022
Whitehaven	Ray	1		0.00036	0.0020		0.0037	*	*
Whitehaven	*Nephrops*	1		0.032	0.16		0.81	*	0.0012
Whitehaven	Whelks	1		0.27	1.4	14	2.5	*	0.0058
Silloth	Mussels	1		1.0	5.1		9.6	*	0.018
Parton	Cod	4					<0.32		
Parton	Crabs	4					<1.2		
Parton	Lobsters	4					1.5		
Parton	Winkles	1		1.8	9.0	90	17	*	0.034
Haverigg	Cockles	1		0.73	4.1		13	0.021	0.020
Millom	Mussels	2					4.8		
Red Nab Point	Winkles	1		0.35	1.9		3.5	*	0.0048

Table 4.3. 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
Morecambe Bay (Flookburgh)	Flounder	1	0.00044	0.0025		0.0047	*	*
Morecambe Bay (Flookburgh)	Shrimps	1	0.0024	0.016	0.086	0.021	*	*
Morecambe Bay (Flookburgh)	Cockles	1	0.45	2.5	22	6.6	*	0.010
Morecambe Bay (Morecambe)	Plaice	4				<0.23		
Morecambe Bay (Morecambe)	Bass	2				<0.21		
Morecambe Bay (Morecambe)	Mussels	1	0.30	1.7		3.0	*	0.0024
Morecambe Bay (Sunderland Point)	Whitebait	1	0.054	0.30	2.7	0.51	*	0.00072
Morecambe Bay (Middleton Sands)	Cockles		0.52	3.0		6.7	*	0.011
River Duddon	Sea trout	1				<0.47		
River Kent	Sea trout	1				<0.20		
River Derwent	Sea trout	1				<0.29		
Fleetwood	Cod	1	0.00076	0.0042		0.0011	*	*
Fleetwood	Plaice	1	0.00029	0.0018		0.0028	*	*
Fleetwood	Lobsters	2				1.10		
Fleetwood	Squid	1				<0.05		
Fleetwood	Whelks	1	0.056	0.31	2.8	0.44	*	0.0012
Isle of Man	Cod	1	0.00011	0.00056		0.0077	0.000020	*
Isle of Man	Herring	1	0.000056	0.00030		0.00045	*	*
Isle of Man	Lobsters	4				<0.19		
Isle of Man	Scallops	1	0.014	0.078		0.065	0.00022	0.00015
Inner Solway	Plaice	3				<0.18		
Inner Solway	Mullet	2				<0.11		
Inner Solway	Flounder	1	0.020	0.11		0.23		
Inner Solway	Lemon sole	2				<0.14		
Inner Solway	Salmon	1				<0.16		
Inner Solway	Sea trout	1	<0.0052	<0.0052		<0.0038		
Inner Solway	Shrimps	1	0.0036	0.014		0.034		
Southerness	Winkles	1	0.32	1.6	15	3.1		
Kirkcudbright	Plaice	1	<0.0016	0.0081		0.020		
Kirkcudbright	Scallops	2	0.011	0.056		<0.081	*	*
Kirkcudbright	Queens	2	0.0081	0.043		0.048	*	*
North Solway coast	Cod	1	0.00023	0.0011		0.0020	*	*
North Solway coast	Crabs	2	0.044	0.22	2.0	0.89	*	0.00098
North Solway coast	Lobsters	2	0.023	0.11	1.1	0.59	*	0.0017
North Solway coast	Winkles	2	0.34	1.7	16	2.9	*	0.0048
North Solway coast	Cockles	4	0.71	3.8	36	11	<0.0061	0.020
North Solway coast	Mussels	2	0.50	2.6	20	4.9	0.013	0.0094
North Solway coast	Razor shells	1				2.4		
Wirral	Shrimps	2				<0.05		
Wirral	Cockles	1	0.11	0.64		1.8	*	*
Knott End	Cockles	1	0.34	1.8		5.0	*	0.010
Ribble Estuary	Flounder	1				<0.08		
Ribble Estuary	Salmon	1				<0.62		
Ribble Estuary	Bass	1				<0.30		
Ribble Estuary	Sea trout	1				<0.25		
Ribble Estuary	Shrimps[c]	1	0.0016	0.0095		0.018	*	0.000059
Ribble Estuary	Cockles	1	0.19	1.1		2.8	0.0022	0.0034
Ribble Estuary	Mussels	1				2.4		
North Anglesey	Rays	1	0.000042	0.00030		0.00043	*	*
North Anglesey	Plaice	2				<0.20		
North Anglesey	Crabs	1	0.0045	0.026		0.072	0.000070	0.000093
North Anglesey	Lobsters	2				<0.33		
Conwy	Mussels	1	0.016	0.097		0.18	*	0.00020

Table 4.3. 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	Cod	8			<0.23		
Northern Ireland	Haddock	4			<0.19		
Northern Ireland	Whiting	1	0.0010	0.0067	0.012	0.000026	0.000022
Northern Ireland	Herring	4			<0.25		
Northern Ireland	Spurdog	8			<0.21		
Northern Ireland	Crabs	3			<0.18		
Northern Ireland	Lobsters	8			<0.17		
Northern Ireland	*Nephrops*	1	0.0044	0.027	0.20	*	*
Northern Ireland	Winkles	1	0.030	0.16	0.19	0.00044	0.00018
Northern Ireland	Mussels	2			<0.32		
West of Scotland	Mackerel	2			<0.36		
Sound of Mull	Salmon	1			<0.16		
Skye	Lobsters	1			<0.14		
Skye	Mussels	1			<0.14		
Islay	Crabs	1			<0.10		
Islay	Scallops	1			<0.12		
Minch	Cod	1	0.000021	0.000080	0.00013	*	*
Minch	Plaice	3			<0.12		
Minch	Haddock	1	0.000021	0.00012	0.00012	*	*
Minch	Herring	1			<0.07		
Minch	Mackerel	1	0.000024	0.00019	0.00014	*	*
Minch	*Nephrops*	1	0.00026	0.0018	0.0052	*	*
Shetland	Fish meal	1	0.000037	0.00093	0.00041	*	*
Shetland	Fish oil	4			<0.13		
Northern North Sea	Cod	1	0.000054	0.00034	0.00043	*	*
Northern North Sea	Plaice	4			<0.06		
Northern North Sea	Herring	3			<0.20		
Northern North Sea	Haddock	1	0.000090	0.00058	0.00065	*	*
Northern North Sea	*Nephrops*	1	0.00012	0.0012	0.0017	*	*
Mid North Sea	Cod	4			<0.08		
Mid North Sea	Plaice	4			<0.14		
Southern North Sea	Cod	1			<0.06		
Southern North Sea	Plaice	2			<0.09		
Southern North Sea	Herring	2			<0.20		
Southern North Sea	Cockles	1	0.0025	0.016	0.0087	*	0.000032
Southern North Sea	Cockles[d]	1	0.0027	0.013	0.019	0.00010	0.00049
Southern North Sea	Mussels	1	0.0029	0.019	0.0065	0.000013	0.000015
Southern North Sea	Mussels[d]	1	0.0015	0.0068	0.0098	*	0.00019
Cromer	Crabs	1			<0.36		
English Channel-East	Cod	4			<0.11		
English Channel-East	Plaice	4			<0.14		
English Channel-East	Scallops	1	0.00077	0.0032	0.0014	*	0.00012
English Channel-West	Mackerel	4			<0.15		
English Channel-West	Plaice	4			<0.15		
English Channel-West	Whiting	4			<0.10		
English Channel-West	Crabs	1	0.00014	0.0011	0.0017	*	0.00014
English Channel-West	Lobsters	2			<0.15		
English Channel-West	Scallops	1	0.00016	0.0034	0.0011	*	*
Gt. Yarmouth (retail shop)	Cod	4			<0.14		
Gt. Yarmouth (retail shop)	Plaice	4			<0.13		
Skagerrak	Cod	3			<0.18		
Skagerrak	Herring	3			<0.16		
Iceland Area	Cod	2			<0.10		
Icelandic processed	Cod	1	0.000023	0.00014	0.00034	*	*
Barents Sea	Cod	4			<0.11		
Baltic Sea	Cod	3			<0.23		
Baltic Sea	Herring	3			<0.20		
Norwegian Sea	Cod	1			<0.10		
Norwegian Sea	Herring	1			<0.15		
Norwegian Sea	Saithe	1			<0.06		
Norwegian Sea	Mackerel	1			<0.10		
Celtic Sea	Cod	4			<0.17		
Celtic Sea	Haddock	1			<0.20		
Celtic Sea	Whiting	1			<0.06		
Celtic Sea	Plaice	2			<0.15		

** Not detected by the method used*
[a] Samples collected by Consumer 971
[b] Aphrodite aculeata, an annelid worm. No evidence of consumption was found in 2002
[c] The concentration of ^{237}Np was 0.00012 Bq kg^{-1}
[d] Landed in Holland

Table 4.4. Individual radiation exposures due to consumption of Irish Sea fish and shellfish, 2002

Exposed population[b]	Foodstuffs consumed	Exposure mSv[a]													
		Total [c]	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am	Others	External
Sellafield fishing community (1998-2002 habits)	Fish Crabs, lobsters and *Nephrops* Winkles and mussels	0.19	0.007		0.003	0.030	0.004	0.003	0.005	0.006	0.033	0.007	0.062	<0.003	0.028
Sellafield fishing community (2002 habits)	Cod and other fish Crabs, lobsters and *Nephrops* Winkles and mussels	0.24	0.008	0.001	0.005	0.032	0.006	0.003	0.007	0.009	0.046	0.009	0.079	<0.002	0.030
Whitehaven commercial fisheries	Plaice and cod *Nephrops* Whelks	0.026	0.001			0.004			0.003	0.001	0.006	0.001	0.009	<0.002	
Dumfries and Galloway	Fish Crabs, lobster and *Nephrops* Whelks and king scallops	0.045	0.003			0.008		0.001	0.002		0.001		0.003	<0.001	0.025
Morecambe Bay	Mixed fish Shrimps Cockles and other molluscs	0.066	0.003			0.005			0.006	0.002	0.011	0.002	0.021	<0.002	0.015
Fleetwood	Plaice and cod Shrimps Whelks	0.018	0.004						0.007		0.002		0.002	<0.003	
Isle of Man	Fish and shellfish	0.007				0.002			0.002				0.001	<0.002	
Northern Ireland	Haddock and other fish *Nephrops* and crabs Mussels and other molluscs	0.012				0.001			0.002				0.002	<0.004	0.003
North Wales	Fish and Shellfish	0.014							0.003					<0.005	0.007
Typical member of the fish eating public consuming fish landed at Whitehaven and Fleetwood	Plaice and cod	0.001												<0.002	

[a] *Due to artificial radionuclides: see text for exposures due to natural radionuclides. Blank data indicate a dose of less than 0.001 mSv. 'Others' comprises data for all radionuclides with doses below 0.001 mSv*

[b] *Representative of people most exposed unless stated otherwise. Adults are the most exposed age group*

[c] *Including external exposure where stated*

Table 4.5. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2002

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, $\mu Gy\ h^{-1}$
Cumbria			
Rockcliffe Marsh	Salt marsh	4^F	0.065
Rockcliffe Marsh	Marsh	1	0.093
Burgh Marsh	Marsh	1	0.081
Port Carlisle 1	Mud and salt marsh	3	0.093
Port Carlisle 2	Mud and salt marsh	1	0.11
Port Carlisle 3	Mud and salt marsh	2	0.098
Greenend 1	Salt marsh	2	0.091
Greenend 2	Mud and sand	1	0.090
Greenend 3	Mud and salt marsh	3	0.098
Cardurnock Marsh	Salt marsh	4	0.084
Newton Arlosh	Salt marsh	4^F	0.10
Newton Arlosh	Salt marsh	4	0.10
Silloth harbour	Mud and stones	4	0.10
Silloth silt pond	Grass	4	0.086
Allonby	Sand	4	0.098
Maryport harbour	Mud, sand and stones	2	0.10
Parton	Winkle bed	4^F	0.086
Workington harbour	Mud and sand	2	0.095
Harrington harbour	Mud and sand	2	0.11
Whitehaven - outer harbour	Mud and sand	12^F	0.081
Whitehaven - outer harbour	Coal and sand	12^F	0.11
Whitehaven - outer harbour	Mud and sand	4	0.12
Saltom Bay	Winkle bed	4^F	0.095
St Bees	Sand	4^F	0.065
St Bees	Sand	4	0.10
Nethertown	Winkle bed	4^F	0.084
Nethertown beach	Sand and stones	2	0.081
Sellafield	Sand	4^F	0.068
Sellafield beach	Sand	3	0.10
Pipeline on foreshore	Stones	2	0.12
Braystones	Stones	2	0.11
Ehen spit seashore	Sand	2	0.098
River Calder downstream of factory sewer	Grass	2	0.34
River Calder upstream of factory sewer	Grass	2	0.099
Seascale	Sand	5	0.095
Drigg Barn Scar	Mussel bed	4^F	0.089
Muncaster Bridge	Grass	4	0.13
Ravenglass - Carleton Marsh	Salt marsh	4^F	0.18
Ravenglass - Carleton Marsh	Salt marsh	4	0.16
Ravenglass - salmon garth	Mud, sand and stones	4^F	0.11
Ravenglass - salmon garth	Sand and stones	4^F	0.084
Ravenglass - salmon garth	Mussel bed	4^F	0.082
Ravenglass - salmon garth	Mud and sand	4	0.11
Ravenglass - boat area	Stones	4	0.11
Ravenglass - ford	Mud and sand	4^F	0.093
Ravenglass - ford	Mud and sand	4	0.11
Ravenglass - River Mite estuary	Salt Marsh	4	0.20
Ravenglass - Raven Villa	Mud	5^F	0.10
Ravenglass - Raven Villa	Mud and sand	7^F	0.10
Ravenglass - Raven Villa	Salt marsh	12^F	0.16
Ravenglass - Raven Villa	Salt marsh	4	0.17
Ravenglass - Eskmeals Nature Reserve	Sand	3	0.084
Newbiggin/Eskmeals 1	Mud	4	0.16
Newbiggin/Eskmeals 2	Mud and salt marsh	4	0.19
Tarn Bay	Sand	2^F	0.058
Tarn Bay	Winkle bed	2^F	0.070
Tarn Bay	Sand	2	0.11
Silecroft	Sand	4	0.11
Haverigg	Mud	4^F	0.086
Haverigg	Sand	4^F	0.058
Haverigg	Sand	2	0.079
Millom	Mud and sand	4^F	0.082
Millom	Mud and sand	2	0.12
Low Shaw	Salt marsh	2	0.092
Askham	Salt marsh	1	0.12
Askham	Sand	1	0.11
Tumner Hill Marsh	Mud and salt marsh	2	0.14
Walney Channel, N of discharge point	Mud	2	0.11
Walney Channel, S of discharge point	Mud	2	0.10
Roa Island	Sand and stones	2	0.096

Table 4.5. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Cumbria (cont.)			
Greenodd Salt Marsh	Salt marsh	2	0.086
Sand Gate Marsh	Salt marsh	4^F	0.087
Sand Gate Marsh	Salt marsh	5	0.10
Flookburgh	Mud and sand	4^F	0.074
Flookburgh	Salt marsh	4	0.095
High Foulshaw	Salt marsh	4^F	0.081
High Foulshaw	Salt marsh	4	0.089
Arnside	Salt marsh	4^F	0.088
Arnside	Mud and sand	4	0.085
Arnside	Salt marsh	4	0.097
Lancashire, Merseyside and North Wales			
Sunderland Point	Mud	4	0.095
Sunderland	Salt marsh	4	0.096
Morecambe Central Pier	Mussel bed	4^F	0.071
Morecambe Central Pier	Mud and sand	4^F	0.073
Morecambe Central Pier	Mud and sand	2	0.069
Half Moon Bay	Mud and sand	4^F	0.075
Half Moon Bay	Mud and sand	2	0.087
Heysham pipelines	Mud and sand	2	0.083
Middleton Sands	Sand	2	0.08
Colloway Marsh	Salt marsh	4^F	0.13
Colloway Marsh	Salt marsh	4	0.092
Lancaster	Grass	4	0.085
Aldcliffe Marsh	Salt marsh	4^F	0.10
Aldcliffe Marsh	Salt marsh	4	0.11
Conder Green	Mud and sand	4^F	0.087
Conder Green	Salt marsh	4^F	0.10
Conder Green	Mud and Salt marsh	4	0.10
Cockerham Marsh	Salt marsh	4^F	0.10
Cockerham Marsh	Salt marsh	3	0.098
Heads - River Wyre	Salt marsh	2^F	0.096
Heads - River Wyre	Salt marsh	4	0.11
Height o’ th’ hill - River Wyre	Salt marsh	4^F	0.10
Height o’ th’ hill - River Wyre	Salt marsh	4	0.10
Hambleton	Mud and Salt marsh	4	0.12
Knott End	Mud and sand	2^F	0.074
Fleetwood shore 1	Sand	4	0.088
Fleetwood shore 2	Salt marsh	3	0.15
Skippool Creek 1	Salt marsh	4	0.11
Skippool Creek 2	Mud and Salt marsh	3	0.11
Skippool Creek 3	Mud and Salt marsh	3	0.093
Skippool Creek boat 2 (boat cabin)	Boat Cabin	2	0.099
Skippool Creek boat 2 (mud)	Salt marsh	4	0.10
Blackpool	Sand	4	0.073
Crossens Marsh	Salt marsh	4	0.095
Ainsdale	Sand	4	0.071
New Brighton	Sand	2	0.074
New Brighton	Mud and sand	2	0.067
West Kirby	Mud and sand	4	0.074
Rock Ferry	Mud and sand	4	0.090
Little Neston Marsh 1	Mud and Salt marsh	3	0.11
Little Neston Marsh 2	Salt marsh	4	0.11
Flint 1	Mud	3	0.092
Flint 2	Salt marsh	4	0.095
Prestatyn	Sand	2	0.090
Rhyl	Mud and grass	2	0.088
Llandudno	Sand and stones	2	0.093
Caerhun	Salt marsh	2	0.11
Llanfairfechan	Salt marsh	2	0.095

Table 4.5. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
South-west Scotland			
Piltanton Burn	Salt marsh	4	0.068
Garlieston	Mud	4	0.078
Innerwell	Mud	5[F,]	0.090
Innerwell	Mud and sand	3[F]	0.076
Bladnoch	Mud	4	0.096
Creetown	Salt marsh	4	0.090
Carsluith	Mud	4	0.095
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.088
Cumstoun	Salt marsh	4	0.092
Kirkcudbright	Salt marsh	4	0.086
Cutters Pool	Winkle bed	8[F]	0.091
Rascarrel Bay	Winkle bed	8[F]	0.11
Palnackie Harbour	Mud	4	0.097
Gardenburn	Salt marsh	4	0.10
Kippford - Slipway	Mud	4	0.11
Kippford - Merse	Salt marsh	4	0.13
Carsethorn	Mud	4	0.084
Glencaple Harbour	Mud and sand	4	0.093
Isle of Man			
Isle of Man	Sand	1	0.080
Northern Ireland			
Narrow Water	Mud	1	0.10
Rostrevor	Sand	1	0.12
Mill Bay	Mud	1	0.10
Greencastle	Sand	1	0.093
Cranfield Bay	Sand	1	0.091
Annalong	Sand	1	0.11
Newcastle	Sand	1	0.10
Dundrum	Mud	1	0.096
Tyrella	Sand	1	0.085
Rossglass	Sand	1	0.080
Killough	Mud	1	0.091
Ardglass	Mud	1	0.10
Kilclief	Sand	1	0.098
Strangford	Stones	1	0.10
Nickey's Point	Mud	1	0.093
Island Hill	Mud	1	0.088
Belfast Lough	Sand	1	0.067
Carrickfergus	Sand	1	0.074
Whitehead	Sand	1	0.068
Giant's Causeway	Sand	1	0.063
Port Ballintrae	Sand	1	0.057
White Rocks	Sand	1	0.064
Portrush	Sand	1	0.067
Portstewart	Sand	1	0.065
Castlerock	Sand	1	0.066
Benone	Sand	1	0.074
Bellerena	Mud	1	0.064
Lough Foyle	Mud	1	0.066
Eglington	Stones	1	0.063
Lishally	Mud	1	0.075

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

Table 4.6. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2002

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}							
			^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Cumbria										
Newton Arlosh	Turf	4[F]	<4.4		<2.8	<3.0	<13	<4.8	<1.2	560
Newton Arlosh	Sediment	4	<3.4		<5.9	<6.0	<16	<8.4	<2.0	340
Maryport Outer Harbour	Sediment	2	<2.3	<1.9	<3.3	<4.0	<11	<5.1	<1.2	85
Workington Harbour	Sediment	2	<3.5		<3.9	<7.3	<12	<5.3	<1.3	120
Harrington Harbour	Sediment	2	<2.1		<5.6	<7.3	<15	<4.8	<1.6	150
Whitehaven Outer Harbour	Sediment	3	<2.4	<2.5	<4.5	<5.6	<14	<7.3	<1.4	150
St Bees	Sand	4[F]	3.6		<1.5	<1.7	<5.5	<1.7	<0.58	78
St Bees	Sediment	4	<3.6		<3.6	<4.3	<9.9	<3.7	<1.0	70
River Calder - upstream	Sediment	2	<2.2		<6.2	<6.5	<21	<7.8	<2.0	71
River Calder - downstream	Sediment	2	<0.85		<3.3	<5.9	<3.0	<2.1	<0.75	80
Sellafield	Sand	4[F]	4.5		<1.5	<1.7	<5.8	<1.8	<0.59	78
Ehen Spit	Sediment	2	<6.0	<1.3	<4.3	<5.4	<13	<5.8	<1.6	62
Seascale	Sediment	4	<4.4		<3.4	<4.5	<9.3	<3.7	<1.1	60
Drigg Stream[a]	Sediment	4	<5.5	12	<5.9	<7.7	<17	<6.0	<2.0	440
Ravenglass - Carleton Marsh	Mud	4[F]	31		<3.4	<3.9	160	14	<1.4	480
Ravenglass - Carleton Marsh	Sediment	4	25		<7.8	<7.0	<65	<11	<2.2	780
River Mite Estuary	Sediment	4	20	280	<8.1	<6.9	<41	<16	<2.3	1200
Ravenglass - Raven Villa	Mud and sand	4[F]	31		<2.8	<3.6	120	14	<1.1	280
Ravenglass - Raven Villa	Sediment	4	<34		<6.1	<8.2	<63	<18	<1.7	420
Newbiggin (Eskmeals)	Sediment	4	47	140	<8.7	<10	<110	<20	<1.9	530
Low Shaw	Sediment	2	<1.9		<4.6	<2.9	<17	<4.0	<1.3	180
Millom	Mud and sand	4[F]	5.5		<1.8	<1.8	<20	<3.3	<0.79	140
Millom	Sediment	2	13		<6.7	<6.4	<43	<10	<2.1	180
Haverigg	Sediment	2	<2.0		<4.0	<3.1	<12	<3.4	<1.1	28
Sand Gate Marsh	Turf	4[F]	<1.1		<1.5	<1.4	<6.2	<2.2	<0.72	170
Sand Gate Marsh	Sediment	4	<2.6		<5.8	<9.0	<15	<6.4	<1.6	280
Flookburgh	Mud and sand	4[F]	<0.50		<1.2	<1.0	<4.8	<1.7	<0.61	110
Flookburgh	Mud and sand	4	<1.9		<5.8	<6.8	<14	<5.3	<1.6	470
Walney Channel - west	Mud and sand	2	6.4		<5.2	<5.9	<32	<12	<2.2	160
Walney Channel - east	Mud and sand	2	4.8		<6.6	<8.4	<18	<8.4	<2.0	94
Lancashire										
Morecambe	Mud and sand	4[F]	3.5		<1.5	<1.5	<11	<4.3	<0.74	170
Morecambe	Sediment	1	2.4							170
Half Moon Bay[b]	Mud and sand	4[F]	5.3		<1.7	<1.5	<12	<4.3	<0.96	170
Half Moon Bay	Sediment	2	<1.7							21
Heysham pipelines	Sediment	2	<2.8							80
Potts Corner	Sediment	2	<1.7							52
Sunderland Point	Mud and sand	4	<2.2		<4.4	<4.5	<11	<5.0	<1.1	85
Conder Green	Turf	4[F]	3.6		<2.1	<2.0	<9.0	<3.2	<1.0	240
Conder Green	Sediment	5	<1.8	<1.2	<3.5	<4.3	<8.3	<4.9	<1.1	200
Hambleton	Sediment	4	<4.2		<5.5	<4.0	<15	<9.4	<1.7	520
Fleetwood	Sediment	4	<1.4		<2.8	<3.0	<6.4	<2.1	<0.86	17
Skippool Creek	Sediment	4	<4.7		<3.7	<4.1	<18	<8.5	<1.5	350
Blackpool	Sediment	4	<1.1		<2.0	<2.2	<6.7	<1.7	<0.98	5.4
Crossen Marsh	Sediment	4	<3.0		<5.2	<5.6	<20	<7.5	<2.0	180
Ainsdale	Sediment	4	<1.1		<1.9	<2.5	<7.7	<1.9	<0.82	9.4
New Brighton	Sediment	4	<0.97		<2.3	<2.5	<7.7	<1.9	<0.76	<4.9
Rock Ferry	Sediment	4	<1.3		<2.1	<2.0	<7.2	<2.6	<0.90	55
Llandudno	Sediment	2	<1.1		<3.0	<2.8	<11	<3.4	<1.3	<5.8
Rhyl	Sediment	2	<1.6		<4.0	<3.0	<11	<3.7	<1.2	52
Llanfairfechan	Sediment	2	<2.2		<4.0	<3.9	<16	<5.7	<1.5	69
Caerhun	Sediment	2	<2.9		<8.6	<6.9	<19	<8.2	<3.0	390

Table 4.6. 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	Total alpha	Total beta
Cumbria											
Newton Arlosh	Turf	4[F]	<6.9	<3.5	<3.2				300		
Newton Arlosh	Sediment	4	<8.3	<3.4	<4.3				170	950	1300
Maryport Outer Harbour	Sediment	2	<7.4	<2.3	<3.4	9.9	58	670	66	280	710
Workington Harbour	Sediment	2	<7.1	<3.3	<5.7				80	120	670
Harrington Harbour	Sediment	2	<7.8	<1.7	<2.9				31	420	600
Whitehaven Outer Harbour	Sediment	3	<6.7	<2.0	<3.6	6.4	35	400	54	550	950
Bees	Sand	4[F]	<3.1	<1.7	<1.5				180		
St Bees	Sediment	4	<6.7	<1.8	<2.4				120	630	550
River Calder - upstream	Sediment	2	<9.0	<2.4	<4.3					390	990
River Calder - downstream	Sediment	2	<3.3	<0.76	<2.2					450	1600
Sellafield	Sand	4[F]	<3.6	<1.7	<1.8				180		
Ehen Spit	Sediment	2	<9.0	<3.0	<3.5	24	130	1700	180	270	620
Seascale	Sediment	4	<5.3	<1.9	<2.6				120	510	640
Drigg Stream[a]	Sediment	4	<16	<4.4	<7.9	14	75	630	69	960	1700
Ravenglass - Carleton Marsh	Mud	4[F]	41	12	5.4				1100		
Ravenglass - Carleton Marsh	Sediment	4	<16	<15	<8.4				1730	4100	2200
River Mite Estuary	Sediment	4	<22	18	<12	210	1100	13000	1700	4900	2700
Ravenglass - Raven Villa	Mud and sand	4[F]	41	7.2	<3.6				670		
Ravenglass - Raven Villa	Sediment	4	<23	<7.4	<5.9				830	2100	1700
Newbiggin (Eskmeals)	Sediment	4	<44	<12	<7.1	130	670	7400	1100	3300	2300
Low Shaw	Sediment	2	<7.1	<2.9	<4.7				190	490	1600
Millom	Mud and sand	4[F]	<6.6	<2.8	<2.4				240		
Millom	Sediment	2	<14	<4.8	<4.3				310	1300	1900
Haverigg	Sediment	2	<6.1	<1.4	<2.2				20	110	620
Sand Gate Marsh	Turf	4[F]	<4.7	<1.7	<2.4				82		
Sand Gate Marsh	Sediment	4	<7.9	<2.5	<3.3				110	750	1100
Flookburgh	Mud and sand	4[F]	<3.3	<1.5	<1.7				48		
Flookburgh	Mud and sand	4	<8.4	<2.7	<4.6				220	900	1200
Walney Channel - west	Mud and sand	2	<16	<4.3	<4.4				200	900	1100
Walney Channel - east	Mud and sand	2	<8.3	<2.9	<3.5				130	410	1000
Lancashire											
Morecambe	Mud and sand	4[F]	<4.5	<1.9	<2.4				120		
Morecambe	Sediment	1							1.0		
Half Moon Bay[b]	Mud and sand	4[F]	<5.3	<2.5	<2.7	16	87		160		
Half Moon Bay	Sediment	2							<12	<100	280
Heysham pipelines	Sediment	2							46	<100	420
Potts Corner	Sediment	2							15	<100	<310
Sunderland Point	Mud and sand	4	<6.2	<2.5	<3.8				<61	500	790
Conder Green	Turf	4[F]	<5.2	<2.6	<2.6				130	1400	
Conder Green	Sediment	5	<6.1	<2.6	<3.3	8.0	42	330	110	720	1100
Hambleton	Sediment	4	<9.2	<3.6	<4.5				320	1200	1700
Fleetwood	Sediment	4	<4.4	<1.1	<2.2				14	<100	500
Skippool Creek	Sediment	4	<8.9	<3.0	<4.0				220	820	1700
Blackpool	Sediment	4	<4.0	<1.1	<1.4				<5.2	<120	320
Crossen Marsh	Sediment	4	<10	<2.5	<3.7				80	590	880
Ainsdale	Sediment	4	<4.9	<1.0	<2.1				3.0	<110	<250
New Brighton	Sediment	4	<4.6	<1.5	<1.9				5.2	<100	380
Rock Ferry	Sediment	4	<5.3	<1.4	<1.9				20	190	860
Llandudno	Sediment	2	<7.2	<2.3	<2.4					<80	320
Rhyl	Sediment	2	<7.1	<1.7	<3.2				<24	340	960
Llanfairfechan	Sediment	2	<8.9	<2.2	<3.9				29	340	1200
Caerhun	Sediment	2	<21	<6.3	<7.1				71	650	1500

Table 4.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}							
			^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Scotland										
Bladnoch	Mud	4	5.4	<0.50	<0.62	8.7	2.4	<0.18	360	<1.4
Garlieston	Sediment	4	0.83	<0.27	<0.27	<1.1	0.70	<0.10	44	<0.74
Innerwell	Mud	2[F]	7.1	<2.9	<4.2	<20	<2.9	<1.0	140	<6.4
Innerwell	Sediment	4	2.2	<0.29	<0.29	<1.6	1.1	<0.10	98	
Carsluith	Sediment	4	3.6	<0.30	<0.36	<3.5	<1.1	<0.10	140	<0.78
Kippford Merse	Turf	4	3.8	<0.33	<0.37	<2.0	<1.0	<0.13	400	<0.81
Kippford Slipway	Sediment	4	7.9	<0.46	<0.80	13	3.3	<0.19	230	<1.9
Palnackie Harbour	Sediment	4	4.3	<0.29	<0.36	7.0	1.4	<0.15	180	<1.4
Carsethorn[c]	Sediment	2	3.0	<0.20	<0.36	<4.3	<1.6	<0.13	120	<0.81
Kirkconnel Merse	Sediment	4	1.6	<0.32	<0.48	<2.1	<1.0	<0.12	390	<1.3
Cambletown	Sediment	1	<0.10	<0.13	<0.12	<0.68	<0.21	<0.10	11	<0.62
Dornoch Brow	Sediment	4	1.3	<0.29	<0.37	<2.2	<1.1	<0.14	130	<0.99
Northern Ireland										
Lough Foyle	Mud	1	<0.34	<3.2	<8.6	<3.7	<0.83	<0.43	2.0	<2.1
Lough Foyle	Shell and sand	1	<0.29	<1.9	<3.4	<3.2	<0.72	<0.33	1.5	<1.7
Portrush	Sand	2	<0.28	<2.1	<4.5	<3.3	<0.79	<0.35	0.99	<2.2
Ballymacormick[d]	Mud	2	<0.43	<1.3	<1.2	<4.3	<1.3	<0.55	25	<2.9
Strangford Lough-										
Nickey's point	Mud	2	<0.56	<1.7	<1.9	<5.3	<1.6	<0.77	39	<3.2
Dundrum Bay	Mud	1	<0.69	<1.8	<1.5	<6.4	<1.6	<0.75	5.7	<3.4
Dundrum Bay	Mud and sand	1	<0.25	<0.98	<1.2	<2.9	<0.77	<0.37	4.9	<2.3
Carlingford Lough	Mud	2	<0.76	<2.3	<2.3	<7.7	<2.2	<1.1	55	<4.3
Oldmill Bay[e]	Mud	2	<0.63	<1.8	<1.8	<6.1	<1.8	<0.76	40	<3.6

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}							
			^{154}Eu	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Scotland										
Bladnoch	Mud	4	2.7	1.8			340			
Garlieston	Sediment	4	0.35	<0.46	5.1	27	46			
Innerwell	Mud	2[F]	<3.5	<3.0			180			
Innerwell	Sediment	4	0.65	<1.1						
Carsluith	Sediment	4	<1.4	<1.4	36	170	300		250	1100
Kippford Merse	Turf	4	3.0	<1.3	82	430	720			
Kippford Slipway	Sediment	4	2.4	1.4	36	190	340			
Palnackie Harbour	Sediment	4	1.5	1.1	26	110	150		300	960
Carsethorn[c]	Sediment	2	<0.92	1.0			110			
Kirkconnel Merse	Sediment	4	1.4	1.3	23	110	180			
Cambletown	Sediment	1	<0.16	<0.28			1.4			
Dornoch Brow	Sediment	4	0.59	<0.83	7.1	36	48			
Northern Ireland										
Lough Foyle	Mud	1	<0.98	<0.77	0.033	0.24	0.34	*		
Lough Foyle	Shell and sand	1	<0.80	<0.71			0.34			
Portrush	Sand	2	<0.89	<0.90			<0.87			
Ballymacormick[d]	Mud	2	<1.5	<1.5	1.9	10	15	0.027		
Strangford Lough-										
Nickey's point	Mud	2	<1.9	<1.6	1.6	8.6	8.7	0.015		
Dundrum Bay	Mud	1	<2.2	<1.8			<2.9			
Dundrum Bay	Mud and sand	1	<0.86	<1.1			<1.4			
Carlingford Lough	Mud	2	<2.2	<2.2	1.7	11	7.4	0.0076		
Oldmill Bay[e]	Mud	2	<1.9	<1.9	2.3	12	21	0.046		

** Not detected by the method used*

[a] The concentrations of ^{210}Po, ^{228}Th, ^{230}Th, ^{232}Th, ^{234}U, ^{235}U and ^{238}U were 47, 33, 25, 20, 83, <3.1 and 74 Bq kg^{-1} respectively

[b] The concentrations of ^{242}Cm and $^{243+244}Cm$ were 0.068 and 0.095 Bq kg^{-1} respectively

[c] The concentration of ^{3}H was <4.9 Bq kg^{-1}

[d] The concentration of ^{242}Cm was 0.042 Bq kg^{-1}

[e] The concentration of ^{242}Cm was 0.061 Bq kg^{-1}

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

Table 4.7. Individual radiation exposures due to external sources around the Irish Sea, 2002

Exposed population[b]	Exposure mSv[a]			
	Total	External	Ingestion of seafood	Intakes of sediment[c]
Sellafield fishing community (2002 habits)	0.24	0.030	0.21	
Sellafield fishing community (1998-2002 habits)	0.19	0.028	0.16	
Ravenglass estuary, recreational use	0.038	0.033		0.005
Sellafield, net handling[d]	0.15	0.15		
Sellafield, sediment handling whilst digging bait[d]	0.22	0.22		
Ribble estuary, houseboats	0.13	0.13		0.005
Dumfries and Galloway	0.037	0.018	0.019	
Northern Ireland	0.012	0.003	0.009	
North Wales	0.014	0.007	0.007	
Typical beach occupancy in Cumbria	<0.001	<0.001		

[a] *Due to artificial radionuclides, see text for exposures due to ingestion of natural radionuclides*
[b] *Representative of people most exposed unless stated otherwise. Adults are the most exposed group*
[c] *Due to inadvertent ingestion of sediment and inhalation of resuspended sediment where appropriate*
[d] *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 3)*

Table 4.8. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2002

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, $\mu Sv\ h^{-1}$
M	Nets	4	0.084
	Ropes	4	0.093
S	Pots	1	0.078
T	Gill nets	4	<0.038
	Pots	2	0.37
W	Gill nets	2	0.12
	Pots	2	0.15
	Ropes	1	0.27
X	Gill nets	4	0.074
	Pots	3	0.13
Z	Nets	4	0.096
	Ropes	2	<0.015

Table 4.9. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2002

Location	Ground type	No. of sampling observ-ations	$\mu Sv\ h^{-1}$
Whitehaven - outer harbour	Mud and sand	2	0.23
St Bees	Sand	2	0.18
Nethertown	Winkle bed	2	0.34
Sellafield pipeline	Sand	2	0.19
Drigg Barn Scar	Mussel bed	2	0.21
Ravenglass - Raven Villa	Salt marsh	2	0.68
Ravenglass - salmon garth	Mussel bed	2	0.24
Tarn Bay	Sand	2	0.11

Table 4.10. Concentrations of radionuclides in surface waters from West Cumbria, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration $Bq\ l^{-1}$									
			^{3}H	^{40}K	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu + ^{240}Pu$	Total alpha	Total beta
Freshwater	Ehen spit issue	4	<140	<13	<0.53	<0.11	<0.45	<0.69	<0.0058	<0.0055	<2.7	13
Freshwater	Seaburn sewer outfall	4	20	<7.0	<0.46	<0.15	<0.45	<0.48	<0.0053	<0.0050	<0.019	0.68
Freshwater	River Calder (downstream)	4	<4.3	<11	<0.45	<0.053	<0.45	<0.45	<0.0050	<0.0050	<0.027	<0.10
Freshwater	River Calder (upstream)	4	<5.4	<7.6	<0.56	<0.055	<0.50	<0.44	<0.0050	<0.0050	<0.020	<0.10
Freshwater	Wast Water	1	<4.0	<5.9	<0.30			<0.30			0.028	<0.10
Freshwater	Ennerdale Water	1	<4.0	<9.9	<0.30			<0.30			<0.020	<0.10
Freshwater	Devoke Water	1	<4.0	22	<0.20			<0.20			<0.020	<0.10
Freshwater	Thirlmere	1	<4.0	<6.0	<0.30			<0.30			<0.020	<0.10

Table 4.11. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2002

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	<1.6	7.8	<1.7	620	3.9	31	34
Gullypot sediment	Seascale SS 233	1	<2.1	7.0	<1.8	920	4.9	40	41
Gullypot sediment	Seascale SS 209	1	<11	<1.0	<5.5	43	1.7	9.3	15
Gullypot sediment	Seascale SS 232	1	<0.06	8.5	<0.04	7.1	0.84	4.8	9.0
Gullypot sediment	Seascale SS 231	1	<19	<5.5	<17	<100	5.7	34	58
Gullypot sediment	Whitehaven SS 201	1	<53	<1.8	<16	<31	<0.46	<0.67	2.1

Table 4.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2002

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb
England													
Silloth	Seaweed	4			<0.86			<2.1	<2.1	4400	<4.3	<0.69	<3.2
Harrington Harbour	Seaweed	2			<2.9			<6.8	<9.2	3200	<8.5	<0.80	<9.4
St Bees	*Fucus vesiculosus*[a]	4[F]	57	<0.06	6.1	<0.17	2.4	<0.18	<0.22	11000	2.5	0.87	1.9
St Bees	*Porphyra*	4[F]	86	<0.07	0.77	<0.19	0.19	<0.16	<0.16	14	10	<0.14	1.5
St Bees	*Rhodymenia spp.*	2[F]		<0.11	0.70	<0.31		<0.34	<0.36		7.1	0.79	<0.83
St Bees	Seaweed	2			7.2			<2.4	<2.6	2200	<7.5	<1.4	<4.4
Braystones South	*Porphyra*	4		<0.07	1.2	<0.21		<0.20	<0.22		20	<0.31	1.9
Sellafield	*Fucus vesiculosus*	4[F]		<0.12	13	<0.37	2.8	<0.38	<0.41	29000	4.7	2.4	2.9
Sellafield	Seaweed	2			23			<4.7	<9.8	19000	<22	<2.3	<4.8
Seascale	*Porphyra*[b]	53[F]		<0.29	<1.3	<0.69		<0.50	<0.31		22	<0.57	<3.1
Ravenglass	Seaweed	2			9.6			<5.9	<4.8	7000	21	<0.75	<4.3
Half Moon Bay	*Fucus vesiculosus*	4[F]		<0.19	<0.43	<0.20		<0.18	<0.16	4700	<0.67	<0.13	0.73
Half Moon Bay	Seaweed	2			<0.85			<0.16	<1.4	5300	<4.8	<0.60	<2.0
Marshside Sands	Samphire	1[F]		<0.03	<0.03	<0.08		<0.07	<0.07		<0.26	<0.05	<0.07
Rabbit Cat How	Samphire	1[F]		<0.04	<0.05	<0.10		<0.10	<0.09	1.5	<0.42	<0.07	<0.10
Cockerham Marsh	Samphire	1[F]		<0.02	<0.02	<0.05		<0.05	<0.04		<0.20	<0.04	<0.05
Isle of Man	*Fucus vesiculosus*	4		<0.15	<0.17	<0.38		<0.32	<0.25	1000	<1.4	<0.25	<0.34
Wales													
Cemaes Bay	*Fucus vesiculosus*	2[F]		<0.11	<0.11	<0.26		<0.27	<0.25	260	<1.1	<0.18	<0.25
Porthmadog	*Fucus vesiculosus*	1[F]	19	<0.06	<0.06	<0.18		<0.17	<0.16	46	<0.49	<0.11	<0.12
Porthmadog	Seaweed	2			<0.45			<1.9	<3.4	29	<2.9	<0.35	<1.3
Fishguard	*Fucus vesiculosus*	1[F]	10	<0.05	<0.05	<0.14		<0.12	<0.10	19	<0.44	<0.09	<0.11
Fishguard	Seaweed	2			<1.0			<1.7	<1.0	28	<6.6	<0.97	<1.8
Lavernock Point	*Fucus serratus*	2[F]		<0.08	<0.09	<0.24		<0.23	<0.23	0.86	<0.71	<0.16	<0.16
South Wales, manufacturer A	Laverbread	4[F]		<0.07	<0.07	<0.17		<0.20	<0.20		<0.68	<0.12	<0.14
South Wales, manufacturer C	Laverbread	4[F]		<0.07	<0.08	<0.19		<0.17	<0.15		<0.76	<0.13	<0.16
South Wales, manufacturer D	Laverbread	4[F]		<0.07	<0.07	<0.17		<0.18	<0.17		<0.65	<0.12	<0.14
Northern Ireland													
Ardglass	*Fucus vesiculosus*	4	17	<0.14	<0.15	<0.37		<0.40	<0.46	590	<1.3	<0.24	<0.30
Portrush	*Fucus serratus*	2		<0.09	<0.11	<0.28		<0.21	<0.19		<0.78	<0.17	<0.20
Portrush	*Fucus vesiculosus*	1		<0.09	<0.10	<0.26		<0.23	<0.20		<0.80	<0.17	<0.21
Strangford Lough	*Rhodymenia spp.*	4		<0.11	<0.11	<0.27		<0.28	<0.29	24	<1.0	<0.18	<0.23
Carlingford Lough	*Fucus spp.*	2		<0.21	<0.22	<0.48		<0.57	<0.65	440	<1.8	<0.35	<0.44
Isles of Scilly	*Fucus vesiculosus*	1[F]	12	<0.11	<0.12	<0.31		<0.25	<0.21	2.4	<1.0	<0.20	<0.23
Scotland													
Lewis	Seaweed	1		<0.10	<0.10	<0.25		<0.19	<0.15	100	<0.72	<0.11	<0.21
Islay	Seaweed	1		<0.10	<0.10	<0.23		<0.15	<0.10		<0.60	<0.10	<0.17
Campbeltown	Seaweed	1		<0.10	<0.10	<0.22		<0.10	<0.16		<0.65	<0.10	<0.18
Port William	*Fucus vesiculosus*	8[F]		<0.08	<0.30	<0.17		<0.14	<0.12	1800	<0.52	<0.11	<0.31
Garlieston	*Fucus vesiculosus*	8[F]		<0.09	1.0	<0.19		<0.15	<0.13	2000	<0.61	<0.12	0.65
Auchencairn	*Fucus vesiculosus*	8[F]		<0.09	1.2	<0.19		<0.16	<0.13	2600	<0.66	<0.13	0.83
Knock Bay	*Porphyra*	8[F]		<0.07	<0.08	<0.13		<0.13	<0.14	22	<0.38	<0.10	<0.11
Cape Wrath	*Fucus vesiculosus*	1[F]	15	<0.05	<0.05	<0.13		<0.12	<0.11	91	<0.42	<0.09	<0.10
Wick	*Fucus vesiculosus*	1[F]	14	<0.05	<0.06	<0.15		<0.13	<0.12		<0.42	<0.09	<0.10

Table 4.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total beta
England													
Silloth	Seaweed	4	<0.87	8.2	<3.8					7.0			
Harrington Harbour	Seaweed	2	<2.1	4.4	<12					<2.0			
St Bees	*Fucus vesiculosus*[a]	4[F]	<0.08	5.0	0.41	<0.16	1.6	6.9		3.2	0.0032	0.008	
St Bees	*Porphyra*	4[F]	<0.07	1.9	<0.47	<0.18	0.58	3.1	30	6.1	0.0080	0.005	200
St Bees	*Rhodymenia spp.*	2[F]	<0.12	5.0	<1.1	<0.28	1.2	5.4		6.6	0.034	0.017	
St Bees	Seaweed	2	<0.85	6.0	<3.8					11			
Braystones South	*Porphyra*	4	<0.08	1.8	<1.1	<0.18	0.44	2.2	24	3.6	0.014	*	
Sellafield	*Fucus vesiculosus*	4[F]	<0.24	7.3	<1.1	<0.39	2.2	8.8		3.5	*	0.005	23000
Sellafield	Seaweed	2	<1.1	7.5	<8.8					11			
Seascale	*Porphyra*[b]	53[F]	<0.32	1.7	<1.6	<0.71				5.4			
Ravenglass	Seaweed	2	<1.6	83	<18					140			
Half Moon Bay	*Fucus vesiculosus*	4[F]	<0.09	3.9	<0.36	<0.20				0.68			3600
Half Moon Bay	Seaweed	2	<0.55	9.2	<2.3					<1.8			
Marshside Sands	Samphire	1[F]	<0.03	0.40	<0.14	<0.07				<0.09			
Rabbit Cat How	Samphire	1[F]	<0.04	0.38	<0.16	<0.06				0.92			
Cockerham Marsh	Samphire	1[F]	<0.02	1.0	<0.13	<0.07				0.57			19
Isle of Man	*Fucus vesiculosus*	4	<0.16	1.2	<0.63	<0.32				<0.33			930
Wales													
Cemaes Bay	*Fucus vesiculosus*	2[F]	<0.11	0.63	<0.53	<0.24				<0.24			330
Porthmadog	*Fucus vesiculosus*	1[F]	<0.07	0.46	<0.26	<0.13				<0.17			
Porthmadog	Seaweed	2	<0.59	<0.60	<2.9					<0.70			
Fishguard	*Fucus vesiculosus*	1[F]	<0.06	0.11	<0.27	<0.15				<0.24			220
Fishguard	Seaweed	2	<0.89	<0.96	<3.5					<1.5			
Lavernock Point	*Fucus serratus*	2[F]	<0.10	0.39	<0.40	<0.20				<0.24			210
South Wales, manufacturer A	Laverbread	4[F]	<0.07	<0.07	<0.24	<0.10				<0.07			
South Wales, manufacturer C	Laverbread	4[F]	<0.08	<0.31	<0.26	<0.11				<0.23			
South Wales, manufacturer D	Laverbread	4[F]	<0.06	<0.05	<0.24	<0.10				<0.05			74
Northern Ireland													
Ardglass	*Fucus vesiculosus*	4	<0.14	0.60	<0.53	<0.26				<0.28			
Portrush	*Fucus serratus*	2	<0.10	<0.19	<0.39	<0.21				<0.27			
Portrush	*Fucus vesiculosus*	1	<0.10	0.20	<0.47	<0.26				<0.40			
Strangford Lough	*Rhodymenia spp.*	4	<0.11	0.54	<0.39	<0.17	0.058	0.31		0.38	*	*	
Carlingford Lough	*Fucus spp.*	2	<0.23	0.83	<1.0	<0.51				<0.79			
Isles of Scilly	*Fucus vesiculosus*	1[F]	<0.12	<0.10	<0.40	<0.17				<0.10			240
Scotland													
Lewis	Seaweed	1	<0.10	1.1	<0.50	<0.25				<0.22			
Islay	Seaweed	1	<0.10	1.3	<0.38	<0.21				<0.19			
Campbeltown	Seaweed	1	<0.10	1.1	<0.42	<0.23				<0.25			
Port William	*Fucus vesiculosus*	8[F]	<0.09	1.6	<0.32	<0.18				0.82			
Garlieston	*Fucus vesiculosus*	8[F]	<0.10	4.8	<0.35	<0.20				6.2			
Auchencairn	*Fucus vesiculosus*	8[F]	<0.10	4.2	<0.37	<0.20				4.6			
Knock Bay	*Porphyra*	8[F]	<0.08	0.28	<0.20	<0.11				0.38			
Cape Wrath	*Fucus vesiculosus*	1[F]	<0.06	0.53	<0.19	<0.10				<0.06			190
Wick	*Fucus vesiculosus*	1[F]	<0.05	0.18	<0.22	<0.11				<0.14			220

** Not detected by the method used*

[a] *The concentration of* ^{129}I *was 6.7 Bq* kg^{-1}

[b] *Counted wet*

[F] *Measurements are made on behalf of the environment agencies unless labelled 'F'. In that case the Food Standards Agency has also participated in the programme*

Table 4.13. Concentrations of radionuclides in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2002

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am
Newton Arlosh	Grass	1				1.2							
Newton Arlosh	Washed grass	1				1.2							
Newton Arlosh	Soil	1				2.8							
Sellafield 1707[b]	Potatoes	1	<0.05	<0.11	<0.09	1.4	<0.40	<0.10	<0.05	<0.04	<0.20	<0.10	<0.13
Sellafield 1707[b]	Soil	1	<0.27	<0.77	<0.82	290	<2.4	<0.68	<0.32	26	<1.6	<0.78	4.6
Sellafield 14[b]	Onions	1	<0.05	<0.13	<0.13	2.6	<0.49	<0.12	<0.05	<0.05	<0.16	<0.07	<0.04
Sellafield 14[b]	Potatoes	1	<0.05	<0.08	<0.06	6.3	<0.38	<0.09	<0.05	0.10	<0.18	<0.10	<0.13
Sellafield 14[b]	Runner Beans	1	<0.07	<0.14	<0.13	26	<0.59	<0.13	<0.07	<0.06	<0.19	<0.09	<0.05
Sellafield 14[b]	Soil	1	3.0	<0.27	<0.21	2300	<1.2	<0.38	<0.15	16	<0.78	<0.44	4.8
Sellafield 1674[b]	Beetroot	1	<0.06	<0.15	<0.13	25	<0.58	<0.14	<0.06	<0.05	<0.28	<0.13	<0.12
Sellafield 1674[b]	Onions	1	<0.06	<0.15	<0.13	1.9	<0.55	<0.12	<0.05	<0.05	<0.21	<0.08	<0.05
Sellafield 1674[b]	Potatoes	1	<0.04	<0.08	<0.06	11	<0.37	<0.09	<0.04	0.09	<0.18	<0.08	<0.05
Sellafield 1674[b]	Soil	1	0.50	<0.57	<0.43	350	<2.4	<0.73	<0.35	51	<1.4	2.5	4.1
Sellafield 1676[b]	Cabbage	1	<0.03	<0.07	<0.05	32	<0.30	<0.07	<0.03	0.04	<0.15	<0.07	<0.07
Sellafield 1676[b]	Potatoes	1	<0.04	<0.07	<0.06	36	<0.30	<0.08	<0.03	0.16	<0.14	0.07	<0.04
Sellafield 1676[b]	Rhubarb	1	<0.06	<0.11	<0.09	17	<0.49	<0.11	<0.05	0.12	<0.18	<0.09	<0.11
Sellafield 1676[b]	Soil	1	1.9	<0.50	<0.34	700	<2.4	<0.76	<0.34	68	<1.3	<0.64	30
Hutton Marsh	Grass	1				2.1							
Hutton Marsh	Washed grass	1				3.5							
Hutton Marsh	Soil	1				15							

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

Table 4.14. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2002

Material	Selection[a]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb
Milk[c]		16	<4.4	<4.9	16	<0.75	<0.28	0.080	<0.0045	<1.9	<0.52
Milk	max		<5.8	9.8	22	1.6	<0.31	0.19		<2.1	<0.58
Apples		4	<11	22	11	<0.20	<0.35	0.19	<0.023	<2.2	<0.70
Apples	max		11	36	18		<0.40	0.28		<2.3	<0.80
Barley		2		<9.5	110	2.1	<0.25	1.9		<1.7	<0.55
Barley	max			13	120	3.0	<0.30	2.3		<2.8	<0.80
Blackberries		2	<8.5	<6.5	4.5	0.40	<0.20	0.50		<1.8	<0.65
Blackberries	max		<12	10	5.0	0.60		0.63		<1.9	<0.70
Bovine kidney		1	3.0	7.0	<10	3.0	<0.20	0.49	<0.031	<1.7	<0.80
Bovine liver		1	<7.0	<7.0	46	3.6	<0.30	0.18	<0.026	<0.80	<0.50
Bovine muscle		2	1.5	5.0	9.5	1.7	<0.25	<0.022	<0.023	<2.0	<0.55
Bovine muscle	max		2.0	6.0	11	2.4	<0.30		<0.024	<2.5	<0.70
Bovine offal		1	<7.0	<7.0	24	1.5	<0.20	0.079	<0.061	<1.5	<0.50
Broad beans		1	<5.0	<5.0	6.0	0.90	<0.50	0.23		<2.7	<0.80
Cabbage		3	<4.5	<4.0	<8.5	0.80	<0.30	0.29		<1.9	<0.40
Cabbage	max		<5.0	4.0	14	1.0		0.35		<2.3	
Carrots		2	<4.0	<4.0	<3.0	0.20	<0.40	0.23	<0.046	<1.7	<0.80
Carrots	max										
Cauliflower		1	<4.0	<4.0	3.0	0.80	<0.30	0.12		<1.8	<0.60
Eggs		1	<6.0	6.0	9.0	1.3	<0.20	0.040		<2.0	<0.70
Elderberries		1	<15	11	8.0	0.70	<0.30	0.53		<2.0	<0.60
Honey		2		<6.0	25	<0.30	<0.20	0.038		<1.7	<0.55
Honey	max				30			0.040			<0.60
Leeks		1									
Ovine muscle		1	<4.0	4.0	48	3.1	<0.40	0.022	<0.019	<1.8	<0.60
Ovine offal		1	<7.0	<7.0	72	5.1	<0.30	0.061	0.048	<2.0	<0.60
Potatoes		3	<6.0	3.5	9.0	0.40	<0.35	0.046		<2.0	<0.45
Potatoes	max		<7.0	4.0	13	0.50	<0.40	0.070		<2.1	<0.60
Runner beans		1	5.0	10	<3.0	<0.30	<0.30	0.28		<1.8	<0.30
Sloe berries		1									
Swede		1	<4.0	<4.0	<3.0	0.50	<0.40	0.30		<1.8	<0.70
Turnips		1	<6.0	<4.0	<3.0	0.20	<0.30	0.51		<2.5	<0.70
Grass		5					<0.47		<0.028	<1.7	<0.57
Grass	max						0.60			<2.5	<0.70
Soil		3					<0.80			<2.3	<1.2
Soil	max						1.0			<2.7	<1.4

Table 4.14. continued

Material	Selection[a]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}							
			^{129}I	^{137}Cs	Total Cs	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[c]		16	<0.023	<0.38	0.26		<0.00018	<0.00018	<0.045	<0.00016
Milk	max		<0.031	<0.68	0.56		<0.00020		<0.047	<0.00023
Apples		4	<0.041		0.32		<0.00025	<0.00038	<0.26	<0.00058
Apples	max		<0.046		0.51		<0.00040	0.00070	0.46	0.0012
Barley		2	<0.056		0.74		<0.00090	0.0072	<0.17	0.012
Barley	max		<0.075				<0.0011	0.0074	0.20	0.017
Blackberries		2	<0.050		0.27		<0.00025	0.0012	<0.068	0.0021
Blackberries	max		<0.052		0.40		<0.00030	0.0019		0.0030
Bovine kidney		1			2.4		0.00050	0.00020	<0.083	0.00050
Bovine liver		1	<0.053		1.1		<0.00060	0.0026	<0.12	0.00090
Bovine muscle		2	<0.049		1.2		<0.00070	<0.00045	<0.25	<0.00030
Bovine muscle	max		<0.052		1.5		<0.00080	<0.00070	0.35	<0.00040
Bovine offal		1	<0.044		0.65		0.00020	0.00040	0.15	0.00060
Broad beans		1	<0.083		0.091		<0.00030	0.00040	<0.070	<0.00020
Cabbage		3	<0.041		0.07		<0.00030	<0.00027	<0.082	<0.00033
Cabbage	max		<0.043		0.10		<0.00030	<0.00030	<0.088	<0.00040
Carrots		2	<0.040		0.07		<0.00030	<0.00025	<0.099	<0.00040
Carrots	max		<0.041				<0.00030	<0.00030	<0.10	<0.00050
Cauliflower		1	<0.041		0.07		<0.00030	<0.00030	<0.069	<0.00030
Eggs		1	0.046		0.08		<0.00020	0.00010	<0.062	0.00030
Elderberries		1	<0.084		0.88		0.0016	0.010	<0.056	0.017
Honey		2	<0.042		0.56		<0.00035	<0.00020	<0.11	0.00050
Honey	max				0.65		<0.00040	0.00020	0.12	0.00060
Leeks		1	<0.044				0.00010	<0.00020	<0.071	<0.00040
Ovine muscle		1	<0.053		0.83		<0.00030	<0.00050	<0.13	0.00030
Ovine offal		1	0.090		0.72		<0.00040	0.00060	<0.12	0.0014
Potatoes		3	<0.051		0.07		<0.00030	<0.00033	<0.089	<0.00053
Potatoes	max		<0.055		0.09		<0.00040	0.00050	<0.13	<0.00060
Runner beans		1	<0.038		0.06		<0.00020	0.00070	<0.081	0.0020
Sloe berries		1	<0.060				<0.00030	0.00080	<0.11	0.00080
Swede		1	<0.046		0.09		<0.00020	<0.00030	<0.071	0.00080
Turnips		1	<0.045		0.05		<0.00010	0.00080	0.069	0.00070
Grass		5		1.3						
Grass	max			1.5						
Soil		3		68		52				
Soil	max			82		53				

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*
[b] *Except for milk where units are Bq l^{-1} and soil where dry concentrations apply*
[c] *The mean concentration of ^{131}I was <0.027 Bq l^{-1} and the maximum was <0.030 Bq l^{-1}*
[d] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

Table 4.15. Individual radiation exposures due to gaseous discharges near Sellafield and Drigg, 2002

Exposed population[b]	Key pathways and foodstuffs	Exposure mSv[a]												
		Total	^{14}C	^{35}S	^{41}Ar	^{60}Co	^{85}Kr	^{90}Sr	^{106}Ru	^{125}Sb	^{129}I	^{131}I	^{137}Cs	Others
Consumers near Sellafield aged 1 y[c]	Milk Fruit External	0.038	0.003	0.003	0.004	0.003	0.001	0.007	0.007	0.001	0.003	0.002	0.003	<0.001
Consumers near Drigg aged 1 y	Milk Fruit	0.017		0.001		0.002		0.004	0.005	0.001	0.002		0.001	<0.001
Consumers near Ravenglass aged 1 y	Milk Potatoes	0.020		0.001		0.003		0.003	0.007	0.001	0.002		0.001	<0.001
Typical adult member of the public eating food grown near Sellafield	Milk Fruit	0.008						0.002	0.002		0.001		0.002	<0.002

[a] *Excluding natural radionuclides. 'Others' comprises data for all radionuclides with doses below 0.001 mSv*
[b] *Representative of people most exposed unless stated otherwise*
[c] *The dose from food pathways was 0.033 mSv*

Table 4.16. Concentrations of radionuclides in terrestrial food and the environment near Ravenglass, 2002

Material and selection[a]		No. of sampling observ-ations[g]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}										
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[c,d,]		3	<3.8	17	<0.56	<0.26	0.060	<0.47	<0.38	<0.0066	<1.9	<0.55	<0.021
Milk[c,d]	max		<4.0	19	<0.68	<0.28	0.069	<0.49	<0.41	<0.0070		<0.58	<0.023
Apples		1	9.0	9.0	<0.20	<0.40	0.16	<0.40	<0.30	<0.026	<2.1	<0.60	<0.040
Barley		1	<6.0	97	1.5	<0.30	0.54	<0.40	<0.30	<0.027	<2.7	<0.80	<0.048
Blackberries		1	<4.0	<4.0	<0.20	<0.40	0.51	<0.40	<0.40	<0.028	<2.6	<0.60	<0.047
Bovine kidney		1	<7.0	9.0	1.4	<0.20	0.20	<0.40	<0.30	<0.026	<1.7	<0.60	
Bovine liver		1	<7.0	15	1.5	<0.30	0.025	<0.50	<0.30	0.046	<1.6	<0.60	<0.052
Bovine muscle		2	<5.0	29	1.6	<0.25	<0.021	<0.40	<0.25	<0.027	<1.8	<0.50	<0.043
Bovine muscle	max			30	1.9	<0.30	0.024	<0.50	<0.30	<0.029	<2.1	<0.60	<0.044
Broad beans		1								<0.022			
Cabbage		1	<4.0	7.0	<0.70	<0.30	0.78	<0.30	<0.30	<0.021	<1.7	<0.40	<0.046
Carrots		1	<4.0	<3.0	<0.20	<0.30	0.18	<0.50	<0.30	<0.029	<2.3	<0.40	<0.049
Honey		1	<6.0	53	<0.20	<0.20	0.047	<0.20	<0.20	0.062	<1.6	<0.70	<0.039
Lettuce[e]		1								<0.049			
Ovine muscle		1	4.0	51	1.9	<0.20	<0.019	<0.40	<0.30	<0.044	<1.6	<0.70	<0.074
Ovine offal		1	<7.0	34	0.90	<0.20	0.026	<0.40	<0.30	<0.016	<1.8	<0.70	
Potatoes		1	5.0	<4.0	<0.20	<0.30	0.055	<0.40	<0.30	<0.023	<2.4	<0.70	<0.036
Runner beans		1	<4.0	<14	0.20	<0.40	0.13	<0.60	<0.40	<0.064	<2.4	<0.70	<0.038
Grass		2								<0.029			

Material and selection[a]		No. of sampling observ-ations[g]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			Total Cs	^{144}Ce	^{147}Pm	^{155}Eu	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[c,d,]		3	0.16	<1.0	<0.10	<0.43		<0.00017	<0.00019	<0.049	<0.00024
Milk[c,d]	max		0.19			<0.44		<0.00018	<0.00023	<0.052	<0.00035
Apples		1	0.078	<1.3		<0.50		<0.00020	0.00060	<0.070	<0.00050
Barley		1	0.18	<1.2		<0.60		<0.0014	0.0010	<0.17	0.0042
Blackberries		1	0.11	<1.1		<0.60		0.00030	0.00050	<0.069	0.0011
Bovine kidney		1	0.33	<1.4		<1.1		0.00010	<0.00040	<0.11	0.0020
Bovine liver		1	0.31	<1.1		<0.50		0.0011	0.0034	<0.077	0.0039
Bovine muscle		2	0.24	<1.1		<0.45		<0.00025	<0.00020	<0.13	0.00025
Bovine muscle	max		0.46	<1.3		<0.50		<0.00030		0.13	0.00030
Broad beans		1					<0.032				
Cabbage		1	0.030	<0.90	0.80	<0.40		0.00050	0.00070	<0.10	0.0021
Carrots		1	0.078	<1.3		<0.50		<0.00030	0.00030	<0.083	<0.00050
Honey		1	0.57	<1.4		<0.90		<0.00020	0.00050	<0.077	0.0010
Lettuce[e]		1					0.17				
Ovine muscle		1	0.30	<1.5		<0.80		<0.00030	<0.00040	<0.10	0.00020
Ovine offal		1	0.22	<1.7		<1.0		<0.00020	0.00080	<0.085	0.00090
Potatoes		1	0.081	<1.0	<0.20	<0.40		<0.00030	0.00080	<0.090	0.00070
Runner beans		1	0.091	<1.2		<0.60		0.00020	<0.00030	<0.062	0.0011
Grass		2			9.3						
Grass	max				15						
Soil		2					42				
Soil[f]	max						47				

[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 mean concentration of ^{137}Cs was <0.30 Bq l^{-1} and the maximum was <0.32 Bq l^{-1}*
[d] *The mean concentration of ^{134}Cs was <0.24 Bq l^{-1} and the maximum was <0.26 Bq l^{-1}*
[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.046, 0.0013 and 0.044 Bq kg^{-1} respectively*
[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 10, 0.45 and 10 Bq kg^{-1} respectively*
[g] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

Table 4.17. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2002

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk		1	<5.3	13	<0.63	<0.24	0.088	<0.0098	<1.7	<0.49	<0.022
Blackberries		1	<3.0	11	<0.20	<0.20	0.52		<1.9	<0.60	<0.045
Cabbage		1	5.0	<3.0	0.80	<0.30	1.4	<0.032	<1.8	<0.50	<0.044
Carrots		1	<4.0	<3.0	0.20	<0.40	0.64		<2.1	<0.60	<0.042
Ovine muscle		1	7.0	48	1.5	<0.30	<0.019	<0.010	<2.6	<0.90	<0.036
Ovine offal		1	<7.0	18	2.1	<0.30	0.21	<0.091	<2.0	<0.70	
Potatoes		1	<4.0	<4.0	<0.20	<0.30	0.084	<0.022	<2.1	<0.30	<0.044
Grass		2						<0.031			
Grass	max							<0.032			
Sediment	Drigg Stream	4[E]				<5.5	12		<17	<6.0	
Freshwater	Drigg Stream	4[E]	<12			<0.53	<0.11				
Freshwater	Railway Drain	1[E]	5.6			<0.50	0.18				

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	^{147}Pm	^{210}Po	^{228}Th	^{230}Th	^{232}Th
Milk		1	<0.22	<0.29	0.28	<0.13				
Blackberries		1			0.21					
Cabbage		1			0.14	0.20				
Carrots		1			0.082					
Ovine muscle		1			0.60					
Ovine offal		1			0.44					
Potatoes		1			0.09	<0.30				
Grass		2				7.4				
Grass	max					7.6				
Sediment	Drigg Stream	4[E]	<2.0	440			47	33	25	20
Freshwater	Drigg Stream	4[E]	<0.45	<0.50			<0.011	<0.0058	<0.0062	<0.0062
Freshwater	Railway Drain	1[E]	<0.40	<0.60			<0.0050	<0.0050	<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					<0.00013	<0.00020	<0.043	<0.00048		
Blackberries		1					<0.00050	0.00040	0.22	0.0066		
Cabbage		1					<0.00020	0.00090	<0.096	0.00070		
Carrots		1					0.00040	<0.00030	<0.093	0.00070		
Ovine muscle		1					0.00040	<0.00030	0.27	<0.00020		
Ovine offal		1					0.00040	0.0020	<0.10	0.00060		
Potatoes		1					<0.00020	<0.00020	<0.060	0.00030		
Grass		2				<0.18						
Grass	max		0.10	0.0045	0.095	0.32						
Soil		2				25						
	max		6.9	0.30	6.5	33						
Sediment	Drigg Stream	4[E]	83	<3.1	74		14	75	630	69	960	1700
Freshwater	Drigg Stream	4[E]	<0.0090	<0.0055	<0.0090		<0.0050	<0.0052	<2.4	<0.0080	0.035	0.59
Freshwater	Railway Drain	1[E]	0.015	<0.0050	<0.0080		<0.0070	<0.0050	<5.0	<0.010	<0.030	0.87

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

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

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

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

Table 4.18(a). Concentrations of radionuclides in food and the environment near Springfields, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}Th
Marine samples												
Flounder	Ribble Estuary	1		<0.07		<0.18	5.2					
Salmon	Ribble Estuary	1		<0.15		<0.35	0.26					
Sea trout	Ribble Estuary	1		<0.09		<0.26	3.5					
Bass	Ribble Estuary	1		<0.13		<0.29	6.8					
Shrimps	Ribble Estuary	2	56	<0.07	3.2	<0.16	2.6	0.018	0.0064	0.00098	0.0023	
Cockles	Ribble Estuary	2		0.51		<0.22	2.4	0.022	0.35	0.59	0.19	
Mussels	Ribble Estuary	1		0.25		0.25	2.5	0.10	0.27	0.49	0.16	
Samphire	Marshside Sands	1		<0.03		<0.07	0.40					
Grass (washed)	Hutton Marsh	1			3.5							
Grass (unwashed)	Hutton Marsh	1			2.1							
Soil	Hutton Marsh	1			15							
Sediment	River Ribble outfall	4[E]		<2.0			230		30	140	32	4300
Sediment	Savick Brook (tidal limit)	2[E]		<2.0			190		29	260	32	51000
Sediment	Lea Gate	2[E]		<2.2			110		33	230	33	32000
Sediment	Penwortham (cadet hut)	2[E]		<2.2			100		33	82	33	1400
Sediment	Lower Penwortham	4[E]		<2.2			510		51	380	49	<7300
Sediment	Penwortham rail bridge	4[E]		<1.3			120		24	100	22	<4200
Sediment	Penwortham position 1	4[E]		<1.3			68		23	59	23	<2300
Sediment	Penwortham position 2	1[E]		<2.0			17		42	180	46	170
Sediment	Lytham	1[E]		2.0			340		40	150	36	1600
Sediment	Becconsall	4[E]		<2.7			360		44	190	44	2800
Sediment	Freckleton	1[E]		<0.70			270		43	320	39	15000
Sediment	Hutton Marsh	1[E]		<2.5			410		32	86	31	260
Sediment	Longton Marsh	1[E]		<8.4			460		60	220	34	1200

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						<0.08				
Salmon	Ribble Estuary	1						<0.62				
Sea trout	Ribble Estuary	1						<0.25				
Bass	Ribble Estuary	1						<0.30				
Shrimps	Ribble Estuary	2				0.0016	0.0095	0.018	*	0.000059		
Cockles	Ribble Estuary	2				0.19	1.1	2.8	0.0022	0.0034		
Mussels	Ribble Estuary	1						2.4				
Samphire	Marshside Sands	1						<0.09				
Sediment	River Ribble outfall	4[E]	33	1.2	26			150			990	3600
Sediment	Savick Brook (tidal limit)	2[E]	38	1.3	36			120			1600	27000
Sediment	Lea Gate	2[E]	37	1.3	34			76			1500	24000
Sediment	Penwortham (cadet hut)	2[E]	21	1.1	19			42			500	1300
Sediment	Lower Penwortham	4[E]	51	1.8	43			270			2000	6900
Sediment	Penwortham rail bridge	4[E]	40	<1.8	35			62			<580	2900
Sediment	Penwortham position 1	4[E]	37	<1.5	29			23			620	3300
Sediment	Penwortham position 2	1[E]	17	0.50	18			51			390	550
Sediment	Lytham	1[E]	29	<0.60	32			220			1300	1800
Sediment	Becconsall	4[E]	33	<1.0	26			200			990	2700
Sediment	Freckleton	1[E]	44	1.3	38			210			2500	7300
Sediment	Hutton Marsh	1[E]	28	1.1	28			170			1000	1500
Sediment	Longton Marsh	1[E]	26	0.80	28			210			1200	1200

Table 4.18(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{129}I	^{137}Cs	Total Cs	^{228}Th	^{230}Th	^{232}Th
Terrestrial samples												
Blackberries		1	<4.0	14	<0.30	0.19	<0.063		0.057		0.0070	0.0024
Blackcurrants		1	4.0	11	<0.20	0.060	<0.056		0.067		0.0083	<0.00070
Cabbage		1	5.0	8.0	<0.40	0.40	<0.038		<0.034		0.017	0.0036
Eggs		1	<4.0	25	<0.20	0.024	<0.039		0.064		0.0036	0.00070
Onions		1	<4.0	8.0	<0.20	0.046	<0.046		<0.028		0.0091	0.0013
Potatoes		1	<4.0	7.0	<0.40	0.040	<0.045		0.071		<0.0079	<0.0089
Runner beans		1	<4.0	<3.0	<0.20	0.076	<0.044		<0.027		0.0074	0.0013
Sediment	Deepdale Brook	2[E]			<1.4			<3.4		36	31	34
Grass		1			<0.30			3.1				
Freshwater	Ulnes Walton	1[E]	<4.0		<0.12			<0.22		<0.0090	<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
Terrestrial samples												
Milk		5				<0.0065						
Blackberries		1					<0.00020	0.00020	0.31	<0.00040		
Blackcurrants		1				0.039	<0.00020	0.00030	0.41	<0.00030		
Cabbage		1	0.0057	0.00050	0.0019	<0.033	<0.00020	0.0013	0.096	0.0032		
Eggs		1				<0.033	<0.00010	<0.00040	<0.086	0.00020		
Onions		1				<0.029	0.00010	0.00010	<0.071	<0.00030		
Potatoes		1				<0.032	<0.00020	0.00020	<0.079	<0.00050		
Runner beans		1				<0.033	<0.00020	<0.00030	0.27	<0.00030		
Sediment	Deepdale Brook	2[E]	39	1.7	41					<1.2	690	840
Grass		2				1.2						
Grass	max	2	0.84	0.033	0.78	1.8						
Grass	Site fence	1[E]	0.80	<0.44	0.80							
Grass	Opposite site entrance	1[E]	1.5	<0.50	2.7							
Grass	Opposite windmill	1[E]	2.6	<0.32	3.2							
Grass	Deepdale Brook	1[E]	0.38	0.017	0.36							
Grass	Field junction	1[E]	3.9	<0.16	3.2							
Grass	Farm entrance	1[E]	1.3	<0.20	1.3							
Soil		1				160						
Soil	Site fence	1[E]	110	4.3	110							
Soil	Opposite site entrance	1[E]	170	5.4	160							
Soil	Opposite windmill	1[E]	250	10	240							
Soil	Deepdale Brook	1[E]	7.3	0.50	5.4							
Soil	Lea Town	1[E]	140	5.3	140							
Soil	N of Lea Town	1[E]	82	3.4	82							
Freshwater	Deepdale Brook	4[E]	<1.1	<0.047	<1.1						2.1	1.6
Freshwater	Ulnes Walton	1[E]	0.81	0.053	0.78						1.5	1.1

** 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

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

Table 4.18(b). Monitoring of radiation dose rates near Springfields, 2002

Location	Material or ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m			
Warton Marsh	Mud	4[F]	0.11
Warton Marsh	Mud[a]	4[F]	0.13
Warton Marsh	Salt marsh	4[F]	0.11
Warton Marsh	Mud	1	0.087
Warton Marsh	Salt marsh	2	0.10
Naze Point	Salt marsh	2	0.11
Banks Marsh	Mud	4[F]	0.12
Banks Marsh	Mud[a]	4[F]	0.13
Banks Marsh	Salt marsh	4[F]	0.14
Banks Marsh	Salt marsh	2	0.096
Hesketh Bank	Salt marsh	2	0.11
Freckleton	Mud	1	0.12
Becconsall	Mud	4	0.11
Becconsall (houseboat)	Mud	2	0.12
Longton Marsh	Salt marsh	1	0.13
Hutton Marsh	Salt marsh	1	0.13
River Ribble outfall	Salt marsh	4	0.12
Pipeline	Salt marsh	1	0.15
Pipeline (south bank)	Mud and grass	2	0.13
Savick Brook, confluence with Ribble	Grass	2	0.11
Savick Brook, Lea Gate	Grass	2	0.13
Lower Penwortham Park	Mud and grass	4	0.094
Lower Penwortham Railway Bridge	Mud	4	0.095
Penwortham Bridge Cadet hut	Mud	2	0.11
River Darwen	Grass	4	0.084
Riverbank Angler location 1	Grass	4	0.082
Riverbank Angler location 2	Grass	1	0.080
Ulnes Walton, BNFL area survey	Grass	21	0.091
Mean beta dose rates			
Lytham - Granny's Bay	Mud and sand	1[F]	0.26
Ribble Estuary	Gill net	2[F]	0.65
Ribble Estuary	Shrimp net	2[F]	0.22
Banks Marsh	Mud	4[F]	3.0
Banks Marsh	Salt marsh	4[F]	0.72
Warton Marsh	Mud	4[F]	2.7
Warton Marsh	Salt marsh	4[F]	0.60

[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*

Table 4.19(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2002

Material	Location	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{40}K	^{60}Co	^{99}Tc	^{137}Cs	^{226}Ra	^{233}Pa	^{234}Th	^{234}U
Aquatic samples											
Flounder	Liverpool Bay	2	<25								
Flounder	Mersey Estuary	2	<25								
Shrimps	Wirral	2	<25		<0.05	16	2.2				
Mussels	Liverpool Bay	2	<25								
Mussels	Mersey Estuary	2	<25								
Cockles	Dee Estuary	4			0.14	16	1.5				
Elodea canadensis	Rivacre Brook	2			<0.05	15	0.39			20	7.9
Mud and sand	Rivacre Brook	1			<0.44	160	5.1	14	32	230	28
Mud, sand and stones	Rivacre Brook	1			<0.46	150	4.8	15	26	290	50
Sediment	Rivacre Brook	1[E]		790		530	13				220
Sediment	Rivacre Brook (1.6 km downstream)	2[E]		440		110	4.5				48
Sediment	Rivacre Brook (3.1 km downstream)	2[E]		450		37	<2.7				14
Sediment	Rossmore (4.3 km downstream)	2[E]		480		120	<4.1				53
Freshwater	Rivacre Brook	2	4.1		<0.11	0.077	<0.11				0.032
Freshwater	Rivacre Brook	2[E]	9.6			0.26					0.26
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	<4.0			<0.20					0.048
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<4.5			<0.25					0.059
Freshwater	Rossmore (4.3 km downstream)	2[E]	<4.6			<0.20					0.041
Freshwater	EA Technology Pond	1[E]	<4.0			<0.30					<0.0050
Freshwater	Dunkirk Lane Pond	2[E]	<4.0			<0.20					<0.0050

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	<3.0	<0.0060				<0.0065
Milk	max		<3.3					
Lettuce		1		<0.026				<0.030
Potatoes		1		0.039	0.0055	<0.00040	0.0070	<0.033
Strawberries		1		0.053				<0.029
Grass		8						<0.37
Grass	max							1.5
Silage		4						0.19
Silage	max							0.26
Soil		4						36
Soil	max				12	0.45	11	44
Grass/herbage	North of Ledsham	1[E]		43	1.4	0.040	1.4	
Soil	North of Ledsham	1[E]		<30	20	0.80	22	
Grass/herbage	South of Capenhurst	1[E]		1.1	<0.61	<0.51	<0.84	
Soil	South of Capenhurst	1[E]		13	14	0.50	15	
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		1.2	0.17	<0.010	0.12	
Soil	Off lane from Capenhurst to Dunkirk	1[E]		12	25	<0.50	24	
Grass/herbage	East of station	1[E]		2.9	0.14	<0.040	0.13	
Soil	East of station	1[E]		10	27	1.1	25	

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

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

[c] *In distillate fraction of sample*

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

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

Table 4.19(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{235}U	^{235}U+ ^{236}U	^{238}U	^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha	Total beta
Aquatic samples											
Flounder	Liverpool Bay	2	<25								
Flounder	Mersey Estuary	2	<25								
Shrimps	Wirral							<0.05			
Mussels	Liverpool Bay	2	<25								
Mussels	Mersey Estuary	2	<25								
Cockles	Dee Estuary	4					0.11	0.64	1.8		
Elodea canadensis	Rivacre Brook	2		0.29	5.0	0.50			<0.23		180
Mud and sand	Rivacre Brook	1		1.0	19	4.3			<1.1		
Mud, sand and stones	Rivacre Brook	1		2.3	30	4.5			<2.0		
Sediment	Rivacre Brook	1[E]	9.2		130	9.2				890	1000
Sediment	Rivacre Brook (1.6 km downstream)	2[E]	2.1		31	4.8				240	810
Sediment	Rivacre Brook (3.1 km downstream)	2[E]	1.0		13	<1.1				110	710
Sediment	Rossmore (4.3 km downstream)	2[E]	2.1		32	3.9				200	900
Freshwater	Rivacre Brook	2	0.00093		0.015	0.00013			<0.13		
Natural water	Rivacre Brook	2[E]	<0.013		0.11	<0.10				0.28	0.61
Natural water	Rivacre Brook (1.6 km downstream)	2[E]	<0.0050			0.025	<0.10			0.063	0.32
Natural water	Rivacre Brook (3.1 km downstream)	2[E]	<0.0050			<0.024	<0.10			0.071	0.41
Natural water	Rossmore (4.3 km downstream)	2[E]	<0.0075			0.029	<0.10			<0.051	0.33
Natural water	EA Technology Pond	1[E]	<0.0050			<0.0050	<0.10			<0.020	0.42
Natural water	Dunkirk Lane Pond	2[E]	<0.0050			<0.0050	<0.10			<0.045	0.38

Table 4.19(b). Monitoring of radiation dose rates near Capenhurst, 2002

Location	Material or ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m			
Rivacre Brook Plant outlet	Brick	1	0.11
Rivacre Brook 1.5km downstream	Grass	1	0.082
Rivacre Brook 3.1km downstream	Soil	1	0.083
Rossmore Road West 4.3km downstream	Soil and grass	1	0.086

Table 4.20(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{99}Tc	^{106}Ru	^{110m}Ag
Marine samples												
Flounder	Inner Solway	4		13	66	<0.10	<0.19	0.76	<0.19	32	<0.64	<0.12
Lemon sole	Inner Solway	2				<0.11	<0.27		<0.37		<0.87	<0.13
Mullet	Inner Solway	2				<0.10	<0.19		<0.30		<0.54	<0.12
Plaice	Inner Solway	3				<0.11	<0.27		<0.24		<0.59	<0.14
Salmon	Inner Solway	1		6.8		<0.10	<0.15		<0.15		<0.46	<0.10
Sea trout	Inner Solway	1		13		<0.10	<0.22		<0.21		<0.71	<0.11
Shrimps	Inner Solway	4	<24	9.9		<0.12	<0.24	0.88	<0.29	<23	<0.68	<0.15
Cockles	North Solway	5		<5.0	72	2.1	<0.18	0.75	<0.17	25	<1.1	<0.12
Mussels	North Solway	8		14	91	0.79	<0.13	0.47	<0.13	270	<1.1	<0.15
Winkles	Southerness	4	<6.1	<9.4		2.2	<0.33	1.7	<0.38	530	<3.0	<0.56
Fucus vesiculosus	Pipeline	4				0.76	<0.17		<0.16	1100	<0.50	<0.10
Sediment	Pipeline	4		<3.8		2.6	<0.42		<0.45		<4.0	<0.18
Salt marsh	Dornoch Brow	4				1.3	<0.33		<0.29		<2.2	<0.13
Seawater	Pipeline	4		6.8		<0.10	<0.10		<0.10		<0.23	<0.10
Seawater (high tide)	Pipeline	4		11		<0.10	<0.10		<0.10		<0.24	<0.10
Seawater	Southerness	4		<7.5		<0.10	<0.10		<0.10		<0.22	<0.10
Seawater	North Solway	4		8.8								

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu
Marine samples									
Flounder	Inner Solway	4	<0.20	<0.10	13	<0.12	0.19	0.020	0.11
Lemon sole	Inner Solway	2	<0.24	<0.11	1.2	<0.12	0.23		
Mullet	Inner Solway	2	<0.16	<0.10	3.7	<0.10	0.15		
Plaice	Inner Solway	3	<0.26	<0.11	2.0	<0.14	0.25		
Salmon	Inner Solway	1	<0.12	<0.10	0.24	<0.10	0.15		
Sea trout	Inner Solway	1	<0.20	<0.10	4.1	<0.10	0.22	<0.0052	<0.0052
Shrimps	Inner Solway	4	<0.35	<0.10	4.6	<0.13	<0.25	0.0036	0.014
Cockles	North Solway	5	<0.32	<0.07	4.0	<0.16	<0.17	0.71	3.8
Mussels	North Solway	8	0.41	<0.08	2.0	<0.14	<0.12	0.50	2.6
Winkles	Southerness	4	1.1	<0.12	1.7	<0.15	<0.28	0.32	1.6
Fucus vesiculosus	Pipeline	4	<0.47	<0.10	20	<0.10	0.45	1.4	6.0
Sediment	Pipeline	4	<1.7	<0.23	230	0.90	1.4	12	63
Salt marsh	Dornoch Brow	4	<1.1	<0.14	130	0.59	<0.83	7.1	36
Seawater	Pipeline	4	<0.10	<0.10	<4.6	<0.10	0.10		
Seawater (high tide)	Pipeline	4	<0.10	<0.10	<0.15	<0.10	0.10		
Seawater	Southerness	4	<0.10	<0.10	<0.14	<0.10	0.10	0.00052	0.0021

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples								
Flounder	Inner Solway	4		0.23				
Lemon sole	Inner Solway	2		<0.14				
Mullet	Inner Solway	2		<0.11				
Plaice	Inner Solway	3		<0.18				
Salmon	Inner Solway	1		<0.16				
Sea trout	Inner Solway	1		<0.0038				
Shrimps	Inner Solway	4		0.03				
Cockles	North Solway	5	36	11	<0.0061	0.020		
Mussels	North Solway	8	20	4.9	0.01	0.0094		
Winkles	Southerness	4	15	3.1				
Fucus vesiculosus	Pipeline	4		15			22	520
Sediment	Pipeline	4		150				
Salt marsh	Dornoch Brow	4		48				
Seawater	Pipeline	4		<0.10				
Seawater (high tide)	Pipeline	4		<0.10				
Seawater	Southerness	4		<0.0014				
Seawater	North Solway	4						

Table 4.20(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		10	<67	<17	<1.6	<0.05	<0.10	<0.14	<0.33
Milk	max		140	22	<2.1	<0.07		<0.25	<0.36
Apples		3	73	<17	<0.39	<0.05	<0.16	<0.05	<0.13
Apples	max		86	19	<0.50		0.22		<0.20
Barley		3	140	96	<3.7	<0.05	0.32	<0.15	<0.43
Barley	max		260	180	6.7		0.43	<0.19	<0.50
Cabbage		3	37	<15	<1.1	<0.05	0.34	<0.06	<0.14
Cabbage	max		61		2.2		0.45	<0.07	<0.27
Cauliflower		1	18	<15	0.60	<0.05	0.49	<0.07	<0.29
Goose		1	5.1	17	4.1	<0.12	<0.1	<0.40	<1.2
Ground Elder		1	<5.0	<15	0.76	<0.05	0.55	<0.07	<0.21
Mallard		1	9.2	25	2.5	<0.12	0.24	<0.36	<1.1
Nettles		1	5.5	16	4.3	<0.05	2.0	<0.08	<0.26
Nettles	max						2.1		
Pheasants		1	15	24	8.3	<0.12	0.66	<0.38	<1.1
Pink potatoes		1	38	24	<0.50	<0.05	<0.10	<0.09	<0.39
Potatoes		6	<40	<23	<0.68	<0.05	<0.10	<0.05	<0.15
Potatoes	max		130	27	1.8				<0.21
Rhubarb		1	49	<15	<0.50	<0.05	0.22	<0.07	<0.31
Rosebay willow herb		1	6.0	27	<0.50	<0.05	1.3	<0.05	<0.14
Rosehips		1	79	49	1.6	<0.05	0.65	<0.11	<0.40
Turnips		4	35	<15	<0.50	<0.05	0.22	<0.07	<0.27
Turnips	max		43				0.29	<0.08	<0.37
Wheat		1	<5	46	0.52	<0.05	0.62	<0.16	<0.32
Widgeon		1	6.4	35	8.7	<0.12	0.031	<0.34	<1.0
Grass		6	<24	<17	<0.96	<0.05	0.40	<0.14	<0.38
Grass	max		46	21	1.5		0.56	<0.23	<0.45
Soil		6	<57	<15	<1.3	<0.05	<1.4	<0.19	<0.45
Soil	max		260		<1.6	<0.06	2.9	<0.26	<0.52

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{110m}Ag	^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am	Total Alpha	Total Beta
Terrestrial samples									
Milk		10	<0.05	<0.05	<0.05		<0.06		
Milk	max		<0.08	<0.07	<0.07		<0.09		
Apples		3	<0.05	<0.05	<0.06		<0.06		
Apples	max				0.07		<0.07		
Barley		3	<0.05	<0.05	<0.08		<0.12		
Barley	max		<0.06		0.13		<0.16		
Cabbage		3	<0.05	<0.05	<0.05		<0.06		
Cabbage	max						<0.09		
Cauliflower		1	<0.05	<0.05	<0.05		<0.05		
Goose		1	<0.18	<0.14	24		<0.24		
Ground Elder		1	<0.05	<0.05	0.07		<0.06		
Mallard		1	<0.13	<0.11	0.66		<0.17		
Nettles		1	<0.05	<0.05	0.09		<0.07		
Nettles	max								
Pheasants		1	<0.14	<0.12	0.88		<0.17		
Pink potatoes		1	<0.05	<0.05	0.06		<0.08		
Potatoes		6	<0.05	<0.05	<0.05		<0.06		
Potatoes	max						<0.07		
Rhubarb		1	<0.05	<0.05	0.35		<0.06		
Rosebay willow herb		1	<0.05	<0.05	<0.05		<0.05		
Rosehips		1	<0.05	<0.05	<0.05		<0.14		
Turnips		4	<0.05	<0.05	<0.14		<0.06		
Turnips	max				0.43		<0.08		
Wheat		1	<0.05	<0.05	0.14		<0.08		
Widgeon		1	<0.13	<0.11	0.59		<0.17		
Grass		6	<0.05	<0.05	<0.17		<0.13	<0.01	210
Grass	max				0.44		<0.14		240
Soil		6	<0.07	<0.06	11	0.85	<0.23	220	660
Soil	max		<0.08	<0.07	18	1.0	0.39	270	790

[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*

Table 4.20(b). Monitoring of radiation dose rates near Chapelcross, 2002

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Southerness	Winkle bed	4	0.078
Glencaple Harbour	Mud and sand	4	0.093
Priestside Bank	Salt marsh	4	0.070
Powfoot Merse	Mud	4	0.085
Pipeline	Sand	4	0.093
Pipeline	Salt marsh	4	0.10
Battlehill	Sand	4	0.078
Dornoch Brow	Mud and sand	4	0.084
Dornoch Brow	Salt marsh	4	0.093
Browhouses	NA	4	0.090
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 4.20(c). Radioactivity in air near Chapelcross, 2002

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Eastriggs	12	<0.011	<0.0080	<0.14
Kirtlebridge	11	<0.013	<0.0067	<0.13
Brydekirk	11	<0.012	<0.0068	<0.15

5. UNITED KINGDOM ATOMIC ENERGY AUTHORITY

The United Kingdom Atomic Energy Authority (UKAEA) operates at licensed nuclear sites in England at Harwell, Winfrith and Windscale, adjacent to the BNFL Sellafield site, and in Scotland at Dounreay. All 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 also undertaken. Tenants, or contractors, such as AEA Technology carry out some of this work. Historically some solid waste was authorised for disposal in a shaft 55 metres deep at Dounreay but no such disposals have been made since 1977. Solid and liquid waste discharges from Dounreay include a minor contribution from the adjoining reactor site (Vulcan Naval Reactor Test Establishment (NRTE)) which is operated by the Ministry of Defence (Procurement Executive) and the activities of AEA Technology at two facilities on the Dounreay site. Discharges from the Windscale site were negligible compared with Sellafield. Regular monitoring of the environment in relation to Dounreay, Harwell and Winfrith was undertaken and discharges from Windscale were monitored as part of the Sellafield programme. Monitoring around Vulcan (NRTE) and AEA Technology (Dounreay) was carried out as part of the Dounreay programme. Amersham plc are also present on the Harwell site. Their facilities make gaseous discharges to atmosphere and make liquid effluent discharges via UKAEA facilities. A low level programme was also undertaken at Culham, a non-nuclear site, which is home to the experimental fusion reactor, the Joint European Torus.

5.1 Dounreay, Highland

Radioactive waste discharges from this establishment are made by UKAEA under authorisations granted by SEPA. The quantities discharged from Dounreay in 2002 were generally similar to those in 2001. This reflects the continuing shut down of processing activities within the fuel cycle area under a formal direction issued by the NII in May 1998. In January 2002, SEPA and HSE’s NII jointly published a closeout report on the audit that followed the 1998 formal direction (HSE, 1998, 2002). Of the original 143 recommendations, 89 had been closed out, leaving 27 short term recommendations to be attended to over the next few years and a further 27 long term strategic recommendations that have been incorporated into the Dounreay Site Restoration Plan.

A plant designed to destroy 1500 tons of sodium coolant from the Prototype Fast Reactor started operations in 2002 although problems with the ion-exchange columns which abate radioactive discharges from this process have limited throughput.

Monitoring included sampling of grass and soil and terrestrial foods including meat, vegetables and cereals. There are no dairy herds in the Dounreay area and therefore no milk samples were collected. Routine marine monitoring involved 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 the Food and Environment Protection Act 1985 (FEPA) (prohibiting the harvesting of seafoods around the pipeline) are collected under consent granted in 1998 by the Scottish Office. The results of SEPA’s monitoring are presented in Tables 5.1(a) and (b).

During 2002, UKAEA continued vehicle-based monitoring of local public beaches for radioactive fragments* in compliance with the requirements of the authorisation granted by SEPA. It should be noted that permission for vehicular access to a publicly accessible beach was withdrawn from 1st July 2002 until late October. Monitoring of this beach resumed on 8th November.

In 2002, five fragments were recovered from Sandside Bay and five from the Dounreay foreshore. The possible presence of an additional radioactive fragment at Sandside Bay was detected but an incoming tide prevented attempts to recover the particle. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 39 kBq and 110 kBq.

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* *‘Fragments’ are mainly considered to be fragments of irradiated fuel which are up to a few mm in diameter*

5. United Kingdom Atomic Energy Authority (UKAEA)

Surveys undertaken during 2002 identified 342 fragments on the offshore seabed, all of which were recovered. The offshore work provided data on repopulation rates of particles to previously cleared areas of the seabed. This work has improved the understanding of particle movements in the marine environment. The current state of knowledge is described in the Dounreay Particles Advisory Group's (DPAG)* Second Interim Report, which is available on SEPA's website (Dounreay Particles Advisory Group, 2003). This report also contains details of the locations where particle sampling was conducted in the area.

Modelling work carried out on behalf of UKAEA had indicated the potential for particles to be present in a number of tidal gyres. Investigations of these gyres using diver surveys detected particles in the marine environment near Brims Ness and Cross Kirk (to the east of Dounreay). SEPA informed the Food Standards Agency (Scotland) of these finds, who accordingly re-assessed the FEPA order. The re-assessment, which can be found on Food Standards Agency's website, concluded that the FEPA area did not need altering (Food Standards Agency, 2003a) as extending the FEPA area would not result in a significant benefit to consumers.

SEPA has commissioned the NRPB to undertake a re-assessment of potential health effects of particles. The assessment is in the form of five modules:

1. Uncertainties in the estimation of doses;
2. Fuel fragment densities;
3. The likelihood of encountering a fuel fragment and duration of resulting exposure;
4. Probabilistic dose assessments (combination of modules 1, 2 and 3);
5. Peer review of beach monitoring.

Module 5, the peer review of beach monitoring, is complete and the report can be found on SEPA's website (Scottish Environment Protection Agency, 2003a). The remainder of the project is expected to be complete in autumn 2004.

SEPA also awarded a contract to NNC to examine the solubility of particles in simulated gastric fluids (see also Section 12). This work was undertaken by Scottish Universities Environment Research Centre and is available on SEPA's website (Scottish Environment Protection Agency, 2003b). The information contained in the report will be incorporated into the NRPB project mentioned above.

The marine monitoring programme relates to the existence of four potential exposure pathways at Dounreay. Details are given in Appendix 4.

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 2002 were generally similar to those for 2001. Technetium-99 in crabs, molluscs and seaweed remained at levels to be expected at 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.

The second potential pathway relates to external exposure over local beaches. Gamma dose rates measured over intertidal areas were similar to those measured in previous years. The radiation dose due to occupancy in such areas was 0.009 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 indicated lower concentrations of radionuclides to those measured in 2001 but the results are known to be very variable. Measurements of gamma dose rates above areas of the foreshore remained similar to those for 2001. 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.

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* *DPAG was set up in 2000 to provide independent advice to SEPA and UKAEA on issues relating to the Dounreay fragments. DPAG continued holding public meetings throughout 2002.*

The fourth potential pathway relates to external exposure from radioactivity adsorbed on fine particulate matter that becomes entrained on fishing gear that is regularly handled. This results in a radiation dose to the skin of the hands and forearms of fishermen, mainly from beta radiation. The critical group is represented by a small number of people who operate a fishery close to Dounreay. Measurements in 2002 indicated that this pathway was of no radiological significance.

The results for terrestrial samples and radioactivity in air are given in Table 5.1(a) and (c) and generally show low levels of radioactivity. Low levels of tritium, strontium-90, iodine-129, caesium isotopes, plutonium isotopes and americium-241 were found in samples. Iodine-129 concentrations increased in potatoes when compared with 2001. Taking these results together with information on consumption rates, the dose to the critical group of local terrestrial consumers, including a contribution due to weapon test fallout, was estimated to be 0.032 mSv, which was about 3% of the annual dose limit for members of the public of 1 mSv. The increase from 2001 (0.014 mSv) was largely due to the observed increase in iodine-129 in potatoes. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

5.2 Harwell, Oxfordshire

Discharges of radioactive wastes from Harwell continued in 2002 with liquid discharges made under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site, while gaseous discharges were made to the atmosphere. The authorisation was revised, with significant reductions in discharge limits, to take effect from 1st May 2003. 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 5.1. Monitoring of the aquatic environment at Newbridge (upstream of the site) is undertaken to indicate background levels remote from nuclear establishments.

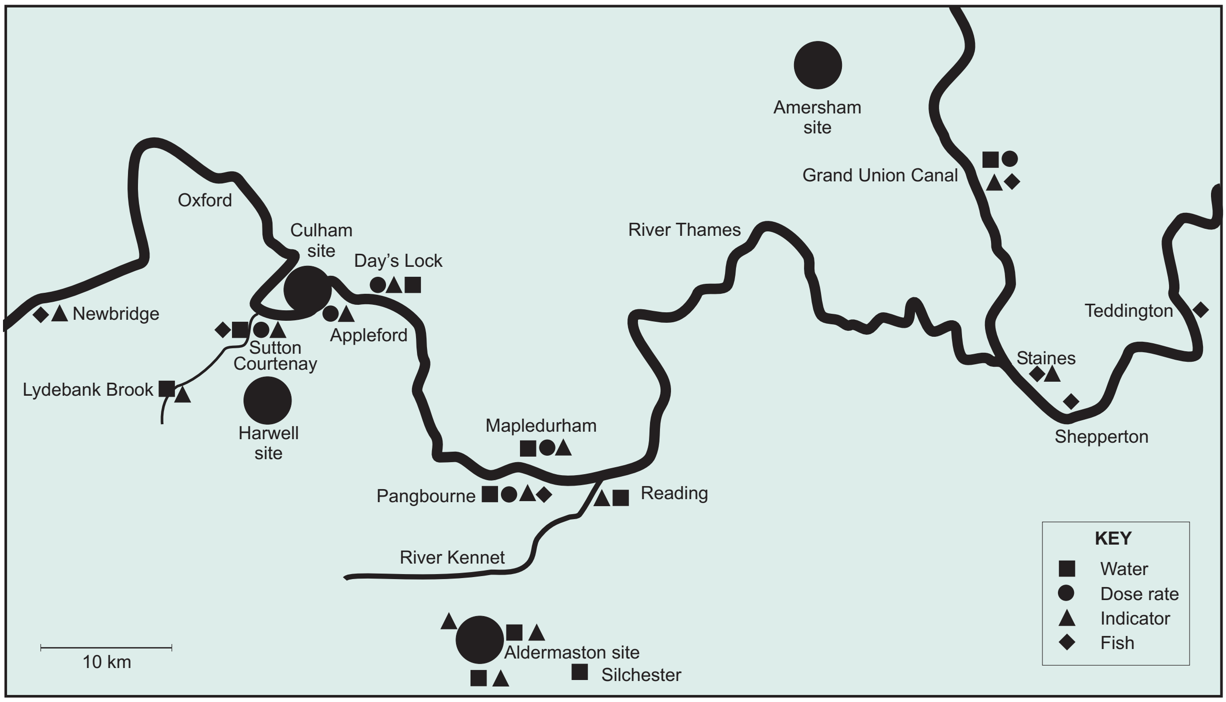

Figure 5.1 Monitoring locations at Thames sites (excluding farms)

The results of measurements of radioactivity concentrations and dose rates are shown in Tables 5.2(a) and (b). Tritium was detected in honey and vegetables collected near the site but at very low levels. No other radionuclides were found above the limit of detection. 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.

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

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 2002 was 0.011 mSv, which was about 1% of the dose limit for members of the public of 1 mSv. The tritium contribution to this dose was substantially less than 0.005 mSv. Thames river water is used as a source of drinking water. The annual dose from drinking River Thames water consisting of discharged radionuclides downstream of the discharge points was much less than 0.005 mSv.

5.3 Winfrith, Dorset

Discharges of radioactive wastes from this site continued in 2002 at the low rates typical of recent years. No changes to the authorisation were made in 2002, however the Environment Agency launched a consultation exercise concerning an application by RWE NUKEM Ltd. to discharge gaseous wastes from the Winfrith site (Environment Agency, 2003a). Liquid wastes are disposed of under authorisation to deep water in Weymouth Bay. The monitoring programme consisted of samples of milk, crops, fruit, seafood, water and indicator materials.

Data are presented in Table 5.3(a) and (b). Results for terrestrial samples gave little indication of an effect due to gaseous discharges. A low level of tritium was found in surface water to the north of the site, similar to previous years. In all cases the total alpha and beta activities were below the WHO's screening values for drinking water. The critical group for gaseous discharges was terrestrial food consumers who were estimated to receive a dose of less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv. Previous assessments have shown that other pathways are insignificant (Environment Agency, 2002a).

Concentrations of radionuclides in the marine environment continued at the low levels found in recent years. Small amounts of technetium-99 found in seaweed may have been due to discharges from Sellafield or Cap de la Hague. 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 2002 at less than 0.007 mSv which was less than 1% of the dose limit for members of the public.

5.4 Culham, Oxfordshire

Monitoring of soils and grass around Culham and of sediment and water from the River Thames was undertaken in 2002 and data is shown in Table 5.4. No significant effects due to site operation were detected. The measured concentrations of caesium-137 in the River Thames sediment are not attributable to Culham, but are due to discharges from Harwell, nuclear weapons testing fallout from the 1950s and 1960s and the Chernobyl reactor accident in 1986. The dose from using the River Thames directly as drinking water downstream of the discharge point at Culham in 2002 was estimated to be much less than 0.005 mSv.

Table 5.1(a). Concentrations of radionuclides in food and the environment near Dounreay, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{134}Cs	^{137}Cs
Marine samples													
Crabs	Pipeline	3	27	<0.13	<0.12	0.59	<0.51	<0.62	8.8	<0.98	<0.13	<0.11	<0.12
Crabs	Pipeline inner zone	1		<0.10	<0.10		<0.62	<1.3		<0.89	<0.11	<0.10	<0.10
Crabs	Pipeline outer zone	2		<0.12	<0.11		<0.44	<0.66		<0.87	<0.12	<0.11	<0.11
Crabs	Strathy	4		<0.10	<0.10		<0.21	<0.16		<0.81	<0.10	<0.10	<0.10
Crabs	Kinlochbervie	3		<0.33	<0.10		<0.16	<0.15	<1.3	<0.55	<0.10	<0.10	<0.11
Crabs	Melvich Bay	4		<0.10	<0.10		<0.21	<0.18	3.3	<0.80	<0.10	<0.10	<0.11
Winkles	Brims Ness	4		<0.10	<0.10	1.6	<0.22	<0.15		<0.80	<0.10	<0.10	<0.16
Winkles	Sandside Bay	4		<0.10	<0.11	0.47	<0.21	<0.26	16	<0.77	<0.10	<0.10	<0.10
Winkles	Kinlochbervie	1		<0.10	<0.10		<0.14	<0.10		<0.65	<0.10	<0.10	<0.10
Mussels	Echnaloch Bay	4		<0.10	<0.11		<0.22	<0.24	19	<0.79	<0.10	<0.10	<0.12
Ascophyllum nodosum	Burwick Pier	1		<0.10	<0.10		<0.11	<0.10		<0.34	<0.10	<0.10	<0.10
Fucus vesiculosus	Sandside Bay	4		<0.10	<0.11		<0.15	<0.17	190	<0.40	<0.10	<0.10	<0.19
Fucus vesiculosus	Brims Ness	4		<0.10	<0.10		<0.15	<0.17		<0.39	<0.10	<0.10	0.14
Fucus vesiculosus	Kinlochbervie	4		<0.10	<0.10		<0.16	<0.18	63	<0.51	<0.10	<0.10	0.30
Fucus vesiculosus	Burwick Pier	1		<0.10	<0.10		<0.10	<0.10		<0.32	<0.10	<0.10	0.19
Seaweed	Burwick Pier	2		<0.10	<0.10		<0.13	<0.10	130	<0.43	<0.10	<0.10	<0.14
Spume / sediment[b]	Oigins Geo	4		<0.13	<0.18		<0.33	<0.25		<1.3	<0.21	<0.18	6.7
Sediment	Sandside Bay	4		<0.10	<0.10		<0.13	<0.11		<0.56	<0.10	<0.10	3.1
Sediment	Rennibister	4		<0.11	<0.10		<0.28	<0.25		<0.77	<0.12	<0.10	14
Seawater	Sandside Bay	4	<1.0	<0.10	<0.10		<0.10	<0.10		<0.22	<0.10	<0.10	<0.10

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	Total alpha	Total beta
Marine samples										
Crabs	Pipeline	3	<0.62	<0.14	<0.24	0.053	0.020	0.034		
Crabs	Pipeline inner zone	1	<0.60	<0.11	<0.22			<0.13		
Crabs	Pipeline outer zone	2	<0.54	<0.12	<0.21			<0.13		
Crabs	Strathy	4	<0.49	<0.12	<0.22	<0.00089	<0.00089	<0.14		
Crabs	Kinlochbervie	3	<0.33	<0.11	<0.15	0.022	0.090	<0.13		
Crabs	Melvich Bay	4	<0.50	<0.12	<0.23	<0.0011	0.0040	<0.14		
Winkles	Brims Ness	4	<0.50	<0.12	<0.22	0.0094	0.052	0.053		
Winkles	Sandside Bay	4	<0.47	<0.11	<0.21	0.024	0.10	0.1		
Winkles	Kinlochbervie	1	<0.37	<0.10	<0.18			<0.11		
Mussels	Echnaloch Bay	4	<0.48	<0.12	<0.22	0.0093	0.051	<0.018		
Ascophyllum nodosum	Burwick Pier	1	<0.22	<0.10	<0.11			<0.10		
Fucus vesiculosus	Sandside Bay	4	<0.29	<0.10	<0.14			<0.24	<11	420
Fucus vesiculosus	Brims Ness	4	<0.29	<0.10	<0.14			<0.14		
Fucus vesiculosus	Kinlochbervie	4	<0.38	<0.11	<0.23			<0.18		
Fucus vesiculosus	Burwick Pier	1	<0.22	<0.10	<0.12			<0.12		
Seaweed	Burwick Pier	2	<0.29	<0.10	<0.15			<0.15		
Spume / sediment[b]	Oigins Geo	4	<1.1	<0.27	<0.75	3.9	15	0.23		
Sediment	Sandside Bay	4	<0.48	0.80	<0.32	3.8	16	14		
Sediment	Rennibister	4	<0.66	<0.16	<0.75			<0.30		
Seawater	Sandside Bay	4	<0.14	<0.10	<0.10			<0.10		

Table 5.1(a). continued

Material	Selection[c]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{129}I	^{134}Cs	^{137}Cs
Terrestrial samples													
Bovine muscle		1	<5.0		<0.05		<0.11	<0.10	<0.36	<0.05		<0.05	0.07
Cabbage		1	<5.0		<0.05	0.17	<0.06	<0.07	<0.14	<0.05	0.50	<0.05	<0.05
Nettles		1	<5.0		<0.05	2.1	<0.05	<0.05	<0.16	<0.05	<0.05	<0.05	0.11
Ovine muscle		1	7.9		<0.05			<0.07	<0.39	<0.05		<0.05	0.23
Potatoes		2	<5.0		<0.05	<0.10	<0.05	<0.05	<0.12	<0.05	0.84	<0.05	0.20
	max								<0.13		1.5		0.32
Wheat		1	<5.0		<0.05	0.63	<0.10	<0.05	<0.41	<0.05	0.20	<0.05	0.18
Grass		6	<5.0		<0.05	0.60	<0.13	<0.13	<0.38	<0.05	<0.06	<0.05	<0.24
Grass	max					0.86	<0.15	<0.15	<0.45	<0.06	<0.01		0.77
Soil		6	<5.0	0.07	<0.07	2.0	<0.22	<0.38	<0.62	<0.10	<0.30	<0.10	25
Soil	max				<0.09	5.0	<0.31	<0.99	<0.88	<0.14	<0.65	0.15	45

Material	Selection[c]	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										
Bovine muscle		1	<0.25							<0.10
Cabbage		1	<0.09					<0.050	<0.050	<0.050
Nettles		1	<0.11					<0.050	<0.050	<0.050
Ovine muscle		1	<0.27							<0.11
Potatoes		2	<0.08					<0.050	<0.050	<0.050
	max		<0.09							
Wheat		1	<0.27					<0.050	<0.050	<0.050
Grass		6	<0.25		<0.090	<0.041	<0.084	<0.050	<0.050	<0.080
Grass	max		<0.29		0.20	<0.050	0.20			<0.14
Soil		6	<0.54	1.0	15	<0.45	16	<0.050	0.53	<0.49
Soil	max		<0.73	1.3	30	1.3	41	0.12	1.9	0.79

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

[b] *The concentrations of activity in individual samples vary significantly as they depend on a varying proportion of more active spume and less active sediments. Individual results are available from SEPA*

[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*

Table 5.1(b). Monitoring of radiation dose rates near Dounreay, 2002

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	0.060
Sandside Bay	Winkle bed	4	0.12
Oigin's Geo	Spume/sludge	4	0.17
Melvich	Salt Marsh	1	0.076
Melvich	Sand	1	0.063
Strathy	Sand	1	0.056
Thurso	Riverbank	1	0.10
Achreregan Hill	Soil	1	0.080
Strathy Park	N/A	1	0.088
Archvarasdal	N/A	1	0.092
Thurso Park	Soil	1	0.097
Borrowston Mains	Soil	1	0.093
East of Dounreay	Soil	1	0.083
Castletown Harbour	N/A	1	0.093
Mean beta dose rates			µSv h^{-1}
Sandside Bay	Sediment	4	<1.0
Oigin's Geo	Surface sediment	3	<1.0
Brims Ness	Surface sediment	4	<1.0

NA Not available

Table 5.1(c). Radioactivity in air near Dounreay, 2002

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Shebster	12	<0.015	<0.0043	<0.088
Reay	12	<0.016	<0.0076	<0.12
Balmore	11	<0.019	<0.0068	<0.11

Table 5.2(a). Concentrations of radionuclides in food and the environment near Harwell, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{60}Co	^{137}Cs	^{238}Pu	^{239}Pu ^{240}Pu	^{241}Am	Total alpha	Total beta
Freshwater samples											
Pike	Outfall (Sutton Courtenay)	1	130	110	<0.05	0.53			<0.14		
Pike	Newbridge	1	<25	<25	<0.14	<0.13	0.00049	0.0023	0.0048		
Pike	Staines	1	<25	<25	<0.04	0.12			<0.10		
Pike	Shepperton	1	<25	<25	<0.06	0.17			<0.15		
Pike	Teddington	1	<25	<25	<0.04	0.13			<0.05		
Flounder	Beckton	1		<25	<0.04	0.19			<0.11		
Nuphar lutea	Newbridge	1		<25	<0.03	<0.02			<0.07		
Nuphar lutea	Staines	1		<25	<0.06	<0.05			<0.04		
Mud	Position 'E' [b]	2			3.5	430			<3.3		
Sediment	Appleford	4[E]			<0.56	13	<0.38	<0.38	<0.85	210	400
Sediment	Outfall (Sutton Courtenay)	4[E]			<0.99	15	<0.42	<0.64	<2.0	400	560
Sediment	Day's Lock	4[E]			<0.52	5.8	<0.37	<0.30	<0.95	290	340
Sediment	Lydebank Brook	4[E]			<0.93	9.1	<0.41	0.92	<1.2	230	600
Freshwater	Day's Lock	4[E]		<4.0	<0.53	<0.50				<0.035	0.35
Freshwater	Lydebank Brook	4[E]		<4.0	<0.55	<0.53				<0.038	0.16
Freshwater	R Thames (above outfall)	4[E]		<4.3	<0.49	<0.51				<0.047	<0.16
Freshwater	R Thames (below outfall)	4[E]		<4.0	<0.49	<0.49				<0.056	0.25

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	<4.0	<4.0	<0.30	<0.30	<0.31
Milk	max				<0.35		<0.33
Apples		1	<3.0	<3.0	<0.30	<0.20	<0.20
Blackberries		1	<3.0	<3.0	<0.40	<0.30	<0.40
Honey		2		<6.0	<0.10	<0.20	<0.20
Honey	max			6.0			
Mangetout		1	3.0	7.0	<0.30	<0.30	<0.30
Potatoes		1	<4.0	<4.0	<0.40	<0.30	<0.40
Spinach		1	2.0	8.0	<0.40	<0.30	<0.30

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

Table 5.2(b). Monitoring of radiation dose rates near Harwell, 2002

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Appleford	Mud and grass	2	0.079
Sutton Courtenay	Mud and grass	2	0.087
Position "E"[a]	Soil	2[F]	0.080
Day's Lock	Mud and grass	2	0.081

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

Table 5.3(a). Concentrations of radionuclides in food and the environment near Winfrith, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{14}C	^{60}Co	^{65}Zn	^{99}Tc	^{131}I	^{137}Cs	^{238}Pu
Marine samples									
Cod	Weymouth Bay	1		<0.06	<0.16		*	0.24	
Plaice	Weymouth Bay	2		<0.04	<0.11		*	0.12	
Ling	Weymouth Bay	1		<0.04	<0.11		*	0.64	
Crabs	Chapman's Pool	1		0.28	<0.14		*	<0.05	0.00073
Crabs	Lulworth Banks	1	37	<0.26	<0.53		*	<0.21	0.0016
Pacific Oysters	Poole	1		<0.04	<0.08		*	0.03	
Cockles	Poole	1		0.59	<0.08		*	<0.03	
Whelks	Weymouth Bay	1		0.14	<0.12		<1.0	<0.05	
Whelks	Poole	1		0.24	<0.15		*	<0.05	0.00085
Fucus serratus	Kimmeridge	2		0.57	<0.22	0.81	<0.15	<0.07	
Fucus serratus	Bognor Rock	2		0.65	<0.18	1.5	<0.39	<0.06	
Seaweed	Arish Mell	2[E]		<0.85		<11	<410	<0.50	
Seawater	Arish Mell	2[E]		<0.33				<0.26	

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								
Cod	Weymouth Bay	1		<0.16				
Plaice	Weymouth Bay	2		<0.08				
Ling	Weymouth Bay	1		<0.11				
Crabs	Chapman's Pool	1	0.0038	0.0095	*	0.000045		
Crabs	Lulworth Banks	1	0.0095	0.015	0.000019	0.000022		
Pacific Oysters	Poole	1		<0.04				
Cockles	Poole	1		<0.04				
Whelks	Weymouth Bay	1		<0.14				
Whelks	Poole	1	0.0043	0.0056	0.000014	0.000069		
Fucus serratus	Kimmeridge	2		<0.21				240
Fucus serratus	Bognor Rock	2		<0.18				
Seaweed	Arish Mell	2[E]		<1.5				
Seawater	Arish Mell	2[E]		<0.41			<4.5	<7.0

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		4	<5.2	<5.2	14	<0.28	<0.28		
Milk	max		<6.8	<6.8	15	<0.33	<0.30		
Apples		1	<4.0	<4.0	19	<0.30	<0.30		
Cabbage		1	<3.0	<3.0	50	<0.40	<0.40		
Carrots		1	<6.0	<4.0	15	<0.20	<0.20		
Gooseberries		1	<4.0	<4.0	10	<0.30	<0.30		
Honey		1		<6.0	23	<0.20	<0.20		
Potatoes		1	<5.0	<4.0	24	<0.40	<0.30		
Grass		2	<5.5	5.5	30	<0.30	<0.75		
Grass	max		<6.0	6.0	40		1.3		
Sediment	North of site	2[E]				<0.70	7.9	<100	<140
Sediment	R Frome (upstream)	2[E]				<0.60	<2.0	<100	<180
Sediment	R Frome (downstream)	2[E]				<2.0	<5.8	<180	470
Sediment	R Win, East of site	2[E]				<0.80	<0.85	<100	<120
Freshwater	North of site	2[E]		22		<0.45	<0.45	<0.026	0.12
Freshwater	R Frome (upstream)	2[E]		<4.0		<0.39	<0.40	<0.030	<0.090
Freshwater	R Frome (downstream)	2[E]		<4.0		<0.40	<0.35	<0.030	<0.10
Freshwater	R Win, East of site	2[E]		<4.0		<0.45	<0.40	0.036	<0.14

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

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

Table 5.3(b). Monitoring of radiation dose rates near Winfrith, 2002

Location	Material or ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Weymouth Bay	Sand and stones	1	0.054
Osmington Mills	Stones	1	0.064
Ringstead Bay	Sand and stones	1	0.063
Durdle Door	Stones	1	0.061
Lulworth Cove	Sand and stones	1	0.053
Swanage Bay 1	Sand	1	0.067
Swanage Bay 2	Sand	1	0.068
Swanage Bay 3	Sand and stones	1	0.056
Poole Harbour	Sand	1	0.058

Table 5.4. Concentrations of radionuclides in the environment near Culham, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	Total ^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha	Total beta
Freshwater	River Thames (upstream)	2	<4.0					<0.35	<0.035	0.25
Freshwater	River Thames (downstream)	2	<4.0					<0.35	<0.045	0.22
Sediment	River Thames (upstream)	2						<1.9		
Sediment	River Thames (downstream)	2						20		
Grass	1 km W of site perimeter	1		<25	75	<10	0.65	<2.0		680
Soil	2 km W of site perimeter	1		<25	57	<10	<1.7	9.7		1500

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

6. NUCLEAR POWER STATIONS OPERATED BY ELECTRICITY GENERATING COMPANIES

This section considers the effects of discharges from 12 locations where nuclear power stations were operating or undergoing decommissioning during 2002. For consistency with previous reports in this series, they are grouped here under the general description 'electricity companies'. The companies in question were British Energy Generation Ltd., British Energy Generation (UK) Ltd., Magnox Electric (a wholly owned subsidiary of BNFL plc.) and BNFL Environmental Services. The ownership of each power station is given in Appendix 1. Other BNFL sites are considered in Section 4. New or varied authorisations which took effect from 18th December 2002 were issued by the Environment Agency to Magnox power stations in England and Wales (Environment Agency, 2002b).

6.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire

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

A habit survey has established that the two potentially critical pathways for public radiation exposure in the aquatic environment were internal radiation following consumption of locally-caught fish and shellfish, and external exposure from occupancy of muddy intertidal areas. Therefore, samples of seafood were analysed and gamma dose rates are monitored. Measurements of tritium in seafood were made in order to monitor the additional local effects of discharges from a radiopharmaceutical plant in Cardiff (see Section 8). 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.

Data for 2002 are presented in Tables 6.1(a) and (b). Where comparisons can be drawn, gamma dose rates and concentrations in the aquatic environment were generally similar to those in recent years. Most of the artificial radioactivity detected was due to radiocaesium. Concentrations of radiocaesium represent the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. The trend in caesium-137 concentrations in sediment is shown in Figure 6.1. Relatively high concentrations of tritium were detected in fish and shellfish but these were mainly due to discharges from Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance. The total dose to the critical group of fish and shellfish consumers was estimated to be 0.008 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv. This includes external radiation and a component due to the tritium originating from Cardiff.

Sulphur-35 was detected at very low levels in some of the terrestrial food samples monitored. Carbon-14 was detected in locally produced foods, at levels slightly above background values. Total alpha and beta concentrations in surface waters were less than the WHO screening levels. An atmospheric dispersion 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 0.013 mSv, which was less than 2% of the dose limit.

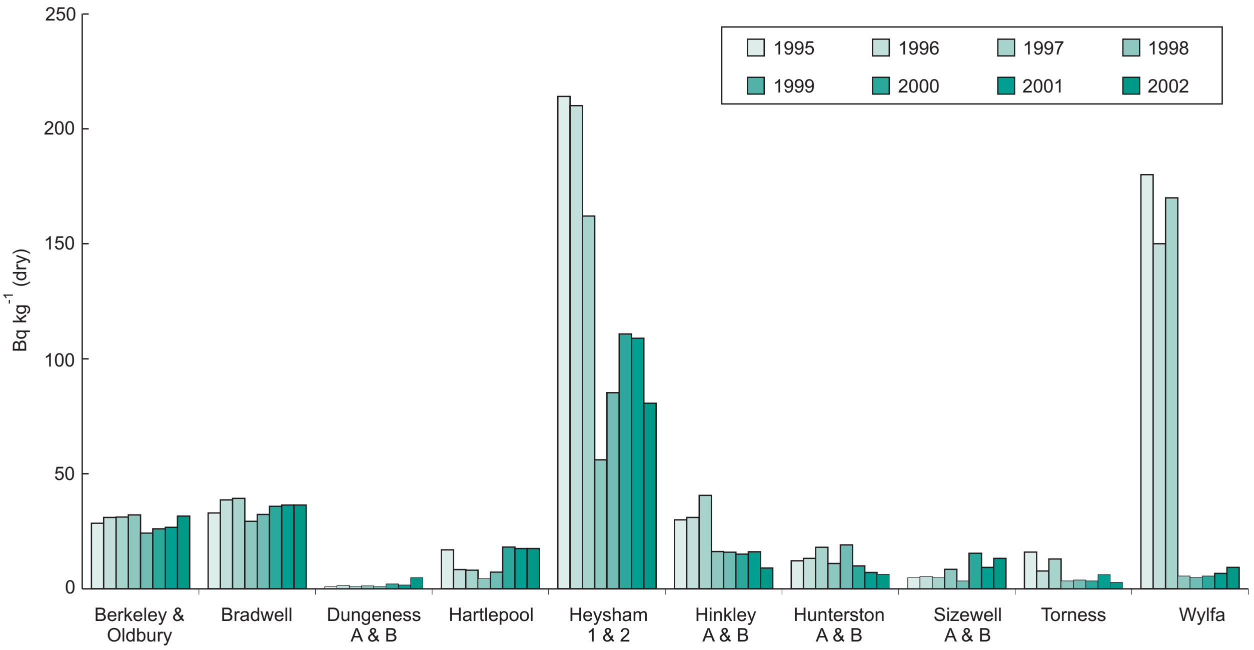

Figure 6.1 Caesium-137 concentration in sediments near nuclear power stations

6.2 Bradwell, Essex

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

Measurements for 2002 are summarised in Tables 6.2(a) and (b). Low concentrations of artificial radionuclides were detected in aquatic materials as a result of discharges from the station, discharges from Sellafield and weapons testing. Apportionment of the effects of these sources is difficult because of the low levels detected; concentrations were similar to those for 2001 (Figure 6.1). The technetium-99 detected in seaweeds at 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}, however the ditch is not known to be used as a drinking water source. Gamma dose rates on beaches were generally difficult to distinguish from natural background. The critical group of seafood consumers received 0.019 mSv, including the effects of external exposure, which was less than 2% of the dose limit for members of the public of 1 mSv.

Concentrations of activity were also low in terrestrial samples. There was nevertheless an indication that tritium and carbon-14 levels had been slightly enhanced by the operation of the power station. Low concentrations of sulphur-35 were also detected in some samples. The critical group dose was estimated to be 0.006 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv. This includes a contribution from radionuclide concentrations in air (Appendix 2).

6.3 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 advanced gas-cooled reactors (AGRs). Discharges are made via separate but adjacent outfalls and stacks, and for the purposes of environmental monitoring these are considered together.

Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples. Marine monitoring included gamma and beta dose rate measurements and analysis of seafood and sediments.

The results of monitoring for 2002 are given in Tables 6.3(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. Trace levels of cobalt-60 in some marine materials are likely to be due to the combined effects of disposals from the site and from other sites on the English Channel coast. The small concentrations of transuranics in whelks and mud were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood. Gamma and beta dose rates were difficult to distinguish from the natural background. The critical group was represented by local bait diggers who also eat fish and shellfish. Their radiation dose was low at 0.007 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv.

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, however some enhancements were observed particularly in peas. Low concentrations of tritium and sulphur-35 were detected in some samples. Concentrations of total alpha and beta activity in freshwater were within WHO screening levels. Relatively high concentrations of argon-41 in air were predicted for this site (Appendix 2). The maximum dose due to gaseous disposals was received by adults. Their dose in 2002 was estimated to be less than 0.12 mSv, which was 12% 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.

6.4 Hartlepool, Cleveland

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

Results of the monitoring programme carried out in 2002 are shown in Tables 6.4(a) and (b). The effects of gaseous disposals from the site were not easily detectable in foodstuffs, though some enhancements of carbon-14 levels in terrestrial samples were apparent. The alpha and beta activities in freshwater were less than the WHO screening levels. The critical group dose in 2002 was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

Although observed in the past, high levels of tritium in seawater were not observed in 2002. However, the level of tritium associated with organic material in crabs and winkles did indicate a possible influence of power station operations. Levels of technetium-99 in *Fucus vesiculosus* increased this year to 100 Bq kg^{-1} and were at a similar level to the peak observed in 1998 (see also Figure 4.15). They remain nevertheless at less than 1% of the equivalent concentrations near Sellafield. Concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. The enhanced dose rates at Paddy's Hole are believed to be due to waste slag from a local steel works, used as sea defences, which can be found containing enhanced levels of gamma-ray-emitting natural radionuclides. The critical occupancy group does not spend time at Paddy's Hole. The radiation dose to the critical group of local fish and shellfish consumers, including external radiation, was low, at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

6.5 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. Parts of the programme are therefore in place in order to monitor the effects of Sellafield disposals.

The results for 2002 are given in Tables 6.5(a) and (b). In general, similar levels to those for 2001 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 may have been partially due to site discharges. Concentrations of technetium-99 in marine samples remained at the higher levels typical of recent years. They were caused by discharges from Sellafield. Concentrations of caesium-137 in sediments were also largely due to Sellafield (Figure 6.1). The radiation dose in 2002 to the critical group of fishermen, including a component due to external radiation, was 0.066 mSv, which is well within the dose limit for members of the public of 1 mSv. There was little change from the estimate for 2001 of 0.059 mSv (Food Standards Agency and SEPA, 2002). Most of this exposure was due to the effects of disposals from Sellafield.

The effects of gaseous disposals were also difficult to detect in 2002. Small enhancements of concentrations of carbon-14 were apparent 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.

6.6 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 is now undergoing defuelling prior to decommissioning. Environmental monitoring covers the effects of the two power stations together. Analyses of milk and crops were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were also carried out. Measurements of tritium and carbon-14 are made primarily to establish the local effects of discharges from the Amersham plc plant at Cardiff.

The environmental results for 2002 are presented in Tables 6.6 (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 2001 (see also Figure 6.1). The relatively high level of tritium in seawater was probably due to the sampling taking place in coincidence with a specific discharge from the 'B' station. Similar values have been detected in the past. Further information of tritium levels in seawater from the Bristol Channel is given in Section 11. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors are Sellafield, weapons test and Chernobyl fallout. Apportionment is generally difficult at the low levels detected. However, the majority of tritium and carbon-14 in seafood was likely to have been due to disposals from Amersham plc, Cardiff. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment, measured using portable instruments, were similar to those for 2001. The critical group of local fishermen was estimated to receive a dose of 0.015 mSv which was less than 2% of the dose limit for members of the public of 1 mSv. This estimate includes the effects of discharges of tritium and carbon-14 from Cardiff.

Results for 2002 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 contains alpha and beta activities less than WHO screening levels. The estimated critical group dose due to radioactivity in the terrestrial environment was 0.005 mSv which was 0.5% of the dose limit for members of the public of 1 mSv.

6.7 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 British Nuclear Fuels. 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. Currently 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 indicator materials. The scope of the terrestrial monitoring programme was enhanced in 2000 and now 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 2002 are shown in Tables 6.7(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 concentration of technetium-99 from Sellafield in lobsters increased from 220 Bq kg^{-1} in 2001 to 310 Bq kg^{-1} in 2002. In *Nephrops*, concentrations remained at 320 Bq kg^{-1}. Small concentrations of tritium and 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 2002, the dose to the critical group from consumption of fish and shellfish was 0.005 mSv, which was 0.5% of the dose limit for members of the public of 1 mSv. Approximately half of the dose to the critical group was from technetium-99 in seafood.

The dose to a separate critical group of shellfish collectors who use local beaches was 0.017 mSv or less than 2% 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 0.009 mSv which was less than 1% 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.

6.8 Sizewell, Suffolk

At this establishment there are two stations. The ‘A’ station has two Magnox reactors whilst at the ‘B’ station power is generated from 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 2002 are shown in Tables 6.8 (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 2002, 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. 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 2002. Levels in local blackberries were the highest. 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 total critical group dose in 2002 was 0.053 mSv or about 5% of the dose limit for members of the public of 1 mSv.

6.9 Torness, East Lothian

This station, which is powered by two AGRs, came into operation at the end of 1987. A review of the monitoring programme at this site was undertaken in 2000, and resulted in increased sampling of milk, vegetables, fruit, seafood, seawater, seaweed and soil. Various plants also were monitored as 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 2002 are shown in Tables 6.9(a), (b) and (c). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout, although trace levels of activation products were detected which were likely to have originated from the station. The dose to fish and shellfish consumers (the critical group) was 0.005 mSv, which was 0.5% of the dose limit for members of the public of 1 mSv.

Beta radiation from fishermen's nets and pots was below the limit of detection. Gamma dose rates on beaches were generally indistinguishable from natural background though data for St Abbs were higher. The effects of discharges from the power station were seen in low levels of tritium and sulphur-35 in terrestrial foods and indicator materials. The dose to the critical group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout was 0.007 mSv**,** which was less than 1% 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.

6.10 Trawsfynydd, Gwynedd

This station is being decommissioned and a public inquiry into the decommissioning proposals heard evidence in 2002. Low level discharges continued during 2002 under authorisations granted by the Environment Agency. Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK terms. Monitoring is carried out on behalf of the Wales Assembly Government, the Environment Agency and the Food Standards Agency. 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 indicator materials, as well as the aquatics programme, are shown in Tables 6.10 (a) and (b). Concentrations of activity in all terrestrial foods were low. Sulphur-35 was detected in potatoes and blackberries but at levels similar to that in the regional diet. The source is unknown but it is very unlikely to be Trawsfynydd as there were no discharges of this radionuclide in recent years. The most likely source of radiocaesium in hazelnuts 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 similar to observations in other areas of England and Wales, where activity was attributable to weapon test fallout. There was therefore no evidence of resuspension of activity in sediment from the lakeshore contributing to increased exposure from transuranic radionuclides in 2002.

The critical group for terrestrial foods at Trawsfynydd in 2002 received doses of 0.008 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv. This assessed dose includes a contribution from the radiocaesium activity detailed above.

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 the possible exposure pathway to anglers is an issue were only slightly enhanced above background and were similar to those in 2001. The time trend of concentrations of caesium-137 in sediments is shown in Figure 6.2.

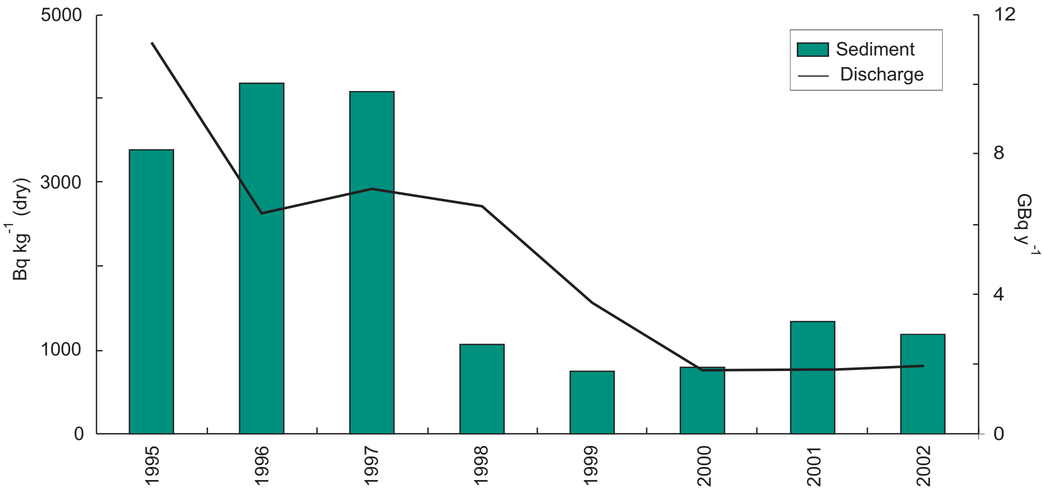

Figure 6.2 Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake

Concentrations of radiocaesium in fish in 2002 were unchanged compared with those in 2001. The activity concentrations in sediments and the residual activity in the fish that result from earlier discharges predominate at this stage. The dose to the critical group of anglers was 0.028 mSv in 2002, which was about 3% of the dose limit for members of the public of 1 mSv.

6.11 Wylfa, Isle of Anglesey

This station generates electricity from two Magnox reactors. Gaseous and liquid wastes from this station were discharged in 2002 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 Wales Assembly Government, the Environment Agency and the Food Standards Agency. Such discharges and effects are very low.

The results of the programme in 2002 are given in Tables 6.11 (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 generally similar to those for 2001, and continued to show the effects of technetium-99 from Sellafield. The dose to the critical group of high-rate fish and shellfish consumers was low, at 0.016 mSv, which was about 2% of the dose limit for members of the public of 1 mSv. Gamma dose rates, measured using portable instruments were similar to those found in 2001.

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.

Table 6.1(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{241}Am	Total alpha	Total beta
Marine samples									
Salmon	Beachley	2	<25	30	<0.06	0.25	<0.06		
Bass	Severn Beach	1	4700		0.26	2.4	<0.10		
Elvers	River Severn	1	<25		<0.10	<0.09	<0.08		
Shrimps[d]	Guscar	2	2000	63	0.09	0.60	0.0029		
Seaweed[e]	Near pipeline	2[E]			<0.80	<1.2	<0.99		
Mud	Hills Flats	2			<3.2	33	<2.7		
Sediment	Hills Flats	2[E]			<0.50	33	<4.4	700	1100
Mud	1 km south of Oldbury	2			3.4	36	<1.9		
Sediment	1 km south of Oldbury	2[E]			2.6	29	<0.98	990	920
Sediment	2 km south west of Berkeley	2[E]			<0.50	36	<4.8	1600	920
Sediment	Sharpness	2[E]			<0.50	28	<3.6	810	1100
Seawater	Local beach	2[E]			<0.59	<0.61	<0.70	<0.95	6.2

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	<3.9	18	<0.55	<0.28	<0.28		
Milk	max		<4.0	21	<0.88	<0.30	<0.30		
Apples		1	<4.0	13	<0.40	<0.20	<0.20		
Blackberries		1	<4.0	20	<0.40	<0.30	<0.30		
Cabbage		1	<4.0	<3.0	0.70	<0.30	<0.30		
Carrots		1	<4.0	<3.0	<0.40	<0.20	<0.30		
Honey		1	<6.0	68	<0.40	<0.20	<0.20		
Potatoes		1	<4.0	17	<0.40	<0.20	<0.30		
Runner beans		1	<4.0	<3.0	0.80	<0.20	<0.30		
Wheat		1	<6.0	44	<0.70	<0.20	<0.30		
Freshwater	Gloucester and Sharpness Canal	2[E]	<4.0		<3.0	<0.60	<0.61	<0.026	0.22
Freshwater	Public supply	2[E]	<4.0		<2.5	<0.59	<0.61	<0.034	0.19

[a] *Except for milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[d] *The concentrations of ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were 0.00091, 0.0032, 0.000033 and 0.000028 Bq kg^{-1} respectively*
[e] *The concentration of ^{99}Tc was <2.0 Bq kg^{-1}*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled 'E'. In that case they are made on behalf of the Environment Agency*

Table 6.1(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2002

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]	0.073
1km south of Oldbury	Mud	2	0.097
2km south west of Berkeley	Mud	2[F]	0.077
2km south west of Berkeley	Mud	2	0.082
Guscar Rocks	Mud and stones	1	0.097
Lydney Rocks	Mud and stones	1	0.085
Sharpness	Mud	2	0.087
Hills Flats	Mud	2[F]	0.071
Hills Flats	Mud	2	0.092

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

Table 6.2(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{60}Co	^{99}Tc	^{134}Cs	^{137}Cs	^{241}Am	Total alpha	Total beta
Marine samples									
Sole	Bradwell	2	<0.08		<0.09	0.74	<0.18		
Bass	Pipeline	1	<0.06		0.30	2.7	<0.27		
Mullet	Pipeline	1	<0.06		0.25	1.7	<0.26		
Lobsters	West Mersea	1	<0.04		0.06	0.40	<0.11		
Native oysters[d]	Tollesbury N. Channel	1	<0.03		<0.04	0.23	0.0032		
Pacific oysters	Goldhanger Creek	2	<0.05		<0.05	0.27	<0.08		
Winkles	Pipeline	2	<0.08		<0.07	0.70	<0.13		
Winkles	Heybridge Basin	2	<0.07		<0.05	0.81	<0.06		
Fucus vesiculosus	Waterside	2	<0.12	13	<0.25	2.0	<0.17		140
Seaweed	Waterside	1[E]	<2.0	39	<0.90	11	<2.0		
Leaf Beet	Tollesbury	1	<0.10		<0.10	<0.08	<0.07		
Samphire	Tollesbury	1	<0.02		0.05	0.42	<0.07		
Sediment	Pipeline	2[E]	<0.55		<0.50	<0.75	<0.75	<100	<120
Sediment	Maldon	2[E]	<3.0		6.0	75	<3.5	430	970
Sediment	West Mersea	2[E]	<2.2		<0.50	8.7	<4.2	560	480
Sediment	Waterside	2[E]	<3.5		<2.2	55	<11	490	1300
Sediment	1.5 km east of pipeline	2[E]	<1.7		<0.50	<2.1	<3.8	<100	<100
Seawater	Bradwell	2[E]	<0.33		<0.29	<0.38	<0.48	<3.1	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	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples										
Milk		5	<3.8	18	<0.41	<0.27	<0.25	<0.27		
Milk	max		<4.0	22	<0.50	<0.33	<0.28	<0.28		
Apples		1	<3.0	14	<0.40	<0.20	<0.30	<0.20		
Cabbage		1	3.0	17	1.3	<0.30	<0.30	<0.30		
Carrots		1	<3.0	13	0.50	<0.30	<0.30	<0.30		
Elderberries		1	<3.0	18	0.60	<0.30	<0.30	<0.30		
Plums		1	<4.0	12	<0.50	<0.40	<0.30	<0.30		
Potatoes		1	<4.0	27	0.10	<0.30	<0.30	<0.30		
Rabbit		1	<4.0	18	1.9	<0.20	<0.20	<0.30		
Wheat		1	32	50	2.4	<0.30	<0.20	<0.30		
Lucerne		1	<3.0	27	<0.70	<0.40	<0.30	<0.30		
Freshwater	Public supply	2[E]	<4.0		<10	<0.35	<0.35	<0.35	<0.043	0.25
Freshwater	Coastal ditch 1	1[E]	7.9		<20	<0.40	<0.40	<0.40	<0.89	11
Freshwater	Coastal ditch 2	1[E]	<4.0		<20	<0.30	<0.30	<0.40	<0.60	1.6
Freshwater	Coastal ditch 3	2[E]	22		<15	<0.35	<0.30	<0.35	<0.55	8.6
Freshwater	Coastal ditch 4	1[E]	19		<20	<0.50	<0.50	<0.50	<0.80	6.9

[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*
[d] *The concentrations of ^{14}C, ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were 11, 0.00029, 0.0013, 0.000022 and 0.00019 Bq kg^{-1} respectively*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled 'E'. In that case they are made on behalf of the Environment Agency*

Table 6.2(b). Monitoring of radiation dose rates near Bradwell, 2002

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m			
Bradwell Beach	Sand and stones	2	0.076
Beach opposite power station, N side of estuary	Mud and sand	2	0.066
0.5km E of pipeline	Sand	2	0.056
Waterside	Mud	2	0.065
West Mersea	Mud and sand	2	0.068
Maldon	Mud	2	0.067

Table 6.3(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{60}Co	^{99}Tc	^{137}Cs	^{155}Eu	^{241}Am	Total alpha	Total beta
Marine samples											
Plaice	Pipeline	2	<25	<25	<0.04		0.11	<0.12	<0.11		
Cod	Pipeline	2		<25	<0.04		0.21	<0.09	<0.08		
Bass	Pipeline	1		<25	<0.06		0.63	<0.18	<0.28		
Crabs	Hastings	1			<0.05		<0.05	<0.13	<0.12		
Shrimps	Pipeline	2	<32	<25	<0.06		0.25	<0.14	<0.11		
Cockles[d]	Greatstone-on-Sea	1			0.50		0.10	<0.14	<0.07		
Whelks[e]	Pipeline	2			<0.11		<0.05	<0.11	0.0041		
Cuttlefish	Hastings	1			<0.05		<0.05	<0.17	<0.26		
Fucus vesiculosus	Copt Point	1				7.6					
Seaweed	Copt Point	2[E]			<0.60	<29	<0.55		<1.2		
Mud and sand[f]	Rye Harbour	2			0.75		0.85	<1.8	0.20		
Sediment	Rye Harbour1	1[E]			<5.0		<5.0		<5.0	510	430
Sediment	Rye Harbour2	1[E]			<4.0		<4.0		<9.0	510	460
Sediment	Camber Sands	2[E]			<0.55		<0.50		<1.2	<100	<160
Sediment	Pilot Sands	2[E]			<0.85		<0.85		<1.5	<100	<140
Seawater	Pipeline	2		<1.5							
Seawater	Dungeness South	2[E]			<0.33		<0.32		<0.42	<4.0	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		3	<4.8	16	<0.48	<0.27	<0.28	<0.28		
Milk	max		<6.5	19	<0.70	<0.30	<0.30	<0.30		
Blackberries		1	<4.0	8.0	0.80	<0.30	<0.30	<0.30		
Honey		1	<6.0	26	1.0	<0.10	<0.20	<0.20		
Peas		1	7.0	100	0.50	<0.30	<0.30	<0.30		
Potatoes		1	13	19	<0.40	<0.30	<0.20	<0.30		
Sea kale		1	<4.0	11	0.70	<0.40	<0.30	<0.40		
Wheat		1	23	110	1.3	<0.40	<0.30	<0.30		
Grass		1				<0.20	<0.20	<0.20		
Freshwater	Long Pits	2[E]	<4.0		<10	<0.35	<0.30	<0.40	<0.035	0.12
Freshwater	Well number 1	1[E]	<4.0		<10	<0.50	<0.50	<0.60	<0.020	0.10
Freshwater	Well number 2	1[E]	<4.0		<10	<0.30	<0.20	<0.30	<0.020	0.34
Freshwater	Well number 3	1[E]	<4.0			<0.50	<0.50	<0.60	<0.030	0.14
Freshwater	Reservoir	1[E]	<4.0		<10	<0.30	<0.20	<0.30	<0.020	0.19

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[d] *The concentration of ^{14}C was 33 Bq kg^{-1}*
[e] *The concentrations of ^{90}Sr, ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were <0.034, 0.00097, 0.0041, 0.000022 and 0.00021 Bq kg^{-1} respectively*
[f] *The concentrations of ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were 0.050, 0.26, not detected by the method used and 0.010 Bq kg^{-1} respectively*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled 'E'. In that case they are made on behalf of the Environment Agency*

Table 6.3(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2002

Location	Ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over intertidal areas			
Littlestone-on-Sea	Sand and stones	2	0.059
Greatstone-on-Sea	Sand and stones	2	0.061
Dungeness East	Sand and stones	2	0.053
Dungeness South	Stones	2	0.058
Jury Gap	Sand and stones	1	0.061
Rye Bay	Sand	2	0.061
Rye Harbour	Mud and sand	2[F]	0.063
Mean beta dose rates			$\mu Sv\ h^{-1}$
Rye Harbour	Mud and sand	2[F]	0.074

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

Table 6.4(a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{54}Mn	^{60}Co	^{99}Tc	^{131}I	^{137}Cs	^{241}Am	Total alpha	Total beta
Marine samples												
Plaice[d]	Pipeline	2	<26	<25	<0.04	<0.05		*	0.34	<0.15		
Cod	Pipeline	2			<0.05	<0.05		<0.33	0.57	<0.21		
Crabs[e]	Pipeline	2	47		<0.06	<0.06		*	0.14	0.0019		
Winkles[f]	Paddy's Hole	2	38	42	<0.07	<0.06		<0.67	0.43	0.031		
Fucus vesiculosus	Pilot Station	2			<0.15	<0.06	110	<1.4	0.21	<0.07		280
Seaweed	Pilot Station	2[E]				<0.55	90	<900	<1.2	<1.5		
Mud	Seal Sands	1			<0.28	<0.25		<0.47	6.9	<0.63		
Sediment	Seaton Carew	2[E]				<1.7			<1.7	<4.7	<100	<180
Sediment	Paddy's Hole	2[E]				<3.5			18	<11	690	1800
Sediment	North Gare	2[E]				<1.2			<2.7	<3.3	<100	<170
Sediment	Greatham Creek	2[E]				<3.4			<5.9	<5.4	450	970
Sea coal	North Sands	2[E]				<1.8			<3.1	<4.9	140	<390
Sea coal	Carr House Sands	2[E]				<2.2			<2.2	<4.8	<100	<200
Sea coal	Seaton Sands	2[E]				<2.8			<3.4	<2.9	<100	<170
Seawater	North Gare	2[E]				<0.40			<0.40	<0.70	<4.5	<15
Seawater	Pipeline	2		8.7								

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	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		9	<3.9	16	<0.41	<0.26	<0.28		
Milk	max		<4.0	18	<0.47	<0.30	<0.35		
Apples		1	<4.0	13	0.40	<0.20	<0.30		
Blackberries		1	<4.0	15	<0.30	<0.40	<0.30		
Cabbage		1	<4.0	<3.0	0.80	<0.20	<0.20		
Carrots		1	<4.0	<3.0	0.20	<0.30	<0.30		
Honey		1	<6.0	51	0.40	<0.20	<0.20		
Leeks		1	<4.0	<3.0	0.70	<0.20	<0.30		
Potatoes		1	6.0	6.0	<0.20	<0.30	<0.30		
Wheat		1	<7.0	73	0.90	<0.30	<0.20		
Freshwater	Public supply	2[E]	<4.0		<5.5	<0.35	<0.30	<0.060	<0.10
Freshwater	Borehole, Dalton Piercy	2[E]	<4.0		<7.5	<0.38	<0.36	<0.060	<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*

[d] *The concentration of ^{14}C was 41Bq kg^{-1}*

[e] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.00047, 0.0027 and 0.000020 Bq kg^{-1} respectively*

[f] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.013, 0.083 and 0.00010 Bq kg^{-1} respectively*

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

Table 6.4(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2002

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1 m over intertidal areas			
Hartlepool North Sands	Sand	2	0.063
Seaton Carew	Sand	2	0.079
Greatham Creek Bird Hide	Salt marsh	2	0.11
North Gare	Sand and stones	2	0.068
Paddy's Hole	Winkle bed	2[F]	0.19
Paddy's Hole	Shale	2	0.18
Carr House	Sand and rock	2	0.074
Seaton Sands	Sand	2	0.080

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

Table 6.5(a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}											
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples														
Flounder	Flookburgh	4			97	<0.12	<0.12			<1.3	<0.22	<0.36	<0.13	11
Plaice	Morecambe	4	32	32		<0.08	<0.09	0.030	7.4	<0.84	<0.16	<0.23	<0.09	5.1
Bass	Morecambe	2				<0.09	<0.10			<0.90	<0.17	<0.26	<0.10	14
Whitebait	Sunderland Point	1				<0.06	<0.07	0.17		<0.54	<0.12	<0.16	<0.07	4.5
Shrimps	Flookburgh	4			110	<0.07	<0.07		6.6	<0.67	<0.13	<0.19	<0.07	4.5
Cockles	Middleton Sands	2				<0.05	2.0			2.1	<0.11	0.40	<0.07	4.0
Cockles[c]	Flookburgh	4			100	<0.06	1.4	0.31	87	<1.1	<0.11	0.46	<0.07	3.7
Winkles	Red Nab Point	4				<0.16	0.91			2.2	<0.14	0.97	<0.07	5.0
Mussels	Morecambe	4	<35	53	77	<0.07	0.57		710	1.7	<0.13	0.60	<0.07	3.5
Fucus vesiculosus	Half Moon Bay	4				<0.19	<0.43		4700	<0.67	<0.13	0.73	<0.09	3.9
Seaweed	Half Moon Bay	2[E]					<0.85		5300	<4.8	<0.60	<2.0	<0.55	9.2
Mud and sand	Flookburgh	4				<0.49	<0.50			<4.8	<0.82	<1.7	<0.61	110
Sediment	Flookburgh	4[E]					<1.9			<14		<5.3	<1.6	470
Mud and sand	Half Moon Bay	4				<0.87	5.3			<12	<1.2	<4.3	<0.96	170
Sediment	Half Moon Bay	2[E]					<1.7							21
Sediment	Pott's Corner	2[E]					<1.7							52
Sediment	Pipeline	2[E]					<2.8							80
Mud and sand	Morecambe Central Pier	4				<0.78	3.5			<11	<1.0	<4.3	<0.74	170
Sediment	Morecambe Central Pier	1[E]					2.4							170
Sediment	Sunderland Point	4[E]					<2.2			<11		<5.0	<1.1	85
Sediment	Conder Green	5[E]					<1.8	<1.2		<8.3		<4.9	<1.1	200
Sediment	Sand Gate Marsh	4[E]					<2.6			<15		<6.4	<1.6	280
Turf	Conder Green	4				<0.80	3.6			<9.0	<1.4	<3.2	<1.0	240
Turf	Sand Gate Marsh	4				<0.58	<1.1			<6.2	<0.96	<2.2	<0.72	170
Samphire	Cockerham Marsh	1				<0.02	<0.02			<0.20	<0.04	<0.05	<0.02	1.0
Seawater	Pipeline	1		77										
Seawater	Heysham Harbour	2[E]					<0.33			<2.9	<0.37		<0.30	<0.31
Seawater	Half Moon Bay	1											0.001	0.17

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Total alpha	Total beta
Marine samples												
Flounder	Flookburgh	4	<0.83	<0.38	0.00044	0.0025		0.0047	*	*		
Plaice	Morecambe	4	<0.49	<0.22				<0.23				
Bass	Morecambe	2	<0.45	<0.21				<0.21				
Whitebait	Sunderland Point	1	<0.28	<0.12	0.054	0.30	2.7	0.51	*	0.00072		
Shrimps	Flookburgh	4	<0.40	<0.19	0.0024	0.016	0.086	0.021	*	*		
Cockles	Middleton Sands	2	<0.26	<0.15	0.52	3.0		6.7	*	0.011		
Cockles[c]	Flookburgh	4	<0.31	<0.15	0.45	2.5	22	6.6	*	0.010		
Winkles	Red Nab Point	4	<0.30	<0.15	0.35	1.9		3.5	*	0.0048		
Mussels	Morecambe	4	<0.36	<0.18	0.30	1.7		3.0	*	0.0024		
Fucus vesiculosus	Half Moon Bay	4	<0.36	<0.20				0.68				3600
Seaweed	Half Moon Bay	2[E]	<2.3					<1.8				
Mud and sand	Flookburgh	4	<3.3	<1.7				48				
Sediment	Flookburgh	4[E]	<8.4	<4.6				220			900	1200
Mud and sand	Half Moon Bay	4	<5.3	<2.7	16	87		160	0.068	0.095		
Sediment	Half Moon Bay	2[E]						<12			<100	280
Sediment	Pott's Corner	2[E]						15			<100	<310
Sediment	Pipeline	2[E]						46			<100	420
Mud and sand	Morecambe Central Pier	4	<4.5	<2.4				120				
Sediment	Morecambe Central Pier	1[E]						130				1400
Sediment	Sunderland Point	4[E]	<6.2	<3.8				<61			500	790
Sediment	Conder Green	5[E]	<6.1	<3.3	8.0	42	330	59			720	1100
Sediment	Sand Gate Marsh	4[E]	<7.9	<3.3				110			750	1100
Turf	Conder Green	4	<5.2	<2.6				140				
Turf	Sand Gate Marsh	4	<4.7	<2.4				82				
Samphire	Cockerham Marsh	1	<0.13	<0.07				0.57				19
Seawater	Pipeline	1										
Seawater	Heysham Harbour	2[E]	<1.3					<0.42			<4.0	13
Seawater	Half Moon Bay	1										

Table 6.5(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[b], 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	<3.9	16	<0.48	<0.30	<2.0	<0.29	<0.30	<0.30	<1.2		
Milk	max		<4.0	22	<0.55	<0.35	<2.4	<0.33		<0.33	<1.3		
Apples		1	<4.0	<3.0	<0.30	<0.30	<0.90	<0.20	<0.20	<0.20	<0.80		
Barley		1	<6.0	20	1.5	<0.30	<2.6	<0.30	<0.30	<0.30	<1.1		
Blackberries		2	5.5	11	<0.50	<0.25	<2.0	<0.25	<0.30	<0.30	<1.7		
	max		8.0	14	0.70	<0.30		<0.30			<2.0		
Cabbage		1	9.0	5.0	0.40	<0.20	<1.8	<0.20	<0.30	<0.30	<1.0		
Honey		1	<6.0	86	<0.30	<0.20	<1.3	<0.20	<0.20	<0.20	<1.4		
Onions		1	3.0	3.0	1.6	<0.30	<2.0	<0.30	<0.30	<0.30	<1.0		
Potatoes		1	<4.0	5.0	0.50	<0.40	<2.2	<0.20	<0.30	<0.30	<1.0		
Sprouts		1	<4.0	10	0.90	<0.30	<2.0	<0.30	<0.30	<0.40	<1.3		
Freshwater	Lancaster	2[E]	<4.0		<10	<0.40			<0.40	<0.45		<0.055	<0.092

* *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 milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply*
[c] *The concentration of ^{210}Po was 19 Bq kg^{-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 6.5(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2002

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1 m over intertidal areas			
Greenodd	Salt marsh	2	0.086
Sand Gate Marsh	Salt marsh	4[F]	0.087
Sand Gate Marsh	Salt marsh	5	0.10
Flookburgh	Mud and sand	4[F]	0.074
Flookburgh	Salt marsh	4	0.095
High Foulshaw	Salt marsh	4[F]	0.081
Arnside Marsh	Mud and sand	4	0.085
Arnside Marsh	Salt marsh	4[F]	0.088
Arnside Marsh	Salt marsh	4	0.097
Morecambe Central Pier	Mussel bed	4[F]	0.071
Morecambe Central Pier	Mud and sand	4[F]	0.073
Morecambe Central Pier	Mud and sand	2	0.069
Half Moon Bay	Mud and sand	4[F]	0.075
Half Moon Bay	Mud and sand	2	0.087
Heysham pipelines	Mud and sand	2	0.083
Middleton Sands	Sand	2	0.080
Colloway Marsh	Salt marsh	4[F]	0.13
Colloway Marsh	Salt marsh	4	0.092
Aldcliffe Marsh	Salt marsh	4[F]	0.10
Aldcliffe Marsh	Salt marsh	4	0.11
Conder Green	Mud and sand	4[F]	0.087
Conder Green	Salt marsh	4[F]	0.10
Conder Green	Salt marsh	4	0.10
Cockerham Marsh	Salt marsh	4[F]	0.10
Cockerham Marsh	Salt marsh	3	0.098

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

Table 6.6(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2002

Material	Location	No. of sampling observa-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am	Total alpha	Total beta
Marine samples												
Cod	Stolford	1	950	1100	37	<0.05	<0.06	0.08	0.70	<0.15		
Grey mullet	Stolford	1	150	180	50	<0.05	<0.05	0.08	1.1	<0.05		
Shrimps[d]	Stolford	2	970	980	43	<0.04	<0.04	<0.05	0.48	0.00081		
Whelks	Stolford	1		1400								
Fucus vesiculosus	Pipeline	2				<1.3	<0.32	<0.70	6.4	<0.35		260
Seaweed[e]	Pipeline	2[E]					<0.70	<0.83	3.7	<1.9		
Mud	1.6 km east of pipeline	2				<0.61	<0.56	2.6	34	<1.7		
Sediment	1.6 km east of pipeline	2[E]					<1.1		5.1	<0.78	440	410
Sediment	Pipeline	2[E]					<0.93		<4.7	<3.1	650	370
Sediment	0.8 km west of pipeline	2[E]					<0.67		4.0	<0.78	390	390
Sediment	Stolford	2[E]					<1.1		<3.5	<2.4	570	920
Sediment	Steart Flats	2[E]					<0.93		<4.7	<2.3	510	440
Mud and sand	River Parrett	2				<0.74	<0.62	2.0	30	<2.5		
Sediment	River Parrett	2[E]					<1.6		32	<3.5	1900	1000
Seawater	Pipeline	2		8300								
Seawater	Pipeline	2[E]					<0.62	<0.60	<0.61	<0.70	<2.3	12

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		6	<3.8	18	<0.40	<0.30	<0.28	<0.28		
Milk	max		<4.3	23	<0.53	<0.35	<0.30	<0.30		
Apples		1	6.0	3.0	0.20	<0.40	<0.20	<0.30		
Cabbage		1	<4.0	4.0	4.8	<0.30	<0.20	<0.20		
Elderberries		1	8.0	14	4.2	<0.50	<0.40	<0.40		
Honey		1	<6.0	32	0.80	<0.20	<0.20	0.20		
Oats		1	<6.0	43	1.0	<0.30	<0.20	<0.30		
Onions		1	<4.0	11	0.40	<0.20	<0.20	<0.20		
Potatoes		1	5.0	22	1.2	<0.30	<0.30	<0.30		
Freshwater	Durleigh Reservoir	2[E]	<4.0		<2.5	<0.62	<0.60	<0.61	0.029	0.19
Freshwater	Ashford Reservoir	2[E]	<4.0		<2.5	<0.62	<0.60	<0.62	<0.026	<0.092

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

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

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

[d] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.00022, 0.00068 and 0.000022 Bq kg^{-1} respectively*

[e] *The concentration of ^{99}Tc was 11 Bq kg^{-1}*

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

Table 6.6(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2002

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Weston-Super-Mare	Sand	3	0.076
Burnham	Sand	2	0.076
River Parrett	Mud and sand	2[F]	0.072
Steart Flats	Sand	2	0.075
Stolford	Sand and stones	2	0.080
Hinkley Point	Sand and stones	2	0.078
Kilve	Stones	2	0.078
Watchet Harbour	Mud and sand	2	0.10
Blue Anchor Bay	Stones	2	0.086

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

Table 6.7(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{3}H	^{14}C	^{54}Mn	^{58}Co	^{60}Co	^{99}Tc	^{110m}Ag	^{125}Sb	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am
Marine samples															
Cod	Millport	2			<0.10	<0.11	<0.10		<0.10	<0.13	2.9	<0.14			<0.13
Hake	Millport	2			<0.10	<0.10	<0.10		<0.10	<0.13	2.4	<0.14			<0.12
Crabs	Millport	2		33	<0.10	<0.10	<0.10		<0.10	<0.10	0.35	<0.10	0.087	0.51	0.030
Nephrops	Millport	2			<0.10	<0.10	<0.10	320	<0.10	<0.10	1.1	<0.10			<0.11
Lobsters	Largs	1			<0.10	<0.10	<0.10	310	<0.10	<0.11	0.66	<0.12			<0.10
Squat lobsters	Largs	4			<0.10	<0.11	<0.10	95	<0.10	<0.12	0.44	<0.11	0.0053	0.022	0.027
Winkles	Pipeline	2			1.1	<0.10	<0.26		0.55	<0.18	0.49	<0.17	0.024	0.11	0.050
Scallops	Largs	4			<0.10	<0.10	<0.10		<0.10	<0.11	0.50	<0.12	<0.0012	0.0085	0.0071
Oysters	Fairlie	1			0.15	<0.10	<0.10		<0.10	<0.10	0.29	<0.10			<0.10
Seaweed	N of pipeline	1			0.72	<0.10	0.29		<0.10	0.20	0.85	<0.12			<0.14
Fucus vesiculosus	N of pipeline	1			1.9	<0.10	0.19		<0.10	<0.10	0.78	<0.10			<0.10
Fucus vesiculosus	Pipeline	1			3.0	<0.10	0.37		<0.10	<0.11	0.98	<0.14			<0.14
Ascophyllum nodosum	Pipeline	1			6.2	<0.10	0.43		<0.15	<0.24	1.6	<0.17			<0.28
Fucus vesiculosus	S of pipeline	1			7.8	<0.21	0.45		<0.15	<0.22	1.6	<0.25			<0.22
Ascophyllum nodosum	S of pipeline	1			6.3	0.10	0.42		0.38	<0.10	0.93	<0.13			<0.14
Sediment	Pipeline	2			<0.18	<0.10	<0.11		<0.10	<0.13	8.4	<0.17			0.51
Sediment	Millport	2			<0.10	<0.10	<0.10		<0.10	<0.12	5.8	<0.19			<0.24
Sediment	Ardneil Bay	2			<0.11	<0.10	<0.10		<0.10	<0.11	3.2	<0.15			<0.14
Sediment	Gulls Walk	2			<0.10	<0.14	<0.10		<0.11	<0.16	7.9	0.47			<0.31
Seawater	Pipeline	1	2.4		<0.10	<0.14	<0.10		<0.10	<0.10	<0.10	<0.10			<0.10

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{110m}Ag	^{137}Cs	^{155}Eu	^{241}Am	Total alpha	Total beta
Terrestrial Samples												
Milk		6	<5.9	<16	<1.2	<0.05	<0.10	<0.05	<0.10		<0.05		
Milk	max		<9.3	<17	<1.5		<0.11		0.28				
Cabbage		1	<2.6	<15	3.3	<0.05	0.52	<0.05	<0.05		<0.09		
Carrots		2	<5.0	<15	<0.50	<0.05	0.13	<0.05	<0.05		<0.07		
Cauliflower		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05	<0.05		<0.08		
Ground elder		1	<5.0	18	2.5	<0.05	0.49	<0.06	0.65		<0.13		
Leeks		1	<5.0	<15	<0.50	<0.05	0.16	<0.05	<0.05		<0.05		
Nettles		1	<5.0	23	4.5	<0.05	1.4	<0.05	0.05		<0.05		
Onions		2	<5.0	<15	<1.4	<0.05	<0.10	<0.05	<0.05		<0.06		
Onions	max				2.3						<0.07		
Potatoes		3	<5.0	<24	<0.50	<0.05	<0.10	<0.05	<0.12		<0.06		
Potatoes	max			31	0.51				0.17		<0.08		
Rabbit		2	<13	17	4.3	<0.05	<0.14	<0.05	0.16		<0.07		
Rabbit	max		21	18	6.5		0.18		0.24				
Rosebay willow herb			1	<5.0	27	0.70	<0.05	0.86	<0.05	0.07		<0.10	
Rowan berries		1	<5.0	23	<0.50	<0.05	0.80	<0.05	0.06		<0.06		
Turnips		2	<5.0	<15	<0.63	<0.05	0.25	<0.05	<0.05		<0.07		
Turnips	max				0.75		0.26				<0.08		
Grass		4	<5.9	21	1.5	<0.05	0.53	<0.05	<0.11		<0.09	<0.92	170
Grass	max		8.6	25	2.0		0.81		0.17		<0.11	2.2	270
Soil		4	<4.9	<15	<1.2	<0.05	1.7	<0.05	12	0.78	<1.0	170	600
Soil	max		<5.0		<2.0		3.2	<0.06	18		<2.8	240	710

[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 6.7(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2002

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Largs Bay	NA	2	0.079
Kilchatten Bay	NA	2	0.054
Millport	NA	2	0.055
Gulls Walk	Mud	2	0.063
0.5 km north of pipeline	Sand	2	0.067
0.5 km south of pipeline	Sand and stones	2	0.076
Ardneil Bay	NA	2	0.054
Ardrossan Bay	NA	2	0.056

NA Not available

Table 6.7(c). Radioactivity in air near Hunterston, 2002

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Fenceby	12	<0.010	<0.0092	<0.13
West Kilbride	12	<0.010	<0.0076	<0.11
Crosbie Mains	12	<0.010	<0.0091	<0.12

Table 6.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Aquatic samples													
Cod	Sizewell	1		<25		0.63			<0.11				
Sole	Sizewell	2	<25	<25		0.20			<0.11				
Crabs	Sizewell	2			37	0.25	0.00011	0.00062	0.0012	0.000049	0.000023		
Pacific Oyster	Blyth estuary	1				0.15			<0.03				
Whelks	Dunwich	1				0.16			<0.09				
Mussels	River Alde	1		<25		<0.12			<0.10				
Sand	Aldeburgh	2				<0.33			<0.48				
Sediment	Rifle range	2[E]				<0.50			<1.2			<100	<100
Sediment	Aldeburgh	2[E]				<0.65			<1.3			<100	<100
Sediment	Southwold	2[E]				13			<4.5			530	870
Seawater	Aldeburgh	2		<1.8									
Seawater	Sizewell	2[E]				<0.31			<0.47			<4.0	14

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total alpha	Total beta
Terrestrial samples													
Milk		6	<4.0	16	<0.39		<0.30						
Milk	max			19	<0.50		<0.33						
Apples		1	<4.0	31	0.80		<0.20						
Beetroot		1	<4.0	15	1.2		<0.30						
Blackberries		1	28	41	18		<0.30						
Cabbage		1	<3.0	12	<0.70		<0.30						
Carrots		1	<4.0	7.0	<0.40		<0.20						
Honey		1	<6.0	58	<0.40		<0.20						
Ovine kidney		1	<7.0	67	<0.50	0.098		0.21	<0.00060	0.00080	0.0021		
Ovine muscle		1	<5.0	15	1.2	<0.024		0.11	<0.00020	<0.00020	0.00060		
Porcine kidney		1	<6.0	49	<0.50	<0.037		0.18					
Porcine muscle		1	<5.0	26	1.2	<0.025		0.071	<0.00020	<0.00010	0.00060		
Potatoes		1	<4.0	22	0.40		<0.30						
Runner beans		1	<4.0	7.0	<0.40		<0.40						
Wheat		1	<6.0	110	<0.40		<0.20						
Freshwater	Nature reserve	2[E]	<4.0		<15		<0.35					<0.035	0.17
Freshwater	The Meare	2[E]	<6.5		<10		<0.45					<0.12	<0.58
Freshwater	Leisure Park	2[E]	<4.0		<10		<0.45					<0.040	<0.27

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

Table 6.8(b). Monitoring of radiation dose rates near Sizewell, 2002

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m			
Sizewell Beach	Sand and stones	2	0.058
Dunwich	Sand and stones	2	0.055
Sizewell Rifle Range	Sand and stones	2	0.086
Aldeburgh	Sand and stones	2[F]	0.046
Aldeburgh	Sand and stones	2	0.057
Southwold Harbour	Mud	2	0.070

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

Table 6.9(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{54}Mn	^{60}Co	^{65}Zn	^{99}Tc	^{137}Cs	^{155}Eu	^{241}Am	Total alpha
Marine samples										
Cod	White Sands	2	<0.10	<0.10	<0.14		0.48	<0.15	<0.14	
Crabs[d]	Cove	2	<0.11	<0.10	<0.24	<1.6	<0.13	<0.24	<0.14	
Lobsters	Cove	1	<0.10	<0.10	<0.17	56	0.21	<0.18	<0.11	
Nephrops[e]	Dunbar	4	<0.10	<0.10	<0.18		0.22	<0.21	0.0013	
Winkles	Pipeline	2	<0.48	<0.23	<0.29		<0.14	<0.28	<0.18	<5.7
Porphyra[f]	Thornton Loch	2	<0.21	0.11	<0.15		<0.16	<0.12	<0.10	1.6
Fucus vesiculosus	Pipeline	2	<0.69	<0.14	<0.15	8.8	0.20	<0.12	<0.11	
Fucus vesiculosus	White Sands	2	<0.10	<0.10	<0.13		0.17	<0.12	<0.10	
Sediment	Dunbar Inner Harbour	2	<0.10	<0.10	<0.28		2.6	<1.0	<0.49	
Sediment	Barns Ness	2	<0.10	<0.10	<0.18		2.1	0.43	<0.21	
Sediment	Thornton Loch	2	<0.10	<0.10	<0.15		1.3	<0.24	<0.16	
Sediment	Heckies Hole	2	<0.10	<0.10	<0.26		4.7	2.0	<0.31	
Sediment	Eyemouth	1	<0.10	<0.10	<0.18		1.1	<0.22	<0.20	
Salt marsh	Belhaven Bay	2	<0.10	<0.10	<0.18		2.2	<0.55	<0.41	
Seawater[g]	Pipeline	4	<0.10	<0.10	<0.12		<0.10	<0.10	<0.10	

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{137}Cs	^{155}Eu	^{241}Am	Total alpha	Total beta
Terrestrial samples												
Milk		1	<5.0	<17	<1.1	<0.05	<0.10	<0.05				
Cauliflower		1	5.2	<15	<0.50	<0.05	0.13	<0.05				
Ground Elder		1	<5.0	21	0.69	<0.05	0.81	<0.05				
Leeks		1	<5.0	20	<0.50	<0.05	0.23	<0.05				
Potatoes		1	<5.0	21	0.79	<0.05	0.42	<0.05				
Rosebay willow herb		1	<5.0	27	1.3	<0.05	0.42	<0.05				
Rosehips		1	<5.0	32	<0.50	<0.05	0.29	<0.05				
Snails		1	<5.0	24	2.7	<0.05	0.27	0.07	0.12			
Turnips		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05				
Grass		6	<10	37	1.4	<0.06	0.57	<0.27		<0.16	1.7	220
Grass	max		33	79	2.7	<0.08	1.1	<0.89		<0.24	3.0	370
Soil		6	<6.7	<14	<2.9	<0.05	2.2	5.7	0.29	<0.28	270	630
Soil	max		<15	<15	11		4.2	12	0.60	0.50	360	830

[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*

[d] *The concentration of ^{14}C was 17 Bq kg^{-1}*

[e] *The concentrations of ^{238}Pu and $^{239+240}$Pu were <0.00092 and 0.0054 Bq kg^{-1} respectively*

[f] *The concentration of total beta was 250 Bq kg^{-1}*

[g] *The concentration of ^{3}H was <3.5 Bq l^{-1}*

Table 6.9(b). Monitoring of radiation dose rates near Torness nuclear power station, 2002

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	0.072
Dunbar Inner Harbour	Sand	2	0.091
Belhaven Bay	Salt marsh	2	0.062
Barns Ness	Mud, sand and stones	2	0.072
Skateraw	Sand	2	0.056
Thornton Loch	Sand	2	0.058
St Abbs	Mud	2	0.092
Eyemouth	Mud	2	0.065
Mean beta dose rates on fishing gear			µSv h^{-1}
Cove	Lobster Pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

Table 6.9(c). Radioactivity in air near Torness, 2002

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Innerwick	10	<0.010	<0.0067	<0.12
Cockburnspath	12	<0.010	<0.012	<0.15

Table 6.10(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu
Freshwater samples											
Brown trout	Lake	6		17		<0.24	3.4	<0.29	50	<0.66	<0.56
Rainbow trout	Lake	6				<0.12		<0.12	0.83	<0.38	<0.27
Perch	Lake	5				<0.14	2.9	<0.38	100	<0.46	<0.49
Rudd	Lake	1				<0.09		0.23	61	<0.29	<0.39
Mud	Pipeline	1				17		10	3000	16	9.4
Sediment	Lake shore	2^E				<3.3	7.1	<4.9	900		
Sediment	Bailey Bridge	2^E				<4.0	15	<5.0	1500		
Sediment	Fish farm	2^E				<19	15	<3.5	1300		
Sediment	Footbridge	2^E				<3.0	4.7	<2.5	180		
Sediment	Cae Adda	2^E				<2.9	3.4	<2.9	270		
Freshwater	Bailey Bridge	1	2.1								
Freshwater	Cold Lagoon	2						*	0.01		
Freshwater	Public supply	2^E	<4.0		<10	<0.40		<0.35	<0.40		
Freshwater	Gwylan Stream	1^E	<4.0		<10	<0.30		<0.30	<0.20		
Freshwater	Diversion culvert	1^E	<4.0		<10	<0.30		<0.20	<0.30		
Freshwater	Hot Lagoon	2^E	<4.0		<10	<0.40		<0.35	<0.40		
Freshwater	Afon Prysor	2^E	<4.0		<10	<0.40		<0.40	<0.35		
Freshwater	Lake	2^E	<4.0		<10	<0.50		<0.35	<0.40		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Freshwater samples								
Brown trout	Lake	6	0.00077	0.00036	0.00062	0.000030		
Rainbow trout	Lake	6			<0.32			
Perch	Lake	5	0.000078	0.00060	0.00044	*		
Rudd	Lake	1			<0.64			
Mud	Pipeline	1			63			
Sediment	Lake shore	2^E	<0.80	<2.6	4.0			
Sediment	Bailey Bridge	2^E	0.98	4.5	6.4			
Sediment	Fish farm	2^E	<6.5	<16	24.0			
Sediment	Footbridge	2^E	<0.14	<0.35	<0.80			
Sediment	Cae Adda	2^E	<0.28	1.3	<2.9			
Freshwater	Bailey Bridge	1						
Freshwater	Cold Lagoon	2						
Freshwater	Public supply	2^E					<0.030	<0.078
Freshwater	Gwylan Stream	1^E					<0.040	0.15
Freshwater	Diversion culvert	1^E					0.049	0.11
Freshwater	Hot Lagoon	2^E					<0.57	<0.13
Freshwater	Afon Prysor	2^E					<0.039	<0.10
Freshwater	Lake	2^E					<0.020	<0.10

Table 6.10(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	^{134}Cs	^{137}Cs	Total Cs
Terrestrial Samples										
Milk		3	<3.9	18		<0.28	0.070			0.26
Milk	max		<4.0	23		<0.30	0.086			0.45
Blackberries		1	<4.0	18	0.40	<0.30		<0.30	0.90	
Carrots		1	<4.0	10	<0.30	<0.30		<0.30	<0.30	
Eggs		1	<4.0	19	<1.8	<0.20		<0.20	<0.20	
Hazlenuts		1	<7.0	55		<1.2		<1.2	15	
Ovine muscle		2	<5.0	76		<0.30	<0.026			0.39
Ovine muscle	max		<5.0	140		<0.40	0.028			0.42
Ovine offal		2	<9.5	40		<0.25	0.38			0.54
Ovine offal	max		12	47		<0.30	0.51			0.60
Potatoes		1	<4.0	17	0.80	<0.20		<0.30	<0.30	
Runner beans		1	<3.0	3.0	<0.20	<0.20		<0.30	<0.30	

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial Samples							
Milk		3	<0.30	<0.44			
Milk	max			<0.47			
Blackberries		1	<0.30	<0.50	<0.00020	0.00020	<0.00030
Carrots		1	<0.30	<0.50	<0.00020	0.00030	0.00080
Eggs		1	<0.40	<0.80	<0.00010	<0.00020	0.00040
Hazlenuts		1	<1.2	<1.7			
Ovine muscle		2	<0.45	<0.75	<0.00025	<0.00020	0.00025
Ovine muscle	max		<0.50	<1.0	<0.00040	<0.00030	0.00040
Ovine offal		2	<0.45	<0.80	<0.00080	<0.00055	<0.00035
Ovine offal	max		<0.50	<1.0	<0.0011	<0.00060	0.00040
Potatoes		1	<0.40	<0.40	<0.00020	0.00010	0.00080
Runner beans		1	<0.30	<0.50			

* *Not detected by the method used*

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

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

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

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

Table 6.10(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2002

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Stones	2[F]	0.086
Footbridge	Mud and stones	2	0.097
Nant Islyn Bay	Mud and stones	2[F]	0.096
West of footbridge	Stones	2[F]	0.093
Lake shore	Mud and stones	2	0.10
Bailey Bridge	Stones	2	0.12
Fish Farm	Stones	2	0.11
Cae Adda	Stones	2	0.11

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

Table 6.11(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{60}Co	^{99}Tc	^{137}Cs	^{241}Am	Total alpha	Total beta
Marine samples								
Plaice[d]	Pipeline	2	<0.05		1.6	<0.20		
Crabs[e]	Pipeline	2	<0.06	9.1	0.47	0.072		
Lobsters	Pipeline	2	<0.07	33	0.17	<0.33		100
Winkles[f]	Cemaes Bay	2	<0.07		0.47	0.18		
Fucus vesiculosus	Cemaes Bay	2	<0.11	260	0.63	<0.24		330
Seaweed	Cemaes Bay	2[E]	<0.60	1100	<0.70	<1.3		
Sediment	Cemaes Bay	2[E]	<1.7		6.9	<4.3	<100	370
Sediment	Cemlyn Bay	2[E]	<2.7		11	<3.3	590	520
Seawater	Cemaes Bay	2[E]	<0.34		<0.26	<0.37	<3.6	12
Seawater	Cemlyn Bay	2[E]	<0.30		<0.30	<0.35	<3.8	12

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	<4.2	15	<0.46	<0.31	<0.29		
Milk	max		<5.5	19	<0.60	<0.33	<0.30		
Apples		1	<4.0	8.0	2.5	<0.40	<0.20		
Barley		1	<6.0	120	0.80	<0.30	<0.30		
Blackberries		1	<4.0	33	1.5	<0.20	<0.20		
Cabbage		1	<4.0	5.0	1.9	<0.20	<0.20		
Carrots		1	<4.0	7.0	1.5	<0.20	<0.30		
Honey		1	<6.0	90	0.40	<0.20	<0.20		
Potatoes		1	<4.0	14	0.70	<0.30	<0.30		
Turnips		1	<4.0	11	0.90	<0.30	<0.30		
Freshwater	Public supply	2[E]	<4.0		<10	<0.35	<0.40	<0.020	0.16

** 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
[d] The concentrations of organic ^{3}H, ^{3}H, and ^{14}C were <25, <25 and 34 Bq kq^{-1} respectively
[e] The concentrations of ^{238}Pu, $^{239+240}$Pu, ^{242}Cm and $^{243+244}$Cm were 0.0045, 0.026, 0.000070 and 0.000093 Bq kg^{-1} respectively
[f] The concentrations of organic ^{3}H, ^{3}H, ^{14}C, ^{238}Pu, $^{239+240}$Pu, ^{241}Pu, ^{242}Cm and $^{243+244}$Cm were <25,<25, 40, 0.023, 0.13, 1.4, not detected by the method used and 0.00022 Bq kg^{-1} respectively
[E] Measurements are made on behalf of the Food Standards Agency unless labelled 'E'. In that case they are made on behalf of the Environment Agency

Table 6.11(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2002

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]	0.055
Cemaes Bay	Sand	2	0.10
Cemlyn Bay	Sand and stones	2	0.087

[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

7. DEFENCE ESTABLISHMENTS

Monitoring by the Environment Agency, Food Standards Agency and SEPA is undertaken routinely near nine defence-related establishments in the UK. Special surveys were also undertaken at a firing range at Eskmeals in Cumbria. Low-level discharges also occur from Burghfield in Berkshire. The authorisation issued to Burghfield does not include aqueous disposals. The operator carries out environmental monitoring at Burghfield. Monitoring at nuclear submarine berths is also carried out by the Ministry of Defence (DSTL, 2003). Monitoring at Greenwich by the Food Standards Agency ceased in 1999 with the closure of the JASON reactor and the associated revocation of the authorisation to discharge.

7.1 Aldermaston, Berkshire

The Atomic Weapons Establishment (AWE) at Aldermaston is authorised to discharge low levels of radioactive waste to the environment. Liquid discharges are made to the River Thames at Pangbourne, to the sewage works at Silchester and to Aldermaston Stream. Samples of milk, other terrestrial foodstuffs, freshwater, fish and sediments were collected. The sampling locations are shown in Figure 5.1. Monitoring of the aquatic environment at Newbridge is undertaken to indicate background levels upstream of the nearby Harwell site.

The results of measurements of radionuclides concentrations are shown in Tables 7.1(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low and similar to those for 2001. Levels of tritium were all below the limit of detection. Caesium-137 concentrations were detected in sediment from the Thames and water courses near the site and were similar to those observed in recent years. Currently, routine discharges from AWE do not include significant levels of radiocaesium. The presence of radiocaesium may be as a result of historical discharges or may be from other sources such as Harwell upstream on the Thames. A recent habit survey has established that the critical group affected by discharges into the river can be represented by anglers whose occupancy of the river bank has been assessed to estimate their external exposures. No consumption of freshwater fish has been established but the assessment has conservatively included consumption of fish at a low rate of 1 kg year^{-1}. The overall radiological significance of liquid discharges was very low: the radiation dose to anglers was much less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv. The total alpha and beta activity concentrations in the freshwater samples were below the WHO screening levels. The drinking water pathway has been shown to be insignificant (Environment Agency, 2002a).

The concentrations of radioactivity in milk, vegetables, fruit and terrestrial indicator materials were also very low. Results for tritium, caesium-137, uranium and transuranic radionuclides were generally similar to those for 2001. Natural background or weapon test fallout would have made a significant contribution to the levels detected. A low level of plutonium-238 was detected in soil near the site. 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 2002, 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.

7.2 Barrow, Cumbria

Discharges from submarine related operations at the Barrow site are very low. The Food Standards Agency's monitoring of Barrow is limited to grass sampling. In 2002, a small amount of tritium activity was detected which was of low radiological significance (Table 7.2(a)). Any significant effects of discharges from Barrow in the marine environment would be detected in the far-field monitoring of Sellafield (Section 4) and as such the aquatic programme for Barrow has been subsumed into the Sellafield programme. No such effects were found in 2002

7.3 Derby, Derbyshire

Rolls-Royce Marine Power Operations Ltd. manufactures fuel for nuclear powered submarines at its two adjacent sites in Derby. Small discharges of liquid effluent are made via the Magaloughton Sewage Treatment Works to the River Derwent and very low levels of alpha activity are discharged in gaseous releases and solid wastes are disposed of to Hilts Quarry. The Environment Agency has begun consideration of an application submitted by the company to vary its discharge authorisations for both sites. The Environment Agency issued a new authorisation in 2002 for the transfer of low-level radioactive waste to BNFL Drigg.

Results of monitoring at Derby are presented in Table 7.2(a). Routine sampling and analysis of uranium activity in grass and soil samples associated with gaseous discharges found levels higher than 2001 but broadly consistent with previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. The total alpha and beta activity levels in river water from the Derwent are less than the WHO screening levels for drinking water. Doses from use of water from the River Derwent as drinking water were previously assessed as much less than 0.005 mSv y^{-1} (Environment Agency, 2002a).

Rolls Royce also operates a waste disposal site at Hilts Quarry in Crich, Derbyshire and disposes of solid low-level radioactive waste there. Results of monitoring around Hilts Quarry are discussed in Section 10.3.

7.4 Devonport, Devon

Discharges of liquid radioactive waste are made by Devonport Royal Dockyard Ltd. (DML) under authorisation and the Ministry of Defence under administrative agreement into the Tamar Estuary. Following a very thorough and open review by the Environment Agency, the DML authorisations have been revised (Department for Environment, Food and Rural Affairs, 2002c) and a new authorisation took effect on 13 March 2002. The Environment Agency undertook a supplementary sampling programme in 2001 in support of their review of the DML authorisation. Air and marine samples were obtained and analysed and the doses for inhalation of resuspended sediment and sea fog and swimming in the discharge plume were estimated to be all substantially less than 0.005 mSv y^{-1} (Environment Agency, 2002f). The Environment Agency is currently assessing the findings of a feasibility study submitted by the company into a range of options, including a pipeline out to sea, in respect of future disposal of liquid radioactive waste from the dockyard (Environment Agency, 2003b).

The routine monitoring programme in 2002 consisted of measurements of gamma dose rate and analysis of fish and shellfish, blackberries and sediments. The results given in Tables 7.2(a) and (b) were similar to those in 2001 where comparisons can be drawn. Trace quantities of fission and activation products and actinides were detected in the marine environment. The dose to the critical group taking account of consumption of marine foods and occupancy times was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv. The radiological significance of this, in common with other defence establishments, continued to be low.

7.5 Eskmeals, Cumbria

A survey was carried out at the Eskmeals Ministry of Defence firing range. Depleted uranium has been used in ammunitions fired on the range. Samples of soil and grass were taken and analysed for uranium-234, uranium-235 and uranium-238. Results were broadly in line with natural background. In addition to this work an airborne gamma survey of the Cumbrian coast was carried out (Sanderson *et al*., 2001) (See Section 4).

7.6 Faslane and Coulport, Argyll and Bute

The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport. During 2002, HMNB Clyde entered into a partnership with Babcock Naval Services (BNS), a subsidiary of Babcock Support Services Limited. The partnership has resulted in a high percentage of

MOD civil servants transferring from Ministry of Defence (MOD) to BNS. However, MOD remains in control of the undertaking in relation to radioactive waste disposal through the Director of the Naval Base Clyde.

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

Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the Ministry of Defence. The discharges made during 2002 are shown in Appendix 1. The disposal of solid radioactive waste from each site is also made under letters of agreement between SEPA and the Ministry of Defence. No disposals of solid waste were made from either site during 2002. This was due to the general embargo imposed by BNFL on the MOD(N) waste.

Habit surveys have been used to investigate exposure pathways. The most recent of which, conducted in 2000, identified fish consumption and external radiation from the shore as the major pathways of exposure. The scope of the monitoring programme reflects these pathways and included the analysis of seawater, sediment and fish samples. Results are given in Tables 7.2(a) and (b). These show that caesium-137 concentrations were consistent with the distant effects of discharges from Sellafield and weapons testing and Chernobyl fallout. Additionally, measurements of gamma dose rates made in the surrounding area were difficult to distinguish from natural background. Taking into account occupancy and consumption rate data from the 2000 habit survey, the dose to the critical group from external radiation and the consumption of fish was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

7.7 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 and concentrations of caesium-137 were similar to those in 2001(Tables 7.2(a) and (b)). The external radiation dose to the critical group was 0.011 mSv in 2002, which was about 1% of the dose limit for members of the public of 1 mSv.

7.8 Rosyth, Fife

Nuclear powered submarine refitting work at Rosyth Royal Dockyard continued throughout 2002 giving rise to the discharge of small quantities of liquid radioactive waste into the Forth Estuary. The discharges remained well within the authorised limits. Small gaseous discharges of argon-41 were also made within the limits of the certificate of authorisation. There were no disposals of low level solid waste as the embargo placed by BNFL on MOD(N) remained in force.

The routine SEPA monitoring programme included sampling and analysis of crabs, seaweed and sediment, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 7.2(a) and 7.2(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 2002 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.

7.9 Vulcan NRTE, Highland

The Vulcan Nuclear Reactor Test Establishment operated by the Ministry of Defence (Procurement Executive) is located adjacent to the UKAEA Dounreay site and the impact of its discharges is considered along with those from Dounreay in Section 5.1.

Table 7.1(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples								
Pike	Newbridge	1	<25	<25	<0.13			
Pike	Outfall (Pangbourne)	1	<25	<25	0.23			
Pike	Staines	1	<25	<25	0.12			
Pike	Shepperton	1	<25	<25	0.17			
Pike	Teddington	1	<25	<25	0.13			
Flounder	Beckton	1		<25	0.19			
Nuphar lutea	Newbridge	1		<25	<0.02			
Nuphar lutea	Staines	1		<25	<0.05			
Clay	Outfall (Pangbourne)	1			1.2			
Sediment	Pangbourne	4^{E}			21	11	<0.35	9.3
Sediment	Mapledurham	4^{E}			22	12	<0.68	11
Sediment	Aldermaston	4^{E}			<7.5	18	<0.75	15
Sediment	Spring Lane	4^{E}			<3.9	13	<0.54	11
Sediment	Stream draining south	4^{E}			<4.8	14	0.61	12
Sediment	Reading (Kennet)	4^{E}			6.8	15	<0.51	14
Freshwater	Pangbourne	4^{E}		<4.0	<0.46	0.016	<0.0058	0.0092
Freshwater	Mapledurham	4^{E}		<5.6	<0.48	0.012	<0.0052	0.010
Freshwater	Aldermaston	4^{E}		<5.9	<0.46	0.0088	<0.0050	<0.0067
Freshwater	Spring Lane	4^{E}		<11	<0.48	0.0088	<0.0052	<0.0065
Freshwater	Reading (Kennet)	4^{E}		<4.0	<0.48	0.014	<0.0062	<0.011
Crude liquid effluent	Silchester treatment works	4^{E}		<39	<0.43	<0.0077	<0.0058	<0.0067
Liquid effluent	Silchester treatment works	4^{E}		<26	<0.41	<0.013	<0.0047	<0.0065
Sewage sludge	Silchester treatment works	4^{E}		<34	<0.44	15	<0.61	13

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	Total alpha	Total beta
Freshwater samples							
Pike	Newbridge	1	0.00049	0.0023	0.0048		
Pike	Outfall (Pangbourne)	1	0.0000065	0.000046	0.000041		
Pike	Staines	1			<0.10		
Pike	Shepperton	1			<0.15		
Pike	Teddington	1			<0.05		
Flounder	Beckton	1			<0.11		
Nuphar lutea	Newbridge	1			<0.07		
Nuphar lutea	Staines	1			<0.04		
Clay	Outfall (Pangbourne)	1			<1.9		410
Sediment	Pangbourne	4^{E}	<0.37	<1.5	<2.8	270	410
Sediment	Mapledurham	4^{E}	<0.19	<0.52	<1.3	<180	450
Sediment	Aldermaston	4^{E}	<0.16	1.9	<0.87	430	680
Sediment	Spring Lane	4^{E}	<0.19	<0.24	<0.61	400	530
Sediment	Stream draining south	4^{E}	<0.13	<0.31	<1.1	280	400
Sediment	Reading (Kennet)	4^{E}	<1.2	<4.8	<1.8	250	590
Freshwater	Pangbourne	4^{E}	<0.0050	<0.0050	<0.010	<0.053	0.18
Freshwater	Mapledurham	4^{E}	<0.0050	<0.0050	<0.010	<0.055	0.25
Freshwater	Aldermaston	4^{E}	<0.020	<0.015	<0.013	<0.067	<0.20
Freshwater	Spring Lane	4^{E}	<0.0095	<0.0087	<0.013	<0.53	<0.61
Freshwater	Reading (Kennet)	4^{E}	<0.0095	<0.0058	<0.013	<0.045	<0.10
Crude liquid effluent	Silchester treatment works	4^{E}	<0.0062	<0.0052	<0.50	<0.21	<0.45
Liquid effluent	Silchester treatment works	4^{E}	<0.0060	<0.0052	<0.49	<0.15	0.46
Sewage sludge	Silchester treatment works	4^{E}	<0.0070	<0.0063	<0.50	<48	280

Table 7.1(a). continued

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg⁻¹ ^{3}H	^{137}Cs	Total U	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk		6	<3.9	<0.28	<0.0065			
Milk	max		<4.0	<0.30				
Blackberries		1	6.0	<0.30	<0.029			
Broad beans		1	<4.0	<0.30	<0.030			
Carrots		1	<3.0	<0.20	<0.031			
Honey		1	<6.0	<0.20	<0.0067			
Lettuce		1	<4.0	<0.30	<0.028			
Potatoes		1	<4.0	<0.30	<0.031			
Rabbit		1	<5.0	<0.30	<0.029			
Wheat		1	10	<0.30	<0.033	0.0023	<0.00050	<0.0014
Grass	East of site 1	1[E]	<25	<1.2		<0.020	<0.020	<0.020
Grass	South-west of site 2	1[E]	<25	<1.9		0.16	<0.020	0.16
Grass	South-east of site 3	1[E]	<96	<1.0		<0.20	<0.20	<0.20
Grass	North-east of site 4	1[E]	<86	<2.0		0.46	<0.020	0.48
Soil	East of site 1	1[E]	<25	<0.90		12	<0.40	10
Soil	South-west of site 2	1[E]	<25	<1.6		12	<0.50	11
Soil	South-east of site 3	1[E]	<25	9.0		12	0.90	12
Soil	North-east of site 4	1[E]	<90	35		18	1.2	17
Soil		4			42			
Soil	max				58	8.7	0.35	8.3

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg⁻¹ ^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total alpha	Total beta
Terrestrial samples							
Milk		6	<0.00012	<0.00012	<0.00017		
Milk	max		<0.00015	<0.00020	<0.00020		
Blackberries		1	<0.00020	<0.00020	<0.00030		
Broad beans		1	0.00010	0.00020	<0.00050		
Carrots		1	<0.00010	<0.00020	<0.00030		
Honey		1	<0.00020	<0.00020	<0.00020		
Lettuce		1	<0.00020	<0.00020	0.00030		
Potatoes		1	0.00010	<0.00020	0.00010		
Rabbit		1	0.00040	<0.00020	0.00030		
Wheat		1	<0.00020	<0.00040	0.00040		
Grass	East of site 1	1[E]	<0.040	0.020		<1.0	200
Grass	South-west of site 2	1[E]	<0.010	<0.010			
Grass	South-east of site 3	1[E]	<0.010	<0.010		1.6	180
Grass	North-east of site 4	1[E]	<0.010	<0.010		5.1	260
Soil	East of site 1	1[E]	<0.10	<0.070		190	1600
Soil	South-west of site 2	1[E]	0.16	0.340		260	1200
Soil	South-east of site 3	1[E]	<0.070	0.25		390	1000
Soil	North-east of site 4	1[E]	<0.12	1.3		390	1000

[a] *Except for 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'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements are made on behalf of the Food Standards Agency unless labelled 'E'. In that case they are made on behalf of the Environment Agency*

Table 7.1(b). Monitoring of radiation dose rates near Aldermaston, 2002

Location	Ground type	No. of sampling observations	µGy h⁻¹
Mean gamma dose rates at 1m over riverbank			
Pangbourne	Mud and grass	4	0.073
Mapledurham	Mud and grass	4	0.072

Table 7.2(a). Concentrations of radionuclides in food and the environment near defence establishments, 2002

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{99}Tc	^{110m}Ag	^{125}Sb	^{131}I	^{137}Cs	^{155}Eu
Barrow													
Grass	Barrow	2^F		16									
Grass	max			25									
Derby													
Mud	River Derwent, downstream	3				<4.7							
Mud	River Derwent, upstream	4				<1.9							
Freshwater	River Derwent, downstream	4				<0.51							
Freshwater	River Derwent, upstream	4				<0.52							
Sediment	Hilt's Quarry 1	2				<10	<10		<10	<15		15	<10
Sediment	Hilt's Quarry 2	2				<10	<10		<10	<15		<10	<10
Sediment	Hilt's Quarry 3	2				<10	<10		<10	<15		<10	<10
Sediment	Hilt's Quarry 4	2				<10	<10		<10	<15		<10	<10
Sediment	Hilt's Quarry 5	2				<10	<10		<10	<15		<10	<10
Water	Hilt's Quarry 1	2				<1.5	<1.0		<1.0	<5.0		<1.0	<1.0
Water	Hilt's Quarry 4	2				<1.0	<1.0		<1.0	<5.0		<1.0	<1.0
Devonport													
Spurdog	Plymouth Sound	1^F				<0.15	<0.33		<0.23	<0.32	*	0.36	<0.21
Crabs	Plymouth Sound	2^F			31	<0.15	<0.35		<0.24	<0.32	*	<0.13	<0.22
Green crabs	River Lynher	1^F	<25	<25		<0.08	<0.18		<0.13	<0.18	*	<0.07	<0.17
Mussels	River Lynher	1^F	<25	<25		<0.13	<0.29		<0.21	<0.26	*	<0.11	<0.19
Oysters	River Lynher	1^F	<25	<25		<0.04	<0.11		<0.08	<0.09	*	<0.04	<0.08
Fucus vesiculosus	Kinterbury	2^F				<0.08	<0.22	2.4	<0.15	<0.17	<3.1	<0.09	<0.17
Mud[c]	Kinterbury	2^F				<0.90	<2.1		<1.6	<2.1	<2.7	4.3	<2.6
Sediment	Torpoint (South)	2		<25		<2.0						<1.9	
Sediment	Lopwell	2		<25		<3.5						6.8	
Seawater	Torpoint (South)	2		<4.0	<4.0	<0.45							
Seawater	Millbrook Lake	2		<4.0	<4.0	<0.45							
Blackberries		1^F		<4.0		<0.40			<0.30			<0.40	
Grass	Devonport	4^F		<6.3		<0.35			<0.25			<0.30	
Grass	max			10		<0.40			<0.30			<0.40	
Faslane													
Fish	Carnban boatyard	2				<0.10	<0.20		<0.11	<0.18		1.2	<0.21
Sediment	Carnban boatyard	2				<0.10	<0.13		<0.10	<0.15		8.2	<0.90
Seawater	Carnban boatyard	1		2.8									
Holy Loch													
Sediment	Mid Loch	1				0.24	<0.10		<0.10	<0.10		4.6	0.46
Rosyth													
Crabs	East of dockyard	2				<0.13	<0.31		<0.14	<0.30		0.18	<0.28
Fucus vesiculosus	East of dockyard	2				<0.10	<0.14		<0.10	<0.11		0.20	<0.13
Sediment	East of dockyard	2				<0.12	<0.13		<0.10	<0.14		10	<0.34
Sediment	Port Edgar	2				<0.15	<0.23		<0.12	<0.20		17	1.2
Sediment	West of dockyard	2				<0.10	<0.19		<0.10	<0.19		3.8	<0.64
Sediment	Blackness Castle	2				<0.10	<0.12		<0.10	<0.13		2.2	<0.35
Sediment	Burntisland Bay	2				<0.10	<0.13		<0.10	<0.12		0.68	<0.26
Seawater	East of dockyard	1		1.0									

Table 7.2(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}										
			^{226}Ra	^{238}Th	^{230}Th	^{232}Th	Total U	^{234}U	^{235}U	^{238}U	^{241}Am	Total alpha	Total beta
Derby													
Mud	River Derwent, downstream	3						46	1.2	43		580	720
Mud	River Derwent, upstream	4						22	<0.80	21		<310	400
Freshwater	River Derwent, downstream	4										<0.048	0.21
Freshwater	River Derwent, upstream	4										<0.051	<0.15
Grass		4[F]					1.1						
Grass	max						1.9						
Soil		4[F]					69						
Soil	max						110						
Sediment	Hilt's Quarry 1	2	59	44	35	15		14	<2.0	14	<10		
Sediment	Hilt's Quarry 2	2	62	28	13	16		22	<2.0	16	<16		
Sediment	Hilt's Quarry 3	2	112	29	34	19		14	<2.0	13	<10		
Sediment	Hilt's Quarry 4	2	140	26	7.0	16		21	<3.1	21	<10		
Sediment	Hilt's Quarry 5	2	240	57	31	24		18	<2.0	19	<10		
Water	Hilt's Quarry 1	2	<12.5	<4.7	<1.2	<3.8		0.025	<0.0050	0.023	<1.0		
Water	Hilt's Quarry 4	2	<10	<2.3	<0.55	<5.1		0.13	<0.0050	0.10	<1.0		
Devonport													
Spurdog	Plymouth Sound	1[F]									<0.11		
Crabs	Plymouth Sound	2[F]									<0.11		
Green crabs	River Lynher	1[F]									<0.10		
Mussels	River Lynher	1[F]									<0.10		
Oysters	River Lynher	1[F]									<0.04		
Fucus vesiculosus	Kinterbury	2[F]									<0.18		
Mud[c]	Kinterbury	2[F]									0.18		
Faslane													
Fish	Carnban boatyard	2									<0.15		
Sediment	Carnban boatyard	2									<0.18		
Seawater	Carnban boatyard	1											
Holy Loch													
Sediment	Mid Loch	1									<0.27		
Rosyth													
Crabs	East of dockyard	2									<0.17		
Fucus vesiculosus	East of dockyard	2									<0.12		
Sediment	East of dockyard	2									<0.16		
Sediment	Port Edgar	2									<0.52		
Sediment	West of dockyard	2									<0.27		
Sediment	Blackness Castle	2									<0.16		
Sediment	Burntisland Bay	2									<0.19		

* *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 concentrations of ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were 0.020, 0.47, 0.000018 and 0.000020 Bq kg^{-1} respectively*

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

Table 7.2(b). Monitoring of radiation dose rates near defence establishments, 2002

Establishment	Location	Ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1 m over intertidal areas				
Devonport	Kinterbury	Mud	2[F]	0.074
Devonport	Torpoint South	Mud	2	0.12
Devonport	Lopwell	Mud	2	0.092
Faslane	Gareloch Head	Mud, sand and stones	2	0.085
Faslane	Gulley Bridge Pier	Sand and stones	2	0.052
Faslane	Rhu	Gravel	2	0.078
Faslane	Rosneath	Sand and gravel	2	0.069
Faslane	Carnban boatyard	Mud and sand	2	0.066
Holy Loch	North Sandbank	Mud and sand	1	0.062
Holy Loch	Kilmun Pier	Sand and stones	1	0.077
Holy Loch	Mid-Loch	Sand	1	0.062
Rosyth	Blackness Castle	Mud and sand	2	0.061
Rosyth	Burntisland Bay	Sand	2	0.059
Rosyth	East of Dockyard	Sand	2	0.067
Rosyth	Port Edgar	Mud	2	0.077
Rosyth	West of Dockyard	Mud and sand	2	0.060

[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*

8. AMERSHAM PLC

This company 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 5). From July 2001, the company changed its name from Nycomed Amersham plc to Amersham plc. The Environment Agency has considered applications by Amersham plc to change its authorisations at the Amersham and Cardiff sites and, in June 2003, forwarded proposals for significantly more rigorous authorisations for the Cardiff site to the Wales Assembly Government. The Environment Agency is also considering an application from Amersham plc to vary its gaseous discharges from its two sites at Harwell.

8.1 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 and sediments. The monitoring locations are shown in Figure 5.1. Monitoring at Newbridge, well upstream on the Thames acts as an indication of background levels in the catchment.

The results are presented in Tables 8.1(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 limit of detection. Concentrations in material from Maple Lodge Sewage Works were lower than in 2001. Total alpha and beta activities in water were below the WHO screening levels. The caesium-137 detected in mud from the canal is unlikely to be due to discharges from Amersham. Gamma dose rates above the banks of the canal were indistinguishable from background.

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

Habits surveys have identified anglers as the critical group affected by discharges into the canal/river system. Their occupancy of the river bank has been assessed to estimate their external exposures. Even though there was no evidence of local consumption of freshwater fish, it is considered prudent to include a component in the assessment of the anglers' exposure. A consumption rate for fish of 1 kg year^{-1} was therefore assumed. The anglers' dose in 2002 was less than 0.007 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv.

The dose to the critical group of terrestrial food consumers was assessed as being less than 0.006 mSv, which was less than 1% of the dose limit for members of the public.

8.2 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. OrthoClinical Diagnostics Ltd. also makes small discharges from the site.

Routine monitoring, carried out on behalf of the Wales Assembly Government, the Environment Agency and the Food Standards Agency, includes consideration of consumption of locally produced food and external exposure over muddy, intertidal areas (Figure 8.1). Measurements of external exposure are

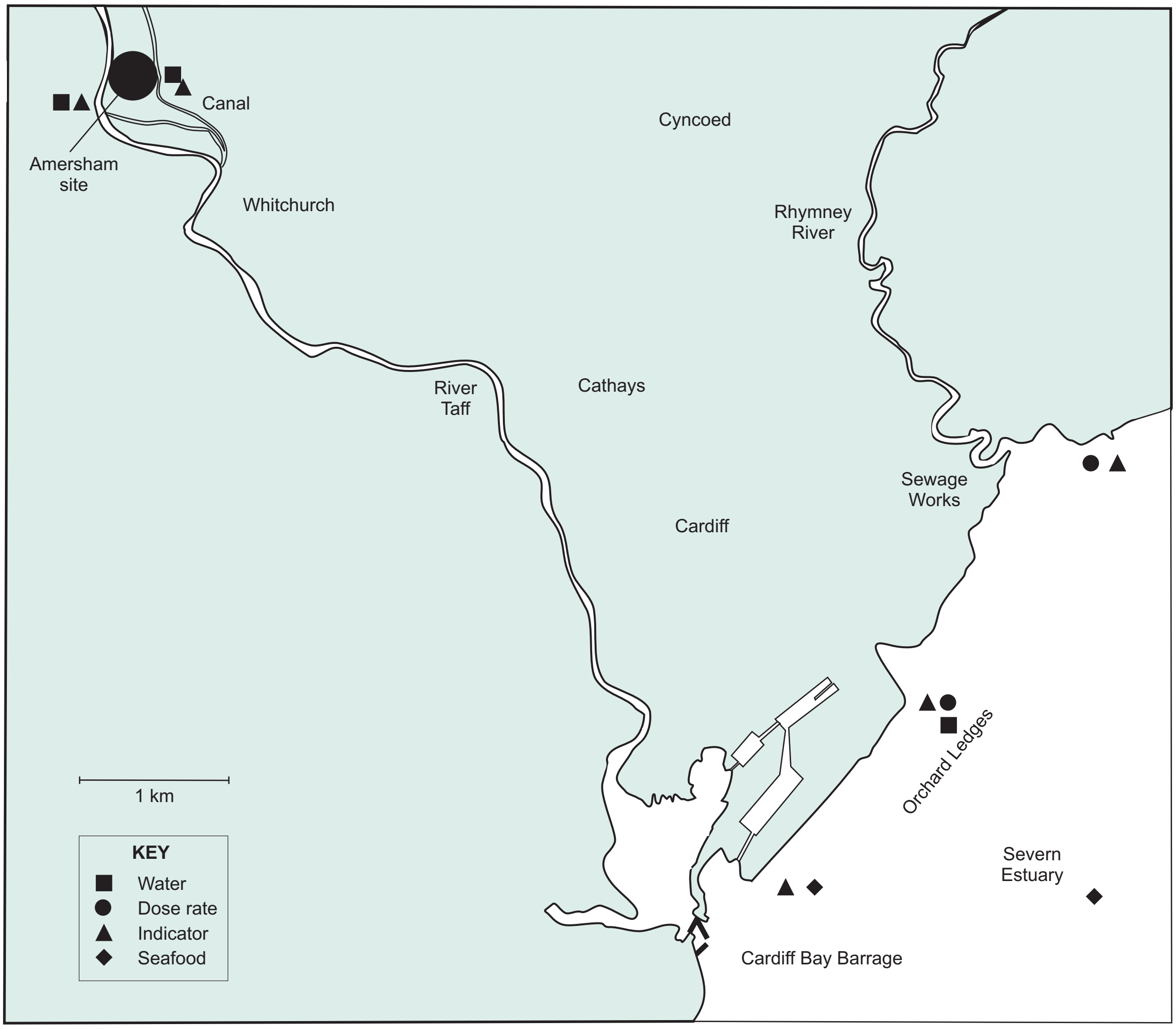

Figure 8.1 Monitoring locations at Cardiff (excluding farms)

supported by analyses of intertidal sediment. Indicator 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, 2001b, Swift, 2001, Leonard *et al.*, 2001b and McCubbin *et al.*, 2001). A full review of monitoring data for tritium bioaccumulation has been undertaken (Rowe *et al.*, 2001).

The results of both routine and supplementary monitoring in 2002 are presented in Tables 8.2(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 over 90% of the total tritium in marine samples was associated with organic matter. This form of tritium is strongly bound to organic matter and sediment 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 Section 3.6.3 and 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 8.2 and 8.3.

Further information on tritium levels in seawater and at other nuclear sites in the Bristol Channel can be found in Sections 6 and 11. Tritium continued to be detected in water from the River Taff and the Glamorganshire Canal.

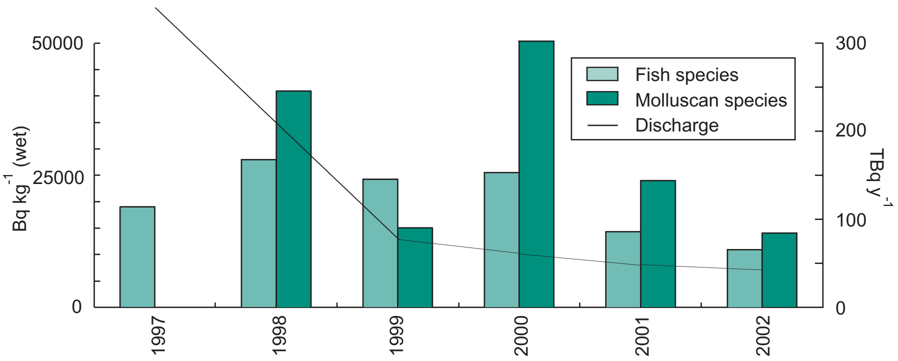

***Figure 8.2** Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)*

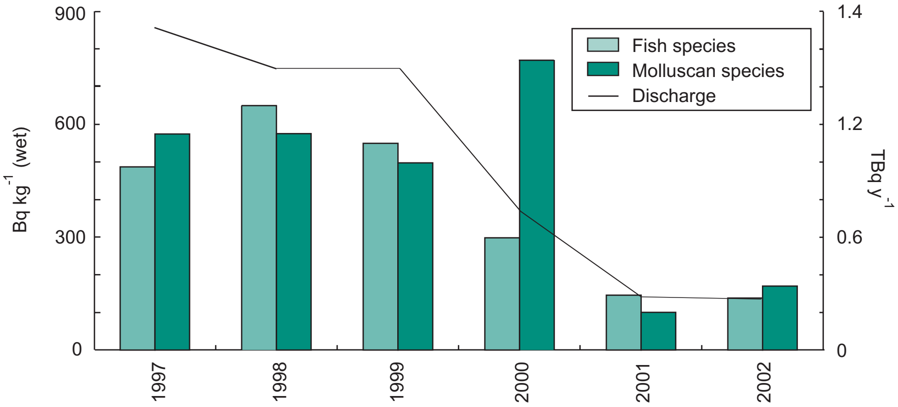

***Figure 8.3** Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)*

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

Relatively high concentrations of radionuclides were found in pelleted sludge produced at the new Waste Water Treatment Works (Table 8.2(a)). An assessment of the use of such pellets in land reclamation and as a soil conditioner on agricultural land has been made as part of the Environment Agency's discharge authorisation procedure (Titley, 2003). This shows that, for discharges at the proposed authorised limits, the doses are three or more times greater for the fish and shellfish pathway than for those pathways associated with the use of pelleted sludge. On the basis of the concentrations detected in 2002, the highest dose would have been less than 0.005 mSv to infants being given food produced from land to which pellets had been added as a soil conditioner. The Environment Agency is continuing to work with the water company to assess the effect of the disposals of sludge pellets at land reclamation schemes.

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 Table 11.5). 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. The critical group received 0.013 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 0.003 mSv from modelled concentrations of radionuclides in air (Appendix 2).

Table 8.1(a). Concentrations of radionuclides in food and the environment near Amersham, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{32}P	^{35}S	^{57}Co	^{125}I	^{137}Cs	^{241}Am	Total alpha	Total beta
Freshwater samples												
Pike[d]	Newbridge	1	<25	<25			<0.07		<0.13	0.0048		
Pike[e]	Outfall (Grand Union Canal)	1	<25	<25			<0.03		0.31	<0.11		
Pike	Staines	1	<25	<25			<0.03		0.12	<0.10		
Pike	Shepperton	1	<25	<25			<0.03		0.17	<0.15		
Pike	Teddington	1	<25	<25			<0.03		0.13	<0.05		
Flounder	Beckton	1		<25			<0.03		0.19	<0.11		
Nuphar lutea	Newbridge	1		<25			<0.02		<0.02	<0.07		
Nuphar lutea	Outfall (Grand Union Canal)	1		<25			0.03		<0.03	<0.07		
Nuphar lutea	Staines	1		<25			<0.02		<0.05	<0.04		
Mud	Outfall (Grand Union Canal)	1					<0.55		35	<2.1		470
Freshwater[f]	Maple Cross	5[E]		<4.0			<0.20	<0.90	<0.44		<0.048	0.35
Crude effluent	Maple Lodge Sewage Treatment Works	4[E]	<37	<4.0	<11	<8.2	<0.12	<0.81	<0.41	<0.48	<0.39	0.67
Digested sludge	Maple Lodge Sewage Treatment Works	4[E]	<24	6.5	<13	<8.2	<0.26	<2.0	<0.21	<0.27	<7.9	19
Final effluent	Maple Lodge Sewage Treatment Works	4[E]	<19	<4.0	<9.5	<8.4	<0.12	<0.84	<0.40	<0.47	<0.19	0.51

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{35}S	^{75}Se	^{125}I	^{131}I	^{137}Cs
Terrestrial samples								
Milk		2	<3.6	<0.68	<0.35	<0.049	<0.020	<0.29
Milk	max		<3.8	<0.80	<0.43	<0.050	<0.022	<0.33
Apples		1	6.0	<0.20	<0.20	0.072		<0.30
Beetroot		1	<3.0	1.6	<0.30	<0.062		<0.30
Blackberries		1	5.0	6.3	<0.40	<0.068		<0.40
Broad beans		1	<4.0	1.0	<0.30	<0.059		<0.40
Cabbage		1	<3.0	1.1	<0.30	<0.092		<0.30
Potatoes		1	<4.0	<0.40	<0.20	<0.061		<0.30
Runner beans		1	<3.0	<0.50	<0.30	<0.083		<0.30
Wheat		1	<6.0	<0.60	<0.30	<0.084		<0.30

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

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

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

[d] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were 0.00049 and 0.0023 Bq kg^{-1} respectively*

[e] *The concentration of ^{14}C was 21 Bq kg^{-1}*

[f] *The concentrations of ^{14}C and ^{131}I were <4.0 and <9100 Bq kg^{-1} respectively*

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

Table 8.1(b). Monitoring of radiation dose rates near Amersham, 2002

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m			
Grand Union Canal	Grass	4	0.065

Table 8.2(a). Concentrations of radionuclides in food and the environment near Cardiff, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{99}Tc	^{125}I	^{134}Cs	^{137}Cs
Marine samples									
Flounder	East of new pipeline	2	27000	30000	310			<0.10	0.44
Sole	East of new pipeline	2		12000	180			<0.14	0.31
Cod	East of new pipeline	1		2000	25			0.06	0.66
Mullet	East of new pipeline	1		420	38			<0.05	0.34
Mussels	Orchard Ledges	2	12000	14000	170			<0.22	<0.21
Fucus vesiculosus	Orchard Ledges	2	100	110	21			<0.13	0.68
Seaweed	Orchard Ledges	2^{E}		410	<25	3.7	<0.87		
Mud	Orchard Ledges East	2	110	140	6.2			<1.1	18
Sediment	East of new pipeline	2^{E}		680	<36		<3.0		19
Sediment	West of new pipeline	2^{E}		200	<68		<3.0		30
Seawater	Orchard Ledges East	2		4.9					
Seawater	Orchard Ledges	2^{E}	5.5	<27	<15		<0.66		

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{32}P	^{35}S	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples													
Milk		8	<7.0	<9.9	18	<0.25	<0.48	<0.056		<0.26	<0.28		
Milk	max		<12	24	23	<0.27	<0.63	<0.066		<0.30	<0.30		
Barley		1		<6.0	120		<0.80	<0.064		<0.30	<0.30		
Blackberries		1	<22	19	18		0.90			<0.30	<0.30		
Cabbage		1	9.0	15	5.0		<0.30	<0.053		<0.20	<0.20		
Courgette/Cucumber		1	<89	88	9.0		<0.40	<0.086		<0.20	<0.30		
Honey		1		<6.0	82		<0.40	<0.052		<0.20	<0.20		
Potatoes		1	2.0	14	12		0.50	<0.074		<0.20	<0.30		
Rape oil		1		<6.0	120		1.8	<0.090		<0.20	<0.20		
Raspberries		1	6.0	36	15		<0.40	<0.082		<0.20	<0.20		
Strawberries		1	<23	23	14		<0.40	<0.076		<0.20	<0.30		
Grass		5	76	200	56					<0.30	<0.33		
	max		220	570	57						0.40		
Silage		2	<20	21	54								
	max		26	28	64								
Soil		3								<0.30	6.4		
	max										8.1		
Sediment	Canal	2^{E}		190	<25			<0.74			2.3		
Freshwater	Run off into River Taff	2^{E}	<12	<25	<15			<0.61	<12		<0.60	<0.025	0.16
Freshwater	Canal	2^{E}	26	71	<15			<0.59	<8.5		<0.64	<0.032	0.14
Freshwater	River Taff	2^{E}	<4.0	30	<15			<0.63	<2.0		<0.62	<0.020	0.19
Sewage sludge pellets	Water Treatment Works	8^{E}		180000	1900								

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

Table 8.2(b). Monitoring of radiation dose rates near Cardiff, 2002

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Orchard Ledges East	Mud	2^{F}	0.077
East of Pipeline	Mud	2	0.077
West of Pipeline	Mud	2	0.12
Mean beta dose rates			µSv h^{-1}
Orchard Ledges East	Mud	2^{F}	<0.011

[E] *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*

9. MINOR SITES

Three minor sites with very low levels of discharge are monitored using a small sampling programme of indicator materials. The results, given in the following sections, show that there was no detected impact on the environment in 2002 due to operation of these sites.

9.1 Imperial College Reactor Centre, Ascot, Berkshire

Two grass samples were analysed by gamma-ray spectrometry. Both results in 2002 were less than the limits of detection except for caesium-137, which was detected at a very low level 0.35 Bq kg^{-1} (wet).

9.2 Imperial Chemical Industries plc, Billingham, Cleveland

The reactor at this site ceased operation on 28 June 1996. However, low level releases have continued as a result of other operations.

Two grass samples were analysed by gamma-ray spectrometry. Both results in 2002 were less than the limits of detection.

The Environment Agency undertook a special sampling programme of grass and soil in 2002. Concentrations of tritium in soil (wet mass) and grass (fresh mass) were in the range <3 to 11 Bq kg^{-1} and 24 - 39 Bq kg^{-1}, respectively. Carbon-14 concentrations were 25 - 55 Bq kg^{-1} in soil and 190 - 460 Bq kg^{-1} in grass. The source of the carbon-14 is not yet formally resolved. However, the radiological significance of the concentrations is very low.

9.3 Scottish Universities' Research Reactor Centre, South Lanarkshire

The small research reactor at this site has now ceased operation. Authorisations for the disposal of solid and gaseous waste arising from decommissioning were issued by SEPA in 2001. Decommissioning of the reactor has progressed well in 2002 and should be complete in 2003. Routine laboratory work continues at the site, resulting in the authorised disposal of small quantities of radioactive substances.

10. INDUSTRIAL AND LANDFILL SITES

10.1 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. 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. Demolition of the plant will start in 2003.

The results of routine monitoring for natural radioactivity near the site in 2002 are shown in Table 10.1. 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 10.1 shows how concentrations of polonium-210 in winkles have decreased substantially since 1990, and more dramatically since 1992. It also demonstrates the seasonal variations in concentrations that have been previously observed (Rollo *et al.*, 1992). Concentrations of lead-210 and polonium-210 were generally similar to those in 2001 (Food Standards Agency and Scottish Environment Protection Agency, 2002). Taking into account the ranges of values observed, it is difficult to distinguish the measured total concentrations from those expected due to natural sources. However, there were small enhancements for some radionuclides and marine species and it is these that form the basis of the dose assessment.

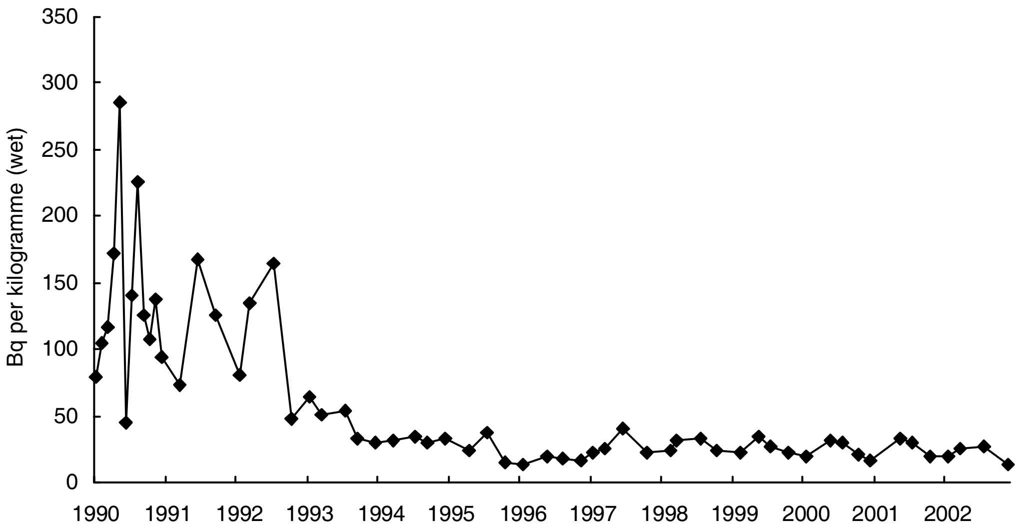

Figure 10.1 Polonium-210 in Parton winkles

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 4). 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 (see Appendix 6). Consumption rates for the critical group were reviewed and revised in 2002.

As discussed in Section 3.6.3, a specific research study involving the consumption of crab meat containing natural levels of polonium-210 provides evidence for a gut transfer factor of 0.8 for polonium. Estimates of exposures due to polonium intakes due to consumption of seafood have therefore been calculated using the conservative assumption that the value of 0.8 applies to the total intake of polonium. These data indicate that the critical group dose increased from 0.34 mSv in 2001 to 0.42 mSv in 2002. The increase was due to changes in consumption rates of the critical group in 2002. The assessments are based on averaging the consumption rates over a five year period from 1998 - 2002.

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 4. In 2002, these exposures added a further 0.19 mSv to the doses above resulting in a total dose to this group of up to 0.61 mSv. The estimated doses in 2002 are therefore below the dose limit for members of the public of 1 mSv.

10.2 Other industrial sites

Levels of radionuclides in gaseous discharges from some other industrial activities also have the potential to raise the radionuclide concentrations in foodstuffs. Examples of such activities are combustion of fossil fuels and waste incineration. Since 1991, a small rolling programme to examine the effects of these activities has been carried out. In 2002, six sites were chosen for study. An additional site, a sewage works near Cambridge, was investigated in view of the possible incorporation of radionuclides in freshwater fish after discharge from non-licensed sites into sewers. In summary, the sites were:

- Bracknell, Berkshire (pesticide research)
- Harlow, Essex (pharmaceuticals)
- Loughborough, Leicestershire (pharmaceuticals)
- Middlesbrough, Cleveland (chemical manufacturer)
- Milton, Cambridgeshire (sewage works)
- Milton Keynes, Buckinghamshire (biochemical research)
- Telford, Shropshire (defence equipment repair)

The results of the sampling of vegetables, grass, soil, indicator materials and animals in 2002 are given in Table 10.2 for all seven sites.

Fish samples were taken upstream and downstream of the Milton Sewage works near Cambridge. Low levels of tritium, carbon-14 and caesium-137 were detected and the concentration of carbon-14 was about twice that expected due to natural sources. An assessment of the dose from consumption of 1 kg of fish, after subtraction of a natural background carbon-14 contribution, gave much less than 0.005 mSv or less than 0.5% of the dose limit for members of the public. The radiological importance of this pathway is therefore very small.

There is considerable variability in the concentrations of natural radionuclides in the terrestrial environment. It is therefore difficult to draw firm conclusions about the possible effects of man-made sources or enhancements of natural radionuclides. With this proviso, it was concluded that in 2002 the concentration of natural radionuclides observed at industrial sites were within the ranges expected for natural sources. The concentrations of man-made radionuclides in samples were all low and of negligible radiological significance. Estimated doses from consumption of rabbit sampled near the sites were all less than 0.005 mSv.

10.3 Landfill sites

Some organisations are authorised by SEPA in Scotland or the Environment Agency in England and Wales to dispose of solid wastes containing low levels of radioactivity to approved landfill sites. Waste with very low levels of radioactivity can also be disposed of in general refuse. Radioactivity in wastes can migrate into leachate and in some cases can enter the groundwater. Monitoring of leachates is carried out by the Environment Agency and SEPA and the results are presented in Tables 10.3 and 10.4. The results, in common with previous years, show very low levels of carbon-14 and 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}) at the highest concentration of tritium observed at a site 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.

Enhanced levels of uranium isotopes were found in water samples taken from near the Rhodia Consumer Specialities Ltd. site in Cumbria. This could be due to the historical operations involving the manufacture of phosphoric acid from phosphate ore (See section 10.1). The levels are significantly less than Generalised Derived Limits for freshwater (20 Bq kg^{-1} for each uranium isotope (Harvey *et al.*, 2000)). Surface waters from this site are not known to be used as a source of drinking water.

A programme of monitoring was carried out around the waste disposal site operated by Rolls Royce at Hilts Quarry. Results are given in Table 7.2. Samples of water and sediment were taken from up to 5 locations upstream and downstream of the Quarry. The presence of cobalt-60 in stream water had been reported on a previous occasion by the company, but subsequent monitoring, including during 2002, has failed to find any. In addition to the Food Standards Agency investigation (Food Standards Agency and Scottish Environment Protection Agency, 2002), the Environment Agency initiated a programme of independent monitoring. Isotopes of uranium and thorium were detected in the stream water at levels similar to those seen elsewhere in Derbyshire.

Table 10.1. Concentrations of natural radionuclides in fish and shellfish, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{210}Po	^{210}Pb	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Rhodia Consumer Specialities Ltd, Whitehaven											
Winkles	Saltom Bay	4	29	1.8							
Winkles	Parton	4	21	1.6	0.073	0.54	0.82	0.40	1.3	0.048	1.1
Winkles	North Harrington	1	28								
Winkles	Nethertown	4	18								
Winkles	Drigg	1				0.61	0.64	0.48			
Winkles	Tarn Bay	1	13								
Mussels	Parton	2	61	3.8							
Mussels	Nethertown	4	52	3.8							
Limpets	St Bees	3	16								
Cockles	Ravenglass	3	20								
Whelks	Sellafield offshore area	2	3.7								
Crabs	Parton	4	24	0.10		0.079	0.012	0.0046	0.059	0.0022	0.051
Crabs	Sellafield coastal area	4	11	0.080							
Lobsters	Parton	4	19	<0.077		0.031	0.0097	0.0042	0.014	*	0.016
Lobsters	Sellafield coastal area	4	12	<0.13							
Cod	Parton	3	0.72	0.040		0.016	0.0032	0.0019	0.0072	0.00020	0.0055
Flounder	Whitehaven	1	1.7								
Other samples											
Mussels	Ribble Estuary	1			0.10	0.27	0.49	0.16			
Limpets	Kirkcudbright	1	12								
Cockles	Southern North Sea	2				0.37	0.22	0.28			
Cockles	Ribble Estuary	1			0.022	0.35	0.59	0.19			
Cockles	Flookburgh	2	19								
Whelks	Fleetwood	1	1.4								
Shrimps	Ribble Estuary	2			0.018	0.0064	0.0098	0.0023			

** Not detected by the method used*

Table 10.2 Concentrations of radionuclides in food and the environment near industrial sites, 2002

Site	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			Organic ^{3}H	^{3}H	^{7}Be	^{14}C	^{32}P	^{33}P	^{35}S	^{40}K	^{82}Br	^{90}Sr	^{99m}Tc	^{125}I	^{131}I
Harlow, Essex	Grass	4		3.3	43	53	<0.50	<0.50	0.73	190	<0.60	0.54	<3.5	<0.020	<0.38
	Soil	4			<2.5	<11			<1.2	530		2.5			
	Rabbit	1		<4.0	<0.90	60	<0.70	0.80	0.40	110	<0.50	0.24		<0.030	0.10
Loughborough, Leicestershire	Grass	4		4.8	41	38	<2.7	<4.1	0.50	140	<0.43	0.21	<2.4	<0.018	<0.28
	Soil	4			<3.0	<9.3			<0.78	410		2.0			
	Rabbit	1		<10	<0.90	38	<0.80	<0.80	2.0	110	<3.0	0.18			0.20
Bracknell, Berkshire	Grass	4		<2.8	48	43	<0.55	<0.50	0.43	130	<0.63	0.34	<3.2	<0.025	<0.35
	Soil	4			<1.9	<10			<0.98	370		2.7			
	Rabbit	1		<5.0	<0.90	20	<0.90	1.1	2.9	110	<0.20	0.40			0.10
Middlesbrough, Cleveland	Grass	4		4.5	35	38	<0.45	<0.45	0.56	180	<0.48	0.37	<5.5	<0.020	<0.25
	Soil	4			<2.0	<7.5			<1.7	390		2.7			
	Rabbit	1		11	<0.90	70	<0.60	1.3	0.70	100	<0.80	0.42		<0.030	0.20
Milton Keynes, Buckinghamshire	Grass	4		<3.5	54	68	<7.4	<7.4	0.60	230	<1.0	0.63	<6.3	<0.020	<0.63
	Soil	4			<2.0	<6.3			<0.90	340		2.6			
	Rabbit	1		<4.0	<1.0	20	<0.60	1.2	4.5	100	<0.90	0.71		<0.030	0.20
Telford, Shropshire	Grass	4		<6.3	51	63	<0.88	<0.88	0.45	220	<0.60	0.57	<3.5	<0.020	<0.40
	Soil	4			<2.5	<5.8			<1.6	530		3.1			
	Rabbit	1		<4.0	<0.80	90	<1.0	<1.0	3.3	100	<0.30	1.4		<0.020	0.10
R Cam, Milton, Cambridgeshire															
upstream	Pike	1	43	52											
downstream	Pike	1	55	54		42									*

Site	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{134}Cs	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am
Harlow, Essex	Grass	4	<0.15	<0.15	1.2	1.6		0.070	0.00014	0.0012	0.00090
	Soil	4	<0.40	5.9	16	20	22	25	0.023	0.17	0.083
	Rabbit	1	<0.10	<0.10	0.040	0.017		0.00050	<0.00050	0.00020	0.00030
Loughborough, Leicestershire	Grass	4	<0.12	<0.12	0.67	1.2		0.036	0.00041	0.0016	0.0030
	Soil	4	<0.38	6.4	18	21	11	17	0.083	0.14	0.17
	Rabbit	1	<0.10	<0.10	0.18	0.030		0.00030	<0.00020	<0.00020	<0.00020
Bracknell, Berkshire	Grass	4	<0.12	<0.15	0.64	1.3		0.024	0.00018	0.0024	0.0034
	Soil	4	<0.38	5.0	16	18	16	17	0.048	0.15	0.068
	Rabbit	1	<0.10	0.07	0.080	0.040		0.00060	<0.00020	0.00010	0.00030
Middlesbrough, Cleveland	Grass	4	<0.09	<0.09	1.3	1.7		0.040	0.00032	0.0016	0.0014
	Soil	4	<0.33	7.4	21	28	18	25	0.028	0.21	0.085
	Rabbit	1	<0.10	0.09	0.070	0.023		0.00050	<0.00020	0.00012	0.00020
Milton Keynes, Buckinghamshire	Grass	4	<0.20	<0.20	1.5	2.0		0.025	0.00067	0.0022	0.0019
	Soil	4	<0.33	6.9	23	16	15	16	<0.021	0.22	0.075
	Rabbit	1	<0.10	0.10	0.070	0.018		0.00020	<0.00010	0.00013	<0.00020
Telford, Shropshire	Grass	4	<0.18	<0.20	1.5	2.0		0.022	0.0014	0.0027	0.0021
	Soil	4	<0.33	5.4	22	17	23	16	<0.018	0.16	0.075
	Rabbit	1	<0.10	<0.10	0.070	0.016		0.00030			<0.00040
R Cam, Milton, Cambridgeshire											
upstream	Pike	1									
downstream	Pike	1	<0.06	0.10							<0.18

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

* *Not detected by the method used*

Table 10.3. Concentrations of radionuclides in surface water leachate from landfill sites in Scotland, 2002

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	8800	<15	0.12	<0.05
City of Glasgow	Summerston Tip	1	440	<15	0.06	<0.05
Clackmannanshire	Black Devon	1	530	<15	<0.05	<0.05
Dundee City	Riverside	1	12	<15	<0.05	<0.05
Fife	Balbarton	1	87	<15	<0.05	<0.05
Fife	Melville Wood	1	150	<15	<0.05	<0.05
Highland	Longman Tip	1	<5.0	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	110	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	35	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	88	<15	<0.05	<0.05

Table 10.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2002

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}								
			^{3}H	^{14}C	^{40}K	^{57}Co	^{60}Co	^{65}Zn	^{125}I	^{131}I	^{137}Cs
City of Bristol											
Crooks Marsh Farm, Avonmouth	Leachate	2	35	<4.0	<5.1	<0.12	<0.19	<0.45	<1.0	<2200	<0.18
Cambridgeshire											
Milton landfill, Cambridge	Borehole	2	<490		<10		<0.62				<0.62
Milton landfill, Cambridge	Drainage	2	<4.0		<4.9		<0.62				<0.62
Milton landfill, Cambridge	Ground water borehole	2	<4.0		<3.6		<1.0				<1.0
Milton landfill, Cambridge	Phase 2 borehole	2	440		33		<0.62				<0.62
Cheshire											
Northwich Tip	Borehole WM6G	2	270		<13		<0.45				<0.40
Northwich Tip	Borehole WM20G	2	<4.0		<6.6		<0.36				<0.37
Northwich Tip	Borehole WM5G	2	17		<15		<0.30				<0.30
Cleveland											
Bewley ICI Tip	On-site stream (downstream)	2	440		<13		<0.45				<0.30
Bewley ICI Tip	On-site stream (upstream)	2	13		<13		<0.35				<0.35
Cumbria											
Rhodia Consumer Specialties Ltd, Hut Bank Quarry	Borehole	1	<4.0		<10		<0.70				<0.50
Rhodia Consumer Specialties Ltd, Ufex	Leachate	1	<4.0		61		<0.60				<0.60
Alco Landfill	Borehole	1	26	<4.0	<2.5	<0.04	<0.09	<0.24	<1.0	<1200	<0.16
BAE Systems Marine Ltd, Walney Island	Waste ponds water	1	<4.0		<8.0		<0.60				<0.50
Derbyshire											
Hilts Quarry, Fritchley Brook	Local water	1	<4.0		<9.0		<0.60				<0.50
Greater London											
Murex Ltd	Local water (East stream)	1	4.5		8.0		<0.50				<0.40
Murex Ltd	Local water (West stream)	1	<4.0		<9.0		<0.50				<0.70
Gwynedd											
Cilgwyn Quarry	Leachate	2	<140	<4.0	<9.0	<0.11	<0.63	<0.64	<0.75	<4.0	<0.62
Cilgwyn Quarry	2nd pit	2	<130	<4.5	<7.0	<0.12	<0.63	<0.59	<0.55	<7.5	<0.63
Hertfordshire											
Braziers Landfill	Borehole W2	2	5.1		<14		<0.62				<0.62
Braziers Landfill	Borehole W5	2	<4.0		<7.7		<0.62				<0.62
Braziers Landfill	Borehole W9	1	<4.0		<5.2		<0.23				<0.21
Cole Green Landfill	Local water (culvert)	2	<4.0		<8.8		<0.62				<0.61
Cole Green Landfill	Static borehole	2	21		<6.0		<0.62				<0.62
Lancashire											
Magnesium Electron, Swinton	Local water	1	<4.0		<10		<0.60				<0.50
Birkacre Mine Shaft	Pool	1	<4.0		<9.0		<0.60				<0.50
Belthorne Mine Shaft	Local water (brook)	2	<4.0		<15		<0.35				<0.31
Clifton Marsh	Borehole 6	2	18		<7.2		<0.35				<0.31
Clifton Marsh	Borehole 19	2	7.5		<7.0		<0.36				<0.31
Clifton Marsh	Borehole 40	2	<4.0		<5.9		<0.36				<0.37
Clifton Marsh	Borehole 59	2	34		<7.2		<0.35				<0.31
Ulnes Walton	River Lostock (downstream)	1	<4.0		<10		<0.60				<0.70
Ulnes Walton	River Lostock (upstream)	1	<4.0		<10		<0.60				<0.50
Near Whittle Hill Quarry	River Lostock	2	<4.0		<6.7		<0.45				<0.40
River Yarrow, Lancashire	Local water	1	<4.0		<8.0		<0.60				<0.60

Table 10.4. continued

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}								
			^{3}H	^{14}C	^{40}K	^{57}Co	^{60}Co	^{65}Zn	^{125}I	^{131}I	^{137}Cs
Merseyside											
Sefton Meadows Tip	Local water	1	<4.0	<4.0	<1.5	<0.04	<0.11	<0.26	<1.0	<750	<0.091
Arpley Landfill	Borehole 25 (groundwater)	2	<4.0	<4.0	<6.1	<0.11	<0.23	<0.52	<1.0	<550	<0.23
Norfolk											
Strumpshaw Landfill	Leachate (borehole NH3)	2	<4.0	<4.0	<5.4	<0.13	<0.63	<0.40	<1.0	<29	<0.63
Strumpshaw Landfill	Leachate (borehole BH2)	2	<4.0	<4.0	<2.9	<0.13	<0.58	<0.41	<1.0	<40	<0.59
Strumpshaw Landfill	Reservoir	1	<4.0	<4.0	<2.3	<0.07	<1.0	<0.37	<1.0	<68	<1.0
Strumpshaw Landfill	Water abstraction	1	<4.0	<4.0	<3.1	<0.06	<1.0	<0.44	<1.0	<89	<1.0
Nottinghamshire											
School of Agriculture, Nottingham	Local water (stream)	1	<4.0		<9.0		<0.80				<0.50
Oxfordshire											
Stanford in the Vale	Local water	2	<4.0		<7.0		<0.35				<0.35
Stanford in the Vale	Borehole 15	2	<4.0		<7.1		<0.40				<0.50
South Glamorgan											
Lamby Way Tip	Borehole 1A	1	160	<4.0	<5.2		<0.50		<0.52	<4.0	<0.50
South Gloucestershire											
Berwick Lane landfill	Local water	2	<38								
South Yorkshire											
Beighton Tip, Sheffield	Local water	1	<4.0	<4.0	<5.4	<0.22	<0.39	<0.96	<1.0	<60	<0.33
Beighton Tip, Sheffield	Borehole	1	<4.0	<4.0	<2.9	<0.15	<0.10	<0.22	<1.0	<0.36	<0.12
Sussex											
Beddingham Quarry	Leachate (site 1)	1	190	<4.0	<5.6	<0.13	<0.28	<0.71	<1.0	<2700	<0.25
Beddingham Quarry	Leachate (site 2)	2	<4.0	<4.0	<5.0	<0.14	<0.28	<0.86	<1.0	<1600	<0.28
Beddingham Quarry	Leachate (site 3)	1	340	<4.0	12	<0.09	<0.20	<0.50	<1.0	<2400	<0.18
Tyne and Wear											
High Urpeth Tip	Local water (downstream)	1	<4.0		<8.0		<0.60				<0.70
Kibblesworth Colliery	Liquid (sampling point)	1	<4.0		<10		<0.50				<0.60
Ryton Tip, Gateshead	Local water	1	<4.0	<4.0	<2.9	<0.09	<0.19	<0.43	<1.0	<390	<0.18
West Yorkshire											
Gelderd Road Tip, Leeds	Borehole	1	<4.0	<4.0	<4.0	<0.13	<0.27	<0.62	<1.0	<2200	<0.26
Dean House Farm Tip	Borehole	2	<4.0	<4.0	<6.8	<0.16	<0.31	<0.62	<1.0	<27	<0.25
Greaseworks	Borehole	1	43	<4.0	<2.9	<0.11	<0.19	<0.46	<1.0	<690	<0.18
Wilson Road Tip	Borehole	1	<4.0	<4.0	<5.5	<0.24	<0.36	<0.94	<1.0	<41	<0.31

Table 10.4. continued

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}								
			^{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								<0.15	<0.60
Cambridgeshire											
Milton landfill, Cambridge	Borehole	2		<0.0070	<0.0050	<0.0050	<0.016	<0.0060	<0.013	<0.28	9.9
Milton landfill, Cambridge	Drainage	2		<0.013	<0.0055	<0.0060	0.030	<0.0055	0.018	0.10	0.20
Milton landfill, Cambridge	Ground water borehole	2		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.016	<0.12	0.74
Milton landfill, Cambridge	Phase 2 borehole	2		<0.0060	<0.0050	<0.0050	<0.011	<0.0055	<0.010	<0.60	44
Carmarthenshire											
Cefnbrynbrain	Liquid	2	<3.0								
Cheshire											
Northwich Tip	Borehole WM6G	2		<0.0080	<0.0050	<0.0050	<0.015	<0.0080	<0.015	<1.5	<18
Northwich Tip	Borehole WM20G	2		<0.035	<0.013	<0.015	<0.0075	<0.0050	<0.0070	<9.0	<13
Northwich Tip	Borehole WM5G	2		<0.016	<0.0050	<0.0050	<0.0090	<0.0050	<0.0090	<0.030	<0.63
Cleveland											
Bewley ICI Tip	On-site stream (downstream)	2		<0.0060	<0.0050	<0.0050	0.044	<0.0055	0.33	<1.4	<10
Bewley ICI Tip	On-site stream (upstream)	2		<0.0075	<0.0050	<0.0055	0.032	<0.0050	0.03	<1.3	11
Cumbria											
Rhodia Consumer Specialties Ltd, Hut Bank Quarry	Borehole	1		<0.0050	<0.0050	<0.0050	0.042	<0.010	0.051	0.030	0.28
Rhodia Consumer Specialties Ltd, Ufex	Leachate	1		<0.0050	<0.0050	<0.0050	2.7	0.11	2.7	<4.5	85
Alco Landfill	Borehole	1								<0.090	0.72
BAE Systems Marine Ltd, Walney Island	Waste ponds water	1		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0070	<0.030	0.27
Derbyshire											
Hilts Quarry, Fritchley Brook	Local water	1		<0.0050	<0.0050	<0.0050	0.017	<0.0050	0.021	<0.040	0.25
Greater London											
Murex Ltd	Local water (East stream)	1		<0.0050	<0.0050	<0.0050	0.03	<0.0080	0.03	<0.10	1.6
Murex Ltd	Local water (West stream)	1		<0.0050	<0.0050	<0.0050	0.027	<0.0050	0.023	<0.10	0.61
Gwynedd											
Cilgwyn Quarry	Leachate	2								0.055	1.6
Cilgwyn Quarry	2nd pit	2								<0.050	1.4
Hertfordshire											
Braziers Landfill	Borehole W2	2		<0.0070	<0.0050	<0.0050	<0.0080	<0.0050	<0.0080	0.087	0.50
Braziers Landfill	Borehole W5	2		<0.013	<0.0075	<0.013	<0.0085	<0.0050	0.0070	<0.080	0.15
Braziers Landfill	Borehole W9	1		<0.0080	<0.0050	<0.0050	0.017	<0.0050	0.013	0.10	0.36
Cole Green Landfill	Local water (culvert)	2		<0.010	<0.0050	<0.0050	0.016	<0.0050	0.015	<0.11	<0.17
Cole Green Landfill	Static borehole	2		<0.0065	<0.0055	<0.0060	0.038	<0.0070	0.048	0.29	4.2
Lancashire											
Magnesium Electron, Swinton	Local water	1		<0.0050	0.0060	<0.0050	0.031	<0.0050	0.035	<0.020	<0.10
Birkacre Mine Shaft	Pool	1		<0.0050	<0.0050	<0.0050	<0.0060	<0.0050	<0.0050	<0.040	<0.10
Belthorne Mine Shaft	Local water										
Clifton Marsh	Borehole 6	2		<0.0060	<0.0050	<0.0050	0.014	<0.0050	0.014	<0.14	2.1
Clifton Marsh	Borehole 19	2		<0.0090	<0.0050	<0.0050	<0.0060	<0.0050	<0.0070	<0.10	1.1
Clifton Marsh	Borehole 40	2		<0.0075	<0.0050	<0.0045	0.039	<0.0050	<0.043	<0.13	1.2
Clifton Marsh	Borehole 59	2		<0.0060	<0.0050	<0.0040	<0.011	<0.0050	<0.0095	<0.19	3.6
Ulnes Walton	River Lostock (downstream)	1		<0.0050	<0.0050	<0.0050	<0.020	<0.010	<0.0050	0.030	0.34
Ulnes Walton	River Lostock (upstream)	1		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0090	<0.030	0.30
Near Whittle Hill Quarry	River Lostock	2		<0.0065	<0.0050	<0.0050	<0.010	<0.0050	<0.0090	<0.020	0.25
River Yarrow, Lancashire	Local water	1		<0.0050	<0.0050	<0.0050	<0.010	<0.0060	<0.010	<0.020	0.18

Table 10.4. continued

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l-1							
			^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
Merseyside										
Sefton Meadows Tip	Local water	1							0.18	0.25
Arpley Landfill	Borehole 25 (groundwater)	2							0.27	0.54
Norfolk										
Strumpshaw Landfill	Leachate (borehole NH3)	2							0.11	0.12
Strumpshaw Landfill	Leachate (borehole BH2)	2							<0.089	0.12
Strumpshaw Landfill	Reservoir	1							0.18	0.45
Strumpshaw Landfill	Water abstraction	1							<0.080	0.070
Nottinghamshire										
School of Agriculture, Nottingham	Local water (stream)	1	<0.0050	<0.0050	<0.0050	<0.014	<0.0060	<0.013	0.090	0.25
Oxfordshire										
Stanford in the Vale	Local water	2	<0.0050	<0.0050	<0.0050	0.0075	<0.0050	<0.0060	<0.045	0.14
Stanford in the Vale	Borehole 15	2	<0.0050	<0.0050	<0.0050	<0.0060	<0.0060	<0.010	<0.065	0.14
South Glamorgan										
Lamby Way Tip	Borehole 1A	1							<0.23	11
South Yorkshire										
Beighton Tip, Sheffield	Local water	1							<0.030	0.21
Beighton Tip, Sheffield	Borehole	1							<0.060	0.57
Sussex										
Beddingham Quarry	Leachate (site 1)	1							<0.20	6.5
Beddingham Quarry	Leachate (site 2)	2							<0.050	0.21
Beddingham Quarry	Leachate (site 3)	1							<0.60	14
Tyne and Wear										
High Urpeth Tip	Local water (downstream)	1	0.0050	<0.0050	<0.0050	0.016	<0.0050	0.017	<0.060	0.33
Kibblesworth Colliery	Liquid (sampling point)	1	<0.0050	<0.0050	<0.0050	0.033	<0.0050	0.016	<0.40	1.1
Ryton Tip, Gateshead	Local water	1							<0.080	0.38
West Yorkshire										
Gelderd Road Tip, Leeds	Borehole	1							<0.040	0.66
Dean House Farm Tip	Borehole	2							<0.090	1.2
Greaseworks	Borehole	1							<0.20	2.7
Wilson Road Tip	Borehole	1							<0.050	0.47

11. CHERNOBYL AND REGIONAL MONITORING

11.1 Chernobyl

Radiocaesium is detected in sheep grazing certain upland areas in the UK which were subjected to heavy rainfall shortly 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 those animals containing more than 1000 Bq kg^{-1} of caesium in their muscle tissues from entering the foodchain; a level that was recommended by an EU expert committee in 1986. The on-going programme of monitoring, in relation to the effects of fallout from this accident, resumed in 2002 after being severely affected by the foot and mouth outbreak in 2001. The areas of restriction are shown in Food Standards Agency and SEPA (2002).

In summer 2002, scientific trials of new monitors were carried out in Cumbria and Scotland. Further trials will be carried out in the coming year and, after full consideration of the results, the new monitors will be validated for future use.

A full derestriction survey was not carried out in Cumbria in 2002 and therefore, there were no farms where controls were lifted. In Scotland, intensive monitoring in 2002 identified two farms where controls could be lifted and this decision was implemented in January 2003, leaving 16 farms subject to restrictions. In addition, the radiocaesium monitoring of sheep carcasses at slaughterhouses, which ensures that the monitoring is effective also reported no failures.

There are still 384 farms, or parts of farms, and approximately 230,000 sheep within the restricted areas of England, Scotland and Wales. This represents a reduction of over 96% since 1986 when approximately 8900 farms were under restriction.

In Northern Ireland, concentrations of activity in sheep are well below 1000 Bq kg^{-1} and restrictions were removed from the remaining 45 farms in 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 11.1 presents concentrations of caesium-134 and caesium-137 in fish and water. Other artificial radionuclides from the Chernobyl accident are no longer detectable. Concentrations in perch were less than 1000 Bq kg^{-1}, the level attained shortly after the accident, and were generally similar to those in recent years. The long-term trend of radiocaesium in freshwater fish has been reviewed (Smith *et al.*, 2000b) and the effective ecological half-life of radiocaesium during the late 1990s has been shown to be between 6 and 30 years.

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously. A consumption rate of fish of 37 kg $year^{-1}$, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures are likely to be much lower, not only because this consumption rate is cautious (Leonard *et al.*, 1990) but also because, in practice, hatchery-reared or farmed fish have much lower radiocaesium concentration and may contribute most to the diet. In 2002, estimated doses were less than 0.1 mSv.

11.2 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 indicator materials and, in the latter case, because of their use as fertilisers.

The results for 2002 are given in Table 11.2. 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 2002, which is less than 1% 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.

11.3 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 wide range of terrestrial foodstuffs. Results are reported in Isle of Man Government press releases in addition to this report. Results of aquatic monitoring are presented in Section 4 but are also included here for completeness (Table 11.3).

Radioactivity monitoring on the Island serves two purposes: firstly to monitor the continuing effects of radiocaesium deposition resulting from the Chernobyl accident in 1986 and secondly 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. Low levels of tritium and sulphur-35 were detected, but taken as a whole, the results demonstrate that there was no significant impact on Manx foodstuffs from operation of mainland nuclear installations in 2002.

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

The effects of liquid discharges from BNFL Sellafield in the Irish Sea are discussed fully in Section 4. The dose to the critical group of Manx fish and shellfish consumers was 0.007 mSv in 2002 or less than 1% of the dose limit.

11.4 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, 2002). The programme is made up of sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 11.1). The external exposure pathway is studied by monitoring of gamma dose rates over intertidal areas. The results are presented in Tables 11.4(a) and (b).

In 2002, 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 2001.

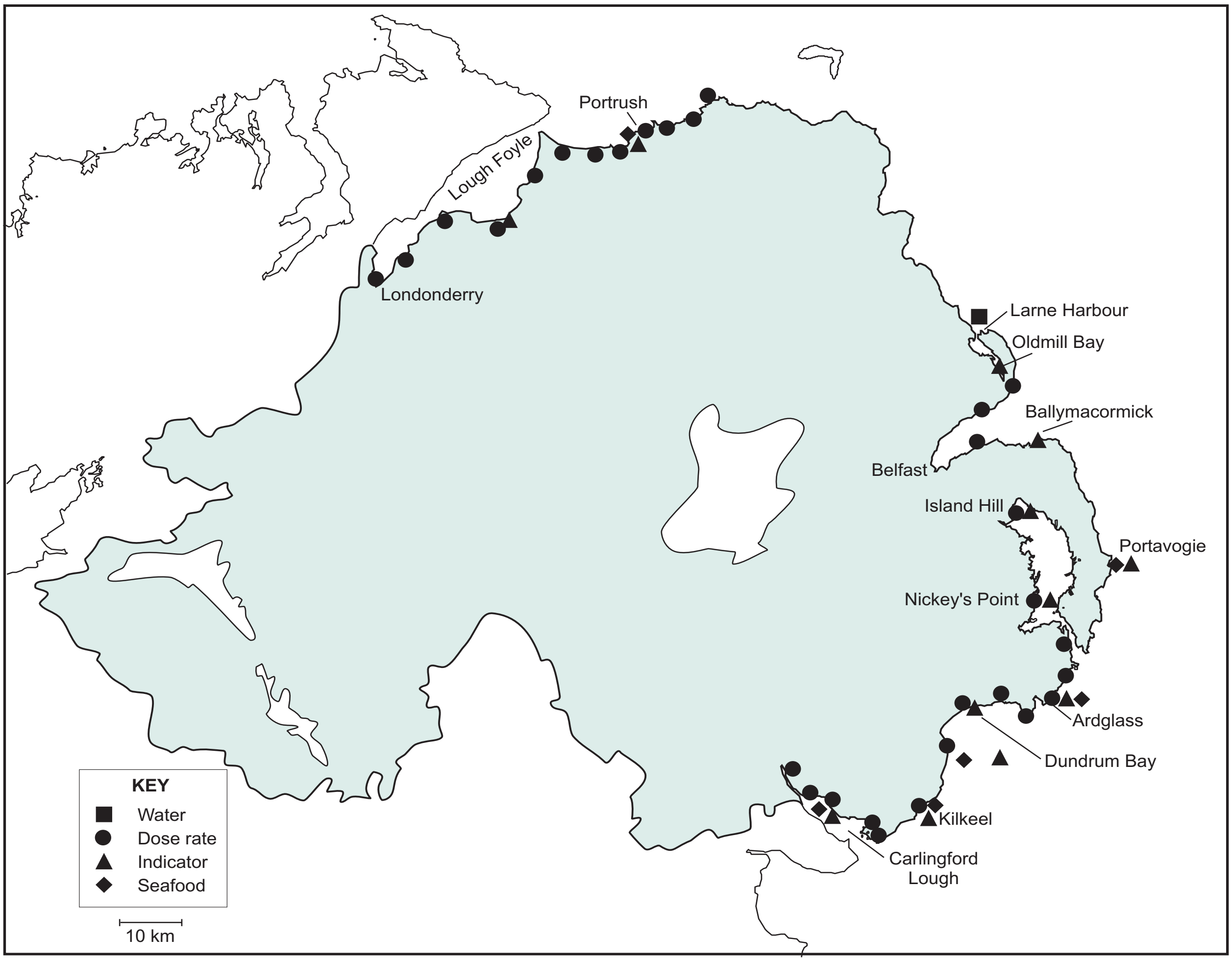

Figure 11.1 Monitoring locations in Northern Ireland

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 2002 was 0.012 mSv, which is less than 2% of the dose limit for members of the public.

11.5 General diet

As part of the Government's general responsibility for food safety, radioactivity in whole diet is determined on a regional basis. Measurements are made on samples of mixed diet from regions throughout the UK. Most samples are derived from the Food Standards Agency's Total Diet Study (TDS). The design of the UK Total Diet Study has been described in detail elsewhere, but basically involves 119 categories of food combined into 20 groups of similar foods for analysis (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al.*, 1983). The relative importance of each food category within a group reflects its importance in the diet and is based on an average of three previous years of consumption data from the National Food Survey (Ministry of Agriculture, Fisheries and Food, 1998). Foods are grouped so that commodities known to be susceptible to contamination (e.g. offals, fish) are kept separate, as are foods which are consumed in large quantities (e.g. bread, potatoes, milk) (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al.*, 1983). These samples are analysed for a range of food components 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 2002. The results are provided in Tables 11.5 and 11.6.

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 11.5 and 11.6 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 11.7. The most important man-made radionuclides were strontium-90 derived from weapons test fallout, and sulphur-35. The nationwide mean dose for all man-made radionuclides was low at 0.013 mSv. There is an increase from the value of 0.003 mSv in 2001, mostly because of increased concentrations of strontium-90. These are most likely to be due to the normal variability observed in the results from location to location and from year to year.

The mean dose due to consumption of natural radionuclides was 0.24 mSv, similar to the value for 2001. In addition to potassium-40 the most important radionuclides continued to be lead-210 and polonium-210. Other members of the uranium-238 and thorium-232 decay series that were not determined in this year's analytical schedule would also have made significant contributions to the mean dose. Further data for these nuclides is provided by MAFF (1995). 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 less than 10% of the mean dose.

Similar results were found in a survey of radioactivity in canteen meals collected across the UK (Table 11.8) (Seaborne *et al.*, 2003).

11.6 Milk

The programme of milk sampling in the UK continued in 2002. 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 Council, 2003).

Where measurements are comparable, detected activity concentrations of all radionuclides in 2002 were similar to those for previous years. These results are summarised in Table 11.9. Tritium and sulphur-35 results were either very 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 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%.

11.7 Crops, bread and meat

The programme of monitoring natural and man-made radionuclides in crops continued in 2002 (Table 11.10). Tritium activity was close to or below the limit of detection 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 2001.

Sampling of bread and meat continued in Scotland in 2002. The results, presented in Table 11.11, 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 2001.

11.8 Air particulate, rain and freshwater

Monitoring of radioactivity in air and rain took place at seven locations as part of a UK wide monitoring programme of background sampling under the EURATOM Treaty. The results are given in Table 11.12. Caesium-137 concentrations were all below or close to the limits of detection. These levels in air, typical of recent years, remain less than 0.01% of those observed in 1986, the year of the Chernobyl reactor accident. Concentrations of beryllium-7, a naturally occurring radionuclide formed by cosmic ray reactions in the upper atmosphere were detected at similar levels at all sampling locations. Peak air concentrations of this radionuclide tend to occur during spring and early summer as a result of seasonal variations in the mixing of stratospheric and tropospheric air (Environment Agency, 2002a). Tritium concentrations in rainwater were similar to those in 2001. Concentrations in air and rainwater are very low and do not currently merit radiological assessment. Monitoring of air in Glasgow gave less than 2.0 mBq m^{-3} of beta activity.

Sampling and analysis of freshwater throughout the UK continued in 2002 (Figure 11.2). 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 11.13, 11.14 and 11.15, show that concentrations of tritium are all below the EU indicator parameter for tritium of 100 Bq/l. Concentrations of total alpha and total beta are also nearly all below the WHO screening values of 0.1 and 1.0 Bq l^{-1} for total alpha and total beta, respectively. As in 2001, total alpha concentrations in groundwater at Meerbrook Lough in Derbyshire exceeded the WHO screening level. Detailed analysis of these waters has previously shown elevated concentrations of natural uranium arising from local geology (Environment Agency, 2002a).

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

The highest annual dose from consumption of drinking water in the UK was assessed as 0.040 mSv in 2002. This was for water from Lough Neagh, County Antrim and the majority of the dose was from naturally occurring radionuclides. The annual dose from artificial radionuclides in drinking water was much less than 0.005 mSv.

11.9 Seawater surveys

Seawater surveys support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 2000) and provide information which can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). In addition, the distribution of radioactivity in seawater around the British Isles is a significant factor in determining the variation in individual exposures at coastal sites, as seafood is a major contribution to food chain doses. Therefore a programme of monitoring into the distribution of key radionuclides is maintained using research vessels and other means of sampling. Data have been used to examine the long distance transport of activity to the Arctic (Leonard *et al.*, 1998; Kershaw *et al.*, 1999) and to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). The results of the research vessel cruises in 2002 are presented in Figures 11.3 - 11.6. Data from shoreline sampling in the Irish Sea and Scottish waters in 2002 are given in Table 11.16.

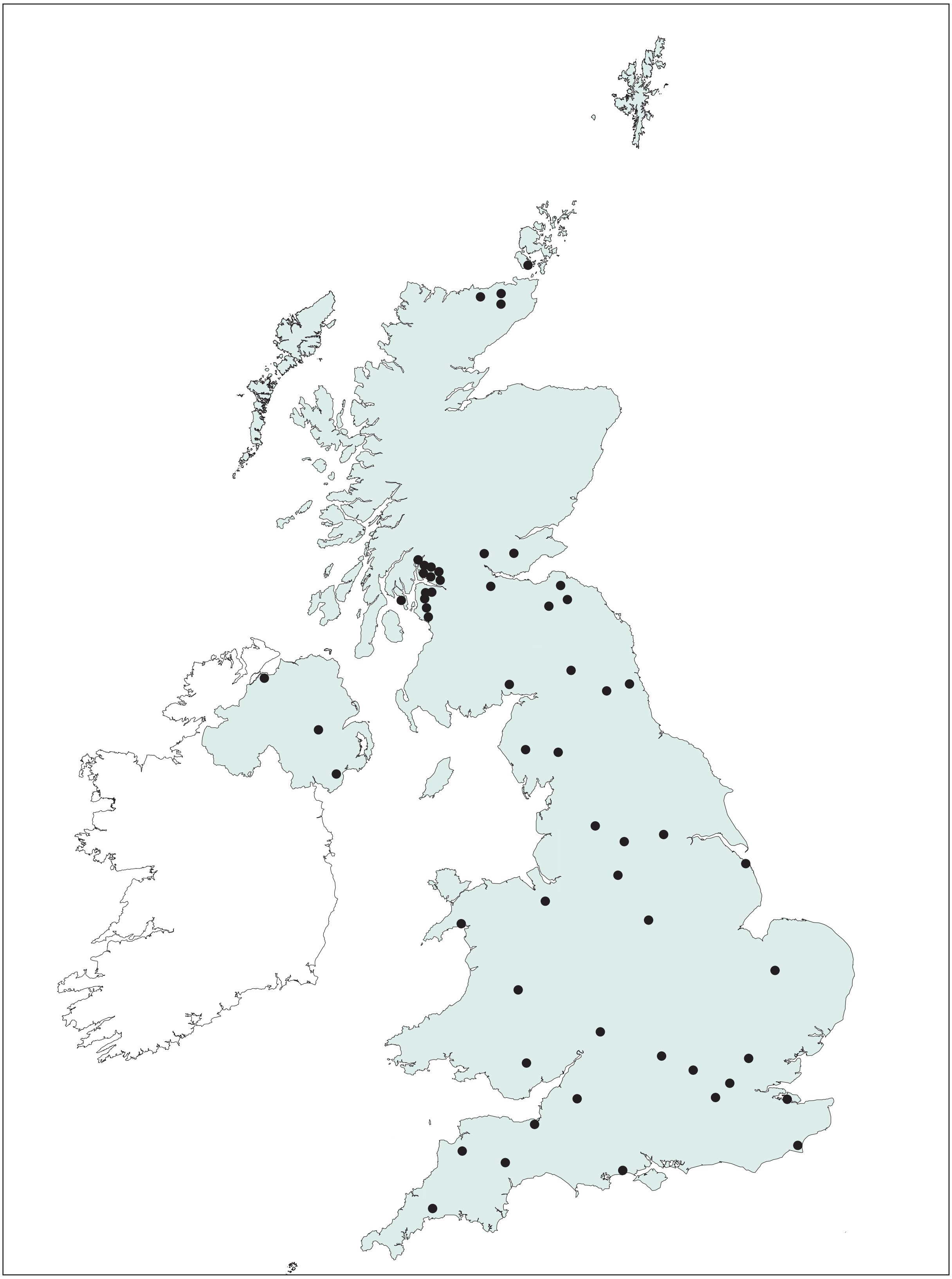

Figure 11.2 Drinking water sampling locations

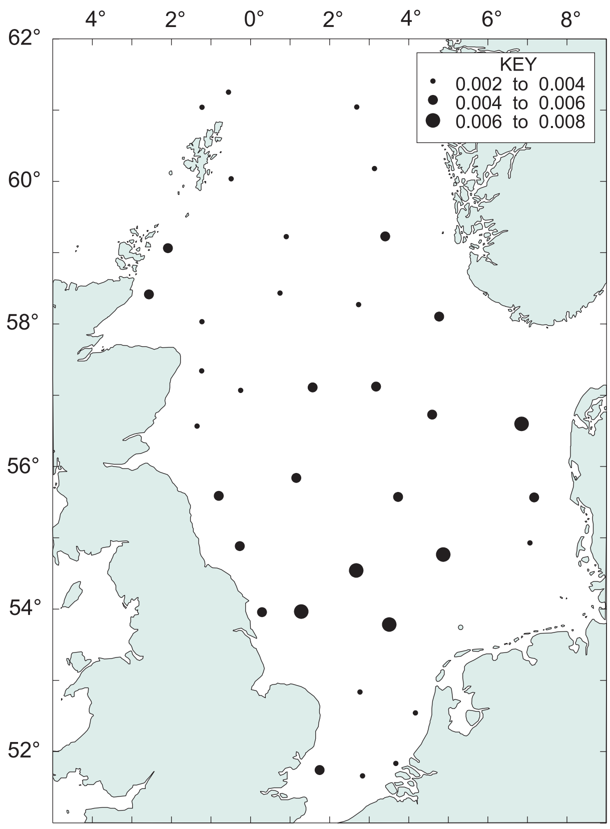

Figure 11.3 ***Concentrations (Bq l⁻¹) of caesium-137 in filtered seawater from the North Sea, August-September 2002***

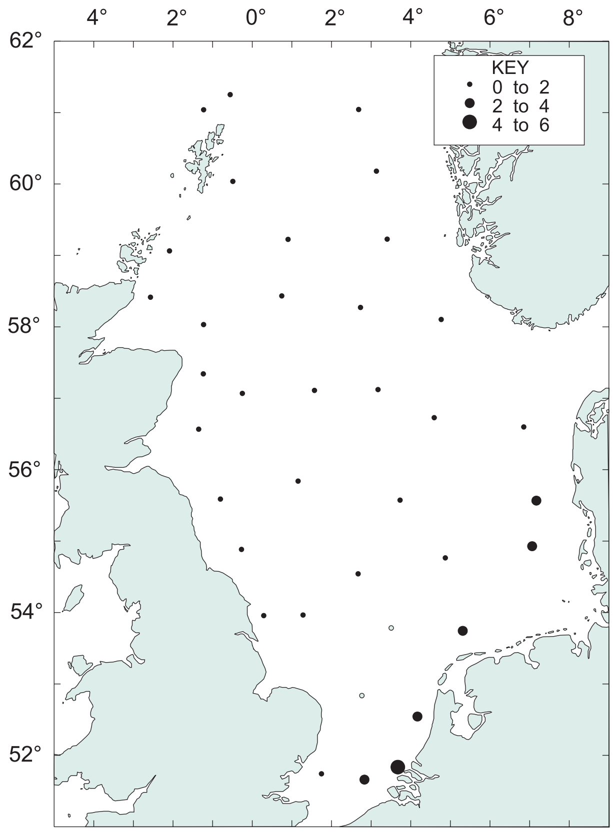

Figure 11.4 ***Concentrations (Bq l⁻¹) of tritium in surface water from the North Sea, August-September 2002***

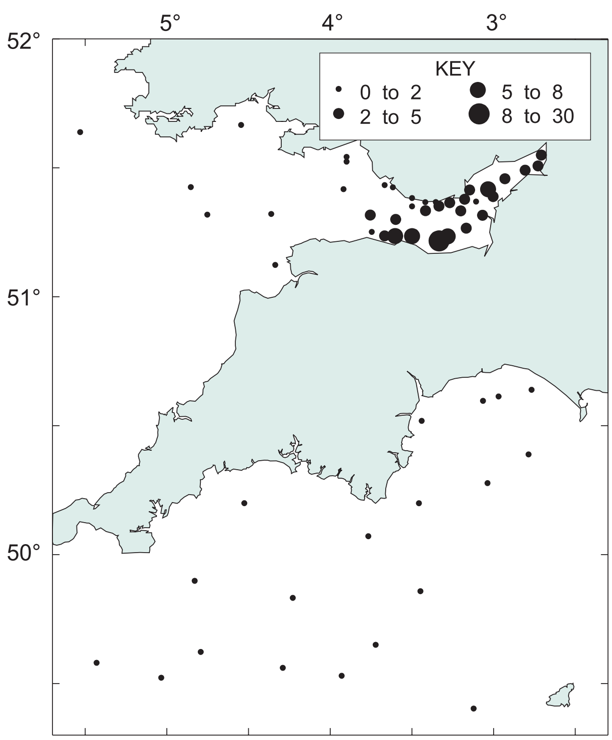

Figure 11.5 ***Concentrations (Bq l⁻¹) of tritium in surface water from the Bristol Channel and western English Channel, September-October 2002***

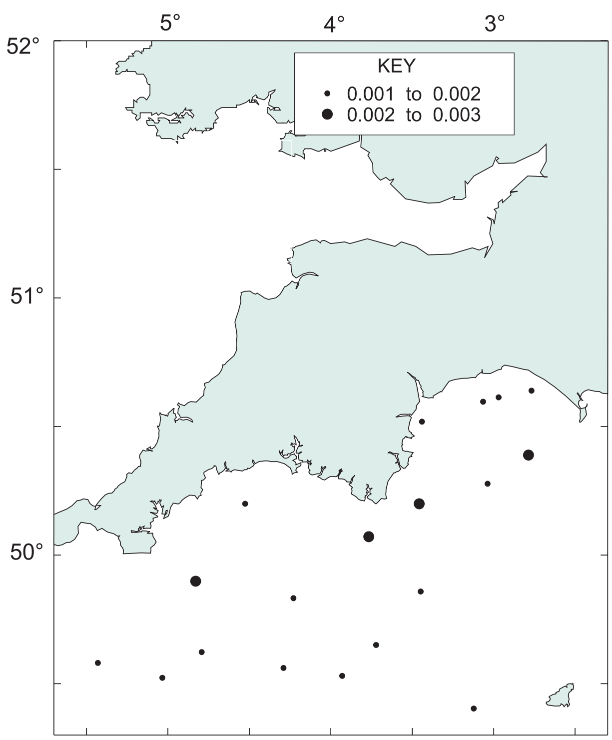

Figure 11.6 ***Concentrations (Bq l⁻¹) of caesium-137 in filtered seawater from the western English Channel, September-October 2002***

Concentrations of caesium-137 typical of (i) the north-eastern Irish Sea and (ii) northern Scottish waters and the North Sea are of the order of 0.05 – 0.5 Bq l^{-1} and 0.002 – 0.02 Bq l^{-1}, respectively. The 2002 data for the North Sea show similar levels to those observed from sampling in recent years, the general distribution throughout UK waters being one of falling concentrations as the distance from Sellafield increases. This distribution is governed by the effects of activity previously discharged which has become associated with seabed sediments but is now being remobilised into the water column, and to a lesser extent, recent discharges from the Sellafield site. The concentrations now observed are only a small percentage of those prevailing in the late 1970s, typically up to 30 Bq l^{-1} (Baxter *et al.*, 1992), when discharges were substantially higher.

The concentrations of tritium observed in the North Sea (Figure 11.4) were generally lower than those observed in the Irish Sea (Food Standards Agency and Scottish Environment Protection Agency, 2002) due to the influence of discharges from Sellafield and other nuclear sites. In the Bristol Channel, the extent of the combined effects of discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is evident (Figure 11.5).

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, 2001a) 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 (2000).

Measurements of beta and potassium-40 activity in water from the Clyde in 2002 gave results of less than 780 and less than 2600 mBq kg^{-1} respectively. These concentrations are similar to those for 2001.

Table 11.1. Concentrations of radiocaesium in the freshwater environment, 2002

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Branthwaite	Rainbow trout	1	<0.07	0.21
Narborough[b]	Rainbow trout	1	<0.06	0.18
Ennerdale Water	Water	1	*	0.002
Devoke Water	Brown trout	1	<0.34	5.9
Devoke Water	Perch	1	0.62	190
Devoke Water	Water	1	*	0.01
Gilcrux	Rainbow trout	1	<0.09	<0.10
Scotland				
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 38, 0.000022, 0.000065 and 0.00012 Bq kg^{-1}(wet) respectively*

Table 11.2. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs
Mackerel	Guernsey	2				<0.13			<1.3		0.24
Pollack	Jersey	2				<0.05			<0.43		0.26
Bass	Jersey	1				<0.05			<0.49		0.32
Edible crabs	Jersey	1				<0.04			<0.33		<0.03
Edible crabs	Alderney	2	<25	<25	27	<0.20		0.28	<1.3		<0.12
Spiny spider crab	Jersey	1				0.44			<0.59		<0.06
Spiny spider crab	Alderney	2				0.73			<1.1		<0.09
Lobsters	Guernsey	1				<0.05			<0.50		<0.05
Lobsters	Jersey	1				<0.12		2.4	<1.1		<0.10
Lobsters	Alderney	1				<0.14			<1.3		<0.12
Oysters	Jersey	1				0.07			<0.32		<0.03
Limpets	Guernsey	1				<0.06			<0.53		<0.05
Limpets	Jersey										
	La Rozel	1				<0.07			<0.51		<0.05
Toothed winkle	Alderney	1	<25	<25	24	0.56	<0.21		<1.3		0.13
Scallops	Guernsey	2				<0.06			<0.51		<0.05
Scallops	Jersey	1				<0.06			<0.48		0.04
Ormers	Guernsey	1				<0.06			<0.54		<0.05
Porphya	Guernsey										
	Fermain Bay	4				<0.11			<0.89		<0.07
Porphya	Jersey										
	Plemont Bay	4				<0.06			<0.67		<0.03
Porphya	Alderney										
	Quenard Point	4				<0.07			<0.76		<0.06
Fucus vesiculosus	Jersey										
	La Rozel	4				0.28	<0.036	5.3	<0.45		<0.06
Fucus vesiculosus	Alderney										
	Quenard Point	2								0.49	
Fucus serratus	Guernsey										
	Fermain Bay	4				0.14	<0.024	2.4	<0.40		<0.04
Fucus serratus	Alderney										
	Quenard Point	4				0.20	0.024	1.9	<0.39		<0.04
Laminaria digitata	Jersey										
	Verclut	4				<0.05			<0.41		<0.04
Mud	Guernsey										
	St. Sampson's Harbour	1				2.1			<1.9		2.5
Mud	Jersey										
	St Helier	1				6.6			<2.9		3.7
Sand	Alderney										
	Lt. Crabbe Harbour	1				0.23			<1.6		1.8
Seawater	Guernsey	4									0.002
Seawater	Jersey	1									0.001
Seawater	Alderney										
	East	4		3.3							<0.002

Table 11.2. 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	Total beta
Mackerel	Guernsey	2	0.00080	0.0037	0.0066	<0.000027	0.000064	110
Pollack	Jersey	2			<0.14			120
Bass	Jersey	1	0.000073	0.00031	0.00056	*	*	89
Edible crabs	Jersey	1	0.00020	0.00041	0.0017	0.000035	0.00023	81
Edible crabs	Alderney	2	0.00096	0.0030	0.0062	<0.000019	0.00042	62
Spiny spider crab	Jersey	1			<0.31			59
Spiny spider crab	Alderney	2	0.0014	0.0028	0.0055	<0.00015	0.00075	53
Lobsters	Guernsey	1			<0.14			49
Lobsters	Jersey	1	0.00041	0.00087	0.0024	*	0.00029	86
Lobsters	Alderney	1	0.00032	0.00073	0.0061	*	0.0013	55
Oysters	Jersey	1	0.0027	0.0068	0.0070	0.000035	0.0011	74
Limpets	Guernsey	1			<0.16			59
Limpets	Jersey							
	La Rozel	1	0.0019	0.0050	0.0070	*	0.0010	57
Toothed winkle	Alderney	1	0.013	0.034	0.040	0.00050	0.0061	47
Scallops	Guernsey	2	0.00069	0.0031	0.0025	*	0.00021	94
Scallops	Jersey	1	0.0027	0.0068	0.0072	0.000014	0.00092	110
Ormers	Guernsey	1			<0.26			55
Porphya	Guernsey							
	Fermain Bay	4	0.0076	0.031	0.047	<0.00011	0.0018	140
Porphya	Jersey							
	Plemont Bay	4			<0.09			100
Porphya	Alderney							
	Quenard Point	4			<0.12			99
Fucus vesiculosus	Jersey							
	La Rozel	4	0.0089	0.021	0.0060	0.000038	0.00089	170
Fucus vesiculosus	Alderney							
	Quenard Point	2						
Fucus serratus	Guernsey							
	Fermain Bay	4	0.0053	0.019	0.0072	0.000034	0.0010	180
Fucus serratus	Alderney							
	Quenard Point	4	0.0049	0.016	0.0054	<0.0000074	0.00082	150
Laminaria digitata	Jersey							
	Verclut	4			<0.11			220
Mud	Guernsey							
	St. Sampson's Harbour	1	0.25	0.78	1.0	0.0043	0.13	500
Mud	Jersey							
	St Helier	1	0.78	2.2	3.7	0.015	0.52	540
Sand	Alderney							
	Lt. Crabbe Harbour	1			<0.70			450

** Not detected by the method used*
[a] Except for seawater where units are Bq l^{-1} and for sediment where dry concentrations apply

Table 11.3. Concentrations of radionuclides in food and the environment from the Isle of Man, 2002[c]

Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
		^{60}Co	^{65}Zn	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Aquatic samples											
Cod	4	<0.06			1.5	0.00011	0.00056	0.0077	0.000020	*	
Herring	4	<0.08			0.86	0.000056	0.00030	0.00045	*	*	
Lobsters	4	<0.05	<0.11	180	0.37			<0.19			200
Scallops	4	<0.08	<0.12		0.31	0.014	0.078	0.065	0.00022	0.00015	
Fucus vesiculosus	4	<0.17	<0.38	1000	1.2			<0.33			930

Material or selection[b]		No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{129}I	Total Cs	^{147}Pm	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples															
Milk		2	<3.8	20	<0.48	<0.28	0.036		<0.026	0.082	<0.20	<0.00020	<0.00020	<0.044	<0.00020
Milk	max		<4.0	23	<0.50	<0.30	0.043			0.086					
Cabbage		1	<4.0	14	1.0	<0.30	0.12	<0.028	<0.037	0.14	<0.40	<0.00020	<0.00030	<0.073	<0.00030
Potatoes		1	9.0	10	0.50	<0.20	<0.015	<0.031	<0.046	0.12	<0.20	<0.00030	<0.00030	<0.082	<0.00040
Strawberries		1	<3.0	7.0	0.30	<0.20	0.20			<0.027					

** 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 1 m over sand at Douglas was 0.080 µGy h^{-1}

Table 11.4(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2002

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Cod	Kilkeel	4	36	<0.05		2.2			<0.35		
Cod	Portrush	4		<0.07		1.6			<0.11		
Haddock	Portavogie	4		<0.06		1.2			<0.19		
Whiting	Kilkeel	4		<0.06		2.4					
Whiting	Portavogie	3		<0.06		2.7	0.0010	0.0067	0.012	0.000026	0.000022
Herring	Ardglass	4		<0.08		0.77			<0.25		
Spurdog	Portavogie	4		<0.08		2.1			<0.22		
Spurdog	Portrush	4		<0.09		2.1			<0.21		
Crabs	Kilkeel	3		<0.11		0.27			<0.18		
Lobsters	Kilkeel	4	27	<0.09	130	0.33			<0.15		
Lobsters	Portrush	4		<0.17	120	0.36			<0.19		
Nephrops	Kilkeel	4		<0.12		0.87			<0.23		
Nephrops	Portavogie	4	25	<0.11	39	1.1	0.0044	0.027	0.20	*	*
Winkles	Ards Peninsula	4		<0.10		<0.30	0.030	0.16	0.19	0.00044	0.00018
Mussels	Carlingford Lough	2	20	<0.12	37	0.46			<0.32		
Fucus vesiculosus	Ardglass	4	17	<0.15	590	0.60			<0.28		
Fucus vesiculosus	Portrush	1		<0.10		0.20			<0.40		
Fucus serratus	Portrush	2		<0.11		<0.19			<0.27		
Rhodymenia spp.	Strangford Lough	4		<0.11	24	0.54	0.058	0.31	0.38	*	*
Fucus spp.	Carlingford Lough	2		<0.22	440	0.83			<0.79		
Mud	Lough Foyle	1		<0.34		2.0	0.033	0.24	0.34	*	*
Mud	Ballymacormick	2		<0.43		25	1.9	10	15	0.042	0.027
Mud	Strangford Lough-Nickey's point	2		<0.56		39	1.6	8.6	8.7	*	0.015
Mud	Dundrum Bay	1		<0.69		5.7			<2.9		
Mud	Carlingford Lough	2		<0.76		55	1.7	11	7.4	*	0.0076
Mud	Oldmill Bay	2		<0.63		40	2.3	12	21	0.061	0.046
Mud and sand	Dundrum Bay	1		<0.25		4.9			<1.4		
Shell and sand	Lough Foyle	1		<0.29		1.5			0.34		
Sand	Portrush	2		<0.28		0.99			<0.87		
Seawater	North of Larne	12			0.021	0.01					

** Not detected by the method used*
[a] Except for sediment where dry concentrations apply and for seawater where units are Bq l^{-1}

Table 11.4(b). Monitoring of radiation dose rates in Northern Ireland, 2002

Location	Ground type	No. of sampling observa-tions	Mean gamma dose rate in air at 1m, $\mu Gy\ h^{-1}$
Northern Ireland			
Narrow Water	Mud	1	0.10
Rostrevor	Sand	1	0.12
Mill Bay	Mud	1	0.10
Greencastle	Sand	1	0.093
Cranfield Bay	Sand	1	0.091
Annalong	Sand	1	0.11
Newcastle	Sand	1	0.10
Dundrum	Mud	1	0.096
Tyrella	Sand	1	0.085
Rossglass	Sand	1	0.080
Killough	Mud	1	0.091
Ardglass	Mud	1	0.10
Kilclief	Sand	1	0.098
Strangford	Stones	1	0.10
Nickey's Point	Mud	1	0.093
Island Hill	Mud	1	0.088
Belfast Lough	Sand	1	0.067
Carrickfergus	Sand	1	0.074
Whitehead	Sand	1	0.068
Giant's Causeway	Sand	1	0.063
Portballintrea	Sand	1	0.057
White Rocks	Sand	1	0.064
Portrush	Sand	1	0.067
Portstewart	Sand	1	0.065
Castlerock	Sand	1	0.066
Benone	Sand	1	0.074
Bellerena	Mud	1	0.064
Carrichue House	Mud	1	0.066
Eglington	Stones	1	0.063
Lishally	Mud	1	0.075

Table 11.5. Concentrations of radionuclides in general diet (TDS survey), 2002[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	South Shields	1	54	52	<0.27	66	0.49	<0.05	0.28	0.079
Northern	Whitehaven	1	10	52	<0.27	70	0.42	<0.07	0.19	0.050
Northern	Normanton	1	<1.7	36	7.8	69	0.20	<0.04	0.13	0.14
Central	Chester	1	21	50	<0.19	84	0.44	<0.05	0.060	<0.022
Central	Matlock	1	3.8	28	<0.17	66	1.0	<0.05	0.10	<0.029
Central	Peterborough	1	2.5	39	<0.24	75	0.62	<0.05	0.046	0.046
Southern	Bodmin	1	2.6	32	<0.25	67	1.1	<0.07	0.17	0.092
Southern	Eastleigh	1	<2.9	64	0.65	67	0.82	0.03	0.11	0.039
Southern	Eastbourne	1	3.9	66	0.34	71	0.87	0.02	0.080	<0.024
Wales	Rhondda	1	<1.7	47	0.80	76	0.84	<0.03	0.20	0.35
Northern Ireland	Londonderry	1	2.4	74	0.86	75	1.0	<0.05	0.13	<0.018
Scotland	Dingwall	1	<20	23	<1.0		0.14	<0.40	<0.018	0.025
Scotland	Livingston	1	<20	30	<1.0		0.099	<0.40	<0.049	0.020
Mean			<11	46	<1.1	71	0.62	<0.10	<0.12	<0.072

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	South Shields	1	0.052	0.0013	0.034	<0.00036	0.00022	<0.00049
Northern	Whitehaven	1	0.029	0.0011	0.024	<0.00016	<0.00016	<0.00074
Northern	Normanton	1	0.052	0.00077	0.029	0.00014	0.00023	<0.00025
Central	Chester	1	0.025	0.00064	<0.023	0.00015	0.00014	<0.00020
Central	Matlock	1	0.029	0.00084	<0.020	0.000063	0.000089	<0.00020
Central	Peterborough	1	0.032	0.00067	<0.022	0.000087	0.00017	<0.00030
Southern	Bodmin	1	0.036	<0.0021	0.030	<0.00039	0.00011	<0.00028
Southern	Eastleigh	1	0.030	0.00072	0.056	0.00010	0.000095	0.00021
Southern	Eastbourne	1	0.033	0.0022	<0.022	0.00014	0.00012	0.00028
Wales	Rhondda	1	0.035	0.0011	<0.022	0.00013	0.00017	0.00019
Northern Ireland	Londonderry	1	0.049	0.0010	0.10	0.000073	0.00014	0.00025
Scotland	Dingwall	1	0.077	<0.010	<0.050	0.0094	0.018	<0.0012
Scotland	Livingston	1	0.13	<0.010	<0.050	0.00082	0.0011	<0.0021
Mean			0.047	<0.0025	<0.037	<0.00092	<0.0016	<0.00051

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

Table 11.6. Concentrations of radionuclides in regional diet in Scotland, 2002

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	<10	<0.73	80	<0.10	<0.05
East Lothian (North Berwick)	12	<4.9	<0.88	86	<0.10	<0.05
Highland (Dingwall)	12	<5.3	<1.5	90	<0.10	<0.08
Renfrewshire (Paisley)	12	<5.9	<1.1	82	<0.10	<0.05

Table 11.7. Estimates of radiation exposure from radionuclides in regional diet, 2002

Nuclide[a]	Exposure, mSv[b]
Man-made radionuclides	
Tritium	0.0003
Sulphur-35	0.001
Strontium-90	0.01
Caesium-137	0.0002
Plutonium-238	0.00007
Plutonium-239+240	0.0001
Americium-241	0.00004
Sub-total	0.013
Natural radionuclides	
Carbon-14	0.01
Lead-210	0.08
Polonium-210	0.1
Radium-226	0.009
Uranium	0.001
Thorium-232	0.0002
Sub-total	0.23
Total	0.24

[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 11.8. Concentrations of radionuclides in canteen meals, 2002[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	40	110	0.28	<0.08	<0.026
Northern Ireland	4	42	85	0.13	<0.06	0.026
Scotland	4	37	89	0.19	<0.07	<0.024
Wales	4	31	93	0.15	<0.05	<0.026

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

Table 11.9. Concentrations of radionuclides in milk remote from nuclear sites, 2002

Location	Selection[a]	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs
Co. Antrim		6				0.023	0.17
Co. Armagh		5	<3.5	16		0.024	0.080
Cambridgeshire		12	<3.0	13		0.019	0.050
Cheshire		12	<3.5	12		0.019	0.088
Clwyd		12	<4.0	20		0.026	0.063
Cornwall		12	<3.5	18		0.035	0.062
Devon		12	<3.5	21		0.035	0.074
Co. Down		6				0.028	0.094
Co. Fermanagh		6				0.028	0.12
Gloucestershire		24	<3.8	10		<0.023	0.052
	max		<4.0	11		<0.025	0.056
Guernsey		7	<2.0	12		0.028	0.041
Gwent		12	<2.1	12		0.029	0.056
	max			15		0.033	0.081
Gwynedd		13	<4.0	15		0.031	0.067
Hampshire		12	<4.0	11		0.024	0.045
Humberside		12	<4.0	8.5		0.022	0.057
Kent		2				0.0085	0.048
Kirkudbrightshire		11	<7.1	<15	<0.52	<0.10	<0.062[b]
Lanarkshire		12	<4.9	<16	<2.0	<0.10	<0.055[b]
Lancashire		12	<3.5	16		0.024	0.085
Leicestershire		12	<4.0	7.5		0.017	<0.050
Lincolnshire		12	<4.0	13		<0.018	<0.034
Middlesex		12	<4.0	12		0.020	0.052
Midlothian		11	<5.2	<14	<1.1	<0.10	<0.050[b]
Nairnshire		12	<4.5	<16	<0.48	<0.10	<0.063[b]
Norfolk		12	<3.5	14		0.016	0.052
Oxfordshire		10	<4.0	17		0.018	0.050
Renfrewshire		12	<5.8	<17	<2.9	<0.10	<0.057[b]
Shropshire		12	<4.0	19		0.028	0.059
Somerset		12	<6.5	10		0.027	0.069
Suffolk		12	<4.0	16		<0.010	0.050
Tyneside		12	<3.5	14		0.029	0.059
Co. Tyrone		18	<2.3	17		0.026	0.12
Yorkshire, North Riding		24	<3.8	12		0.022	0.062
	max		<4.0	13			0.054
Mean Values							
Channel Isles			<2.0	12		0.028	0.041
England			<3.7	13		<0.022	<0.058
Northern Ireland			<2.4	17		0.026	0.12
Wales			<2.6	13		0.029	0.062
Scotland			<5.5	<16	<1.4	<0.10	<0.058
United Kingdom			<4.2	<14	<1.4	<0.035	<0.065

[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] *^{137}Cs only*

Table 11.10. Concentrations of radionuclides in crops remote from nuclear sites, 2002[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
Buckinghamshire									
Denham	Lettuce	1	<4.0	12		<0.017	<0.029	0.12	0.027
	Raspberries	1	4.0	<3.0		0.11	<0.037	0.19	<0.014
Channel Isles									
Guernsey	Chard	1	3.0	6.0		0.28	<0.030	0.31	0.079
	Raspberries	1	<4.0	7.0		0.050	<0.027	0.056	0.027
Cornwall									
Bude	Potatoes	1	<4.0	10		0.039	0.052	0.075	<0.0040
	Strawberries	1	<3.0	5.0		0.10	<0.026	0.083	<0.011
Camborne	Cabbage	1	<3.0	5.0		0.072	0.029	<0.046	<0.0030
	Potatoes	1	<4.0	13		0.035	0.041	<0.038	0.017
Dorset									
Shaftesbury	Raspberries	1	<4.0	13		0.042	0.058	0.060	0.018
	Spinach	1	<4.0	9.0		0.18	<0.025	0.29	0.14
Dumfriesshire									
Dumfries	Lettuce	4	<4.4	<12	<0.51	<0.10	<0.050[b]		
East Lothian									
North Berwick	Lettuce	4	<5.0	<13	<0.56	<0.10	<0.050[b]		
Essex									
Saffron Walden	Cabbage	1	<4.0	8.0		0.62	0.030	0.35	0.12
	Potatoes	1	<4.0	22		0.028	0.039	<0.030	0.011
Hampshire									
St Mary Bourne	Cabbage	1	<3.0	<3.0		0.28	<0.027	0.19	0.019
	Potatoes	1	<4.0	20		0.034	<0.029	<0.046	0.0064
Lancashire									
Warrington	Cabbage	1	<3.0	3.0		0.50	0.10	<0.035	0.024
	Potatoes	1	<4.0	16		0.033	0.055	<0.061	<0.0030
Lincolnshire									
Boston	Cabbage	1	<4.0	<3.0		0.065	<0.036	0.069	<0.0020
	Potatoes	1	6.0	6.0		<0.013	<0.028	<0.034	<0.0090
Northumberland									
Berwick	Cabbage	1	<3.0	14		0.066	0.041	<0.036	<0.0020
	Potatoes	1	<4.0	38		<0.011	<0.026	<0.029	0.0049
Corbridge	Cabbage	1	4.0	7.0		0.47	<0.034	<0.036	0.083
	Raspberries	1	5.0	12		0.027	<0.032	<0.038	0.019
Pembrokeshire									
St David's	Cabbage	1	5.0	6.0		0.56	<0.027	0.16	0.036
	Potatoes	1	<4.0	13		0.037	0.045	<0.040	0.0067
Renfrewshire									
Paisley	Lettuce	4	<4.4	<13	<0.50	<0.10	<0.050[b]		
Ross-shire									
Dingwall	Lettuce	4	<5.5	<13	<0.50	<0.10	<0.050[b]		
Somerset									
Taunton	Potatoes	1	<4.0	22		0.049	0.057	0.058	<0.0080
	Runner Beans	1	<3.0	7.0		0.088	<0.027	<0.034	0.013
Suffolk									
Needham Market	Calabrese	1	<4.0	2.0		0.14	0.065	0.45	0.087
	Strawberries	1	3.0	9.0		<0.013	<0.026	<0.035	0.0064
Worcestershire									
Kings Norton	Beetroot/Carrots	1	<3.0	8.0		0.041	<0.026	<0.035	0.013
	Lettuce	1	3.0	<3.0		0.16	0.064	0.076	0.062
Pershore	Cabbage	1	<4.0	9.0		0.21	0.056	0.080	0.029
	Raspberries	1	5.0	13		0.080	<0.023	0.10	0.022
Wrexham									
Holt	Cabbage	1	<3.0	13		0.20	0.098	0.060	0.040
	Loganberries/ Tayberries	1	<3.0	17		0.12	<0.026	0.081	0.033
Yorkshire, East Riding									
Bridlington	Chard	1	<4.0	7.0		0.28	0.041	0.61	0.15
	Raspberries	1	<3.0	14		0.059	<0.033	<0.034	0.024
Yorkshire, North Riding									
Middlesbrough	Cabbage	1	<3.0	9.0		0.44	0.068	0.25	0.076
	Potatoes	1	<4.0	12		0.062	0.060	<0.031	0.0052
Yorkshire, West Riding									
Sheffield	Cabbage	1	<3.0	8.0		0.52	<0.028	0.23	0.078
	Parsnips/Turnips	1	<4.0	9.0		0.23	<0.028	<0.032	0.029
Mean Values									
Channel Isles			<3.5	6.5		0.16	<0.029	0.18	0.053
England			<3.8	<10		<0.15	<0.041	<0.11	<0.034
Wales			<3.8	12		0.23	<0.049	<0.085	0.029
Scotland			<4.9	<13	<0.52	<0.10	<0.050		
Great Britain			<4.1	<11	<0.52	<0.14	<0.044	<0.11	<0.033

Table 11.10. 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
Buckinghamshire									
Denham	Lettuce	1	0.0090	<0.0011	<0.033	<0.00010	0.00020	<0.00010	
	Raspberries	1	0.0040	0.0013	<0.023	0.00020	<0.00020	0.00040	
Channel Isles									
Guernsey	Chard	1	0.068	0.0041	<0.031	0.00010	0.00020	<0.00020	
	Raspberries	1	0.0050	0.0010	<0.026	0.00010	<0.00020	<0.00030	
Cornwall									
Bude	Potatoes	1	0.0080	0.0026	<0.031	<0.00010	0.00010	0.00020	
	Strawberries	1	0.020	0.0030	<0.018	<0.00020	0.00010	<0.00040	
Camborne	Cabbage	1	0.012	<0.0012	<0.032	<0.00010	<0.00020	0.00030	
	Potatoes	1	0.012	0.0086	0.053	<0.00020	<0.00020	0.00020	
Dorset									
Shaftesbury	Raspberries	1	0.011	<0.0031	<0.031	0.00010	<0.00010	<0.00040	
	Spinach	1	0.14	0.0066	<0.047	<0.00010	0.00030	<0.00020	
Dumfriesshire									
Dumfries	Lettuce	4							<0.18
East Lothian									
North Berwick	Lettuce	4							<0.15
Essex									
Saffron Walden	Cabbage	1	0.024	0.013	0.061	<0.00020	0.00040	<0.00080	
	Potatoes	1	0.0070	0.0010	<0.029	<0.00030	<0.00020	<0.00020	
Hampshire									
St Mary Bourne	Cabbage	1	0.0080	0.0018	<0.025	0.00010	0.00010	<0.00040	
	Potatoes	1	0.011	0.0018	<0.032	<0.00010	0.00010	<0.00040	
Lancashire									
Warrington	Cabbage	1	0.018	0.0020	<0.034	<0.00020	<0.00020	<0.00030	
	Potatoes	1	0.0040	<0.00060	<0.028	<0.00020	<0.00020	0.00030	
Lincolnshire									
Boston	Cabbage	1	0.0080	<0.00060	<0.026	<0.00020	0.00010	0.00010	
	Potatoes	1	0.010	0.0046	<0.025	<0.00010	<0.00010	<0.00020	
Northumberland									
Berwick	Cabbage	1	0.0060	<0.0014	<0.029	<0.00030	<0.00030	<0.00020	
	Potatoes	1	<0.0030	<0.0011	<0.030	<0.00020	<0.00020	<0.00020	
Corbridge	Cabbage	1	0.062	<0.0010	<0.033	<0.00020	<0.00020	<0.00020	
	Raspberries	1	0.012	0.00070	<0.031	<0.00020	<0.00030	<0.00030	
Pembrokeshire									
St David’s	Cabbage	1	0.044	0.0014	<0.030	<0.00020	<0.00030	<0.00030	
	Potatoes	1	0.010	0.0029	<0.027	<0.00020	<0.00020	0.00020	
Renfrewshire									
Paisley	Lettuce	4							<0.21
Ross-shire									
Dingwall	Lettuce	4							<0.22
Somerset									
Taunton	Potatoes	1	0.0090	0.0059	<0.028	<0.00010	0.00020	<0.00030	
	Runner Beans	1	0.010	0.0029	<0.032	<0.00020	0.00020	0.00040	
Suffolk									
Needham Market	Calabrese	1	0.013	0.0023	<0.042	<0.00030	<0.00010	0.00050	
	Strawberries	1	0.017	<0.00090	<0.022	<0.00010	0.00010	<0.00020	
Worcestershire									
Kings Norton	Beetroot/Carrots	1	0.016	0.0066	<0.031	<0.00020	<0.00020	0.00020	
	Lettuce	1	0.019	0.022	0.12	<0.00020	<0.00020	<0.00030	
Pershore	Cabbage	1	<0.0040	<0.0021	<0.031	0.00010	<0.00020	<0.00060	
	Raspberries	1	0.016	<0.0016	<0.029	<0.00040	<0.00030	<0.00030	
Wrexham									
Holt	Cabbage	1	0.0070	<0.0019	<0.032	0.00010	<0.00020	0.00030	
	Loganberries/ Tayberries	1	0.023	0.0012	<0.023	<0.00020	<0.00020	<0.00030	
Yorkshire, East Riding									
Bridlington	Chard	1	0.050	0.013	0.035	0.00030	0.00020	<0.00030	
	Raspberries	1	0.0040	<0.00090	<0.028	0.00010	<0.00020	0.00080	
Yorkshire, North Riding									
Middlesbrough	Cabbage	1	0.046	<0.00080	0.060	<0.00010	0.00010	<0.00030	
	Potatoes	1	0.012	0.0024	<0.031	<0.00020	0.00010	<0.00020	
Yorkshire, West Riding									
Sheffield	Cabbage	1	0.035	0.0026	<0.034	<0.00020	0.00010	<0.00030	
	Parsnips/Turnips	1	0.024	0.0030	<0.030	0.00020	0.00020	<0.00040	
Mean Values									
Channel Isles			0.037	0.0026	<0.029	0.00010	<0.00020	<0.00025	
England			<0.020	<0.0036	<0.035	<0.00018	<0.00018	<0.00032	
Wales			0.021	<0.0019	<0.028	<0.00018	<0.00023	<0.00028	
Scotland									<0.19
Great Britain			<0.020	<0.0035	<0.035	<0.00018	<0.00019	<0.00032	<0.19

[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 11.11. Concentrations of radionuclides in bread and meat in Scotland, 2002

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	<4.1	73	<2.4	64	<0.10	<0.05	<0.70
(Dumfries)	Meat	4	<5.4	44	<1.1	93	<0.10	<0.09	<0.24
East Lothian	Bread	4	<5.0	79	<1.6	61	<0.10	<0.05	<0.61
(North Berwick)	Meat	4	<5.0	36	<0.76	90	<0.10	0.10	<0.26
Highland	Bread	4	<5.3	67	<3.4	62	<0.10	<0.05	<0.82
(Dingwall)	Meat	4	<8.0	34	<1.4	87	<0.10	0.12	<0.25
Renfrewshire	Bread	4	<5.0	74	<1.9	80	<0.10	<0.05	<0.60
(Paisley)	Meat	4	<5.0	46	<1.3	75	<0.10	<0.08	<0.22

Table 11.12. Concentrations of radionuclides in rainwater and air 2002

Location	Sample	No. of sampling obser-vations	Mean radioactivity concentration[a] in rainwater and air				
			^{3}H	^{7}Be	^{137}Cs	^{208}Tl	^{210}Pb
Ceredigion							
Aberporth	Rainwater	4	<1.8	0.75	<0.035	*	*
	Air	4		0.0019	<0.00000081	*	0.00011
Co. Down							
Conlig	Rainwater	4		1.1	<0.026	*	*
	Air	4		0.0019	<0.00000086	0.0000010	0.000085
Dumfries and Galloway							
Eskdalemuir	Rainwater	4	<2.2	1.1	<0.018	*	*
	Air	4		0.0014	<0.00000083	0.00000071	0.000086
North Yorkshire							
Dishforth	Rainwater	4		1.5	<0.033	*	*
	Air	4		0.0014	<0.00000083	0.00000089	0.00011
Oxfordshire							
Chilton	Rainwater	4		<1.4	<0.043	*	<1.6
	Air	13		0.0015	<0.00000070	*	<0.00020
Shetland							
Lerwick	Rainwater	4		1.5	<0.029	0.027	*
	Air	4		0.0014	<0.00000074	*	0.000094
Suffolk							
Orfordness	Rainwater	4	<1.8	<1.9	<0.051	*	*
	Air	4		0.0020	<0.00000080	0.0000011	0.00015

Location	Sample	No. of sampling obser-vations	Mean radioactivity concentration[a] in rainwater and air				
			^{210}Po	^{228}Th	^{234m}Pa	$^{239}Pu+^{240}Pu$	^{241}Am
Ceredigion							
Aberporth	Rainwater	4		0.22		<0.0000050	<0.000091
	Air	4		*	*	0.00000000091	<0.00000000050
Co. Down							
Conlig	Rainwater	4		*	*		
	Air	4		*	*		
Dumfries and Galloway							
Eskdalemuir	Rainwater	4		*	*		
	Air	4		*	*		
North Yorkshire							
Dishforth	Rainwater	4		*	<5.2		
	Air	4		*	*		
Oxfordshire							
Chilton	Rainwater	4		*	*		
	Air	13	<0.0000084	0.000019	*		
Shetland							
Lerwick	Rainwater	4		*	*		
	Air	4		*	*		
Suffolk							
Orfordness	Rainwater	4		*	*		
	Air	4		*	0.000098		

** Not detected by the method used*

[a] Bq l^{-1} for rainwater and Bq kg^{-1} for air

Table 11.13. Concentrations of radionuclides in sources of drinking water in Scotland, 2002

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	12	<1.1	<0.0050	<0.0094		
Argyll and Bute	Auchengaich	1	<1.0	<0.0050		<0.010	<0.076
Argyll and Bute	Helensburgh Reservoir	3			<0.010	<0.010	<0.076
Argyll and Bute	Loch Ascog	3			<0.010	<0.011	<0.083
Argyll and Bute	Loch Eck	1	<1.0	0.0075		<0.010	<0.076
Argyll and Bute	Loch Finlas	3			<0.010	<0.010	<0.076
Argyll and Bute	Lochan Ghlas	3			<0.010	<0.010	<0.076
Clackmannanshire	Gartmorn	1	<1.0	<0.0050		<0.015	0.083
Dumfries and Galloway	Purdomstone	1			<0.010	<0.010	<0.076
East Lothian	Hopes Reservoir	1	1.0	<0.0050		<0.018	<0.076
East Lothian	Thorters Reservoir	1	<1.0	<0.0050		<0.010	<0.076
East Lothian	Whiteadder	2			<0.010	<0.010	<0.076
Fife	Holl Reservoir	1	<1.0	<0.0050		<0.010	<0.076
Highland	Loch Baligill	1	<1.0	<0.0050		<0.010	<0.076
Highland	Loch Calder	2			<0.030	<0.010	<0.076
Highland	Loch Glass	12	<1.1	<0.0053	<0.010		
Highland	Loch Shurrerey	1	<1.0	<0.0050		<0.010	<0.076
North Ayrshire	Camphill	1	<1.0	0.0060		<0.010	<0.076
North Ayrshire	Knockendon Reservoir	2			<0.010	<0.010	<0.076
North Ayrshire	Munnoch Reservoir	1	<1.0	0.0063		<0.010	<0.076
North Ayrshire	Outerwards	1	<1.0	0.0050		<0.010	<0.076
Orkney Islands	Heldale Water	1	<1.0	0.0050		<0.012	<0.076
Perth and Kinross	Castlehill	3			<0.010	<0.010	<0.076
Scottish Borders	Knowsdean	10	<1.2	<0.0054	<0.010		
Stirling	Loch Katrine	10	<1.1	<0.0060	<0.010		
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0	0.0050		<0.010	<0.076
West Lothian	Morton No. 2	1	<1.0	<0.0050		<0.010	<0.076

Table 11.14. Concentrations of radionuclides in sources of drinking water in England and Wales, 2002

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	0.031	<0.0014		<0.0010	<0.010
Cheshire	River Dee	4	<4.0	0.13	0.0044	<0.010	<0.0010	<0.010
Cornwall	River Fowey	4	<4.0	0.042	0.0025	<0.010	<0.0010	<0.010
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.058	0.0022		<0.0010	<0.010
County Durham	River Tees	4	<4.0	0.032	<0.0031	<0.010	<0.0010	<0.010
County Durham	Tunstall Reservoir	4	<4.0	0.025	0.0023		<0.0010	<0.010
Cumbria	Haweswater Reservoir	3	<4.0	0.011	0.0017		<0.0010	<0.010
Cumbria	Ennerdale Lake	3	<4.0	0.020	0.0018		<0.0010	<0.010
Derbyshire	Meerbrook Sough groundwater	4	<4.0	0.035	<0.0011		<0.0010	<0.010
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	0.018	<0.0011		<0.0011	<0.010
Devon	River Exe	4	<4.0	0.063	<0.0023	<0.010	<0.0010	<0.010
Gloucestershire	River Severn, Tewkesbury	4	<4.0	0.15	<0.0034	<0.010	<0.0010	<0.010
Greater London	River Lee, Chingford	4	<4.0	0.24	<0.0018	<0.010	<0.0010	<0.010
Hampshire	River Avon, Christchurch	4	<4.0	0.076	<0.0014	<0.010	<0.0010	<0.010
Humberside	Littlecoates, Groundwater	4	<4.0	0.099	0.0019		<0.0010	<0.010
Kent	Denge, Shallow Groundwater	4	<4.0	0.14	<0.0028		<0.0010	<0.010
Kent	Deep Groundwater	4	<4.0	0.032	<0.0013		<0.0010	<0.010
Lancashire	Corn Close, Groundwater	3	<4.0	0.037	<0.0010		<0.0010	<0.010
Norfolk	Stoke-Ferry, River	4	<4.0	0.084	<0.0019	<0.010	<0.0010	<0.010
Northumbria	Kielder Reservoir	4	<4.0	0.014	0.0023		<0.0010	<0.010
Oxfordshire	River Thames, Oxford	4	<4.0	0.14	<0.0015	<0.010	<0.0010	<0.010
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.065	0.0018		<0.0010	<0.010
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.12	0.0024		<0.0010	<0.010
Surrey	River Thames, Walton	4	<4.0	0.18	<0.0023	<0.010	<0.0015	<0.010
Surrey	River Thames, Chertsey	4	<4.0	0.17	0.0020	<0.010	<0.0010	<0.010
Yorkshire	Eccup No.1 Works Inlet	4	<4.0	0.063	<0.0033		<0.0010	<0.010
Yorkshire	Chellow Heights, Bradford	4	<4.0	0.023	0.0031		<0.0010	<0.010
Wales								
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	0.0083	0.0049		<0.0011	<0.010
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	0.015	0.0045		<0.0010	<0.010
Powys	Elan Valley Reservoir	4	<4.0	0.0080	0.0037		<0.0010	<0.010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta[1]	Total beta[2]
England									
Buckinghamshire	Bourne End, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.031	<0.075	<0.066
Cheshire	River Dee	4	<0.010	<0.010	<0.010	<0.010	<0.027	0.33	0.20
Cornwall	River Fowey	4	<0.011	<0.010	<0.010	<0.010	<0.042	0.12	0.094
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.11	0.082
County Durham	River Tees	4	<0.010	<0.010	<0.010	<0.010	<0.031	0.11	0.093
County Durham	Tunstall Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.024	0.70	0.061
Cumbria	Haweswater Reservoir	3	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050
Cumbria	Ennerdale Lake	3	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050
Derbyshire	Meerbrook Sough groundwater	4	0.016	0.041	<0.010	0.021	0.14	0.14	0.11
Derbyshire	Arnfield Water Treatment Plant	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.053	<0.050
Devon	River Exe	4	<0.010	<0.010	<0.010	<0.010	<0.024	0.13	0.10
Gloucestershire	River Severn, Tewkesbury	4	<0.010	0.019	<0.010	<0.011	<0.037	0.25	0.20
Greater London	River Lee, Chingford	4	<0.010	0.010	<0.010	<0.0093	<0.037	0.38	0.28
Hampshire	River Avon, Christchurch	4	<0.010	<0.010	<0.010	<0.010	<0.039	0.14	0.12
Humberside	Littlecoates, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.037	0.17	0.13
Kent	Denge, Shallow Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.024	0.35	0.29
Kent	Deep Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.027	0.074	<0.064
Lancashire	Corn Close, Groundwater	3	<0.010	<0.0093	<0.010	<0.010	<0.020	<0.11	<0.088
Norfolk	Stoke-Ferry, River	4	<0.010	0.012	<0.010	<0.011	<0.034	0.17	0.14
Northumbria	Kielder Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.024	<0.055	<0.050
Oxfordshire	River Thames, Oxford	4	<0.010	<0.010	<0.010	<0.0095	<0.045	0.25	0.19
Somerset	Ashford Reservoir, Bridgwater	4	<0.010	<0.0095	<0.010	<0.010	<0.029	0.13	0.11
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.010	<0.012	<0.010	<0.011	<0.037	0.23	0.17
Surrey	River Thames, Walton	4	<0.010	<0.010	<0.010	<0.010	<0.035	0.26	0.21
Surrey	River Thames, Chertsey	4	<0.010	<0.011	<0.010	<0.0093	<0.035	0.24	0.19
Yorkshire	Eccup No.1 Works Inlet	4	<0.010	<0.010	<0.010	<0.010	<0.022	0.13	0.12
Yorkshire	Chellow Heights, Bradford	4	<0.010	<0.010	<0.010	<0.010	0.029	0.096	0.073
Wales									
Gwynedd	Cwm Ystradllyn Treatment Works	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.052	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.021	<0.052	<0.050
Powys	Elan Valley Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050

[1] *Using ^{137}Cs standard*
[2] *Using ^{40}K standard*

Table 11.15. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2002

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	3	<1.7	0.0062	<0.05	0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.11
Co. Antrim	Lough Neagh	3	<1.7	0.0044	<0.05	0.016	<0.010	<0.010	<0.010	<0.010	<0.020	0.09
Co. Down	Silent Valley	3	<1.7	0.0040	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	0.026	<0.08

Table 11.16. Concentrations of radionuclides in sea water from the Irish Sea and Scottish waters, 2002

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}										
		^{3}H	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Cs	^{241}Am	Total alpha	Total beta
Seascale	4[F]						<0.003	<0.16				
Seascale (Particulate)	2		<0.01	0.012		<0.01	<0.01	<0.01	<0.01	<0.01	0.22	0.12
Seascale (Filtrate)	2		<0.33	<0.090	<0.090	<2.9	<031	<0.45	<2.0	<0.48	<3.0	8.9
St. Bees	12[F]	23			0.26		<0.002	0.13				
St. Bees (Particulate)	2		<0.06	<0.012		<0.06	<0.06	<0.06	0.06	<0.01	0.034	0.16
Seascale (Filtrate)	2		<0.35	0.35	3.2	<4.0	<0.35	<0.25	<1.6	<0.75	<4.0	17
Whitehaven	1[F]						*	0.10				
Maryport	1[F]						*	0.13				
Silloth	1[F]						0.002	0.19				
Silecroft	1[F]						*	0.09				
Walney - west shore	4[F]	13					*	0.12				
Isle of Whithorn	1[F]						*	0.05				
Drummore	1[F]						*	0.04				
Half Moon Bay	1[F]						*	0.17				
Rossal (Fleetwood)	1[F]						0.002	0.12				
Ainsdale	1[F]						*	0.11				
New Brighton	1[F]						*	0.07				
Ross Bay	1[F]						*	0.06				
North of Larne	12[F]				0.021		*	0.02				
Seafield	4	6.8					<0.10	<4.6				
Seafield (high water)	4	11					<0.10	<0.15				
Southerness[a]	4	<7.5					<0.10	<0.14		<0.0014		
Carsethorn	2	9.9										
North Solway	4	8.8										
Knock Bay	8	<2.8					<0.05	<0.06				
Prestatyn	1[F]						*	0.03				
Llandudno	1[F]						*	0.03				
Holyhead	4[F]	<1.5					*	0.01				

** Not detected by the method used*
[a] The concentrations of ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were 0.00052, 0.0021 and <0.0014 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

12. RESEARCH IN SUPPORT OF THE MONITORING PROGRAMME

The Food Standards Agency and the environment agencies have programmes of special investigations and supporting research and development studies to complement the routine monitoring programmes. This additional work is primarily directed at the following objectives:

- to evaluate the significance of potential sources of radionuclide contamination of the food chain and the environment;
- to identify and investigate specific topics or pathways not currently addressed by the routine monitoring programmes and the need for their inclusion in future routine monitoring;
- to develop and maintain site-specific habit and agricultural practice data, in order to improve the realism of dose assessment calculations;
- to develop more sensitive and/or efficient analytical techniques for measurement of radionuclides in natural matrices;
- to evaluate the competence of laboratories' radiochemical analytical techniques for specific radionuclides in food and environmental materials;
- to develop improved methods for handling and processing monitoring data.

Other studies include projects relating to effects on wildlife, emergency response and planning and development of new environmental models and data.

The contents of the research programmes are regularly reviewed and open meetings are held each year to discuss ongoing, completed and potential future projects. Occasionally specific topics are the subject of dedicated workshops (e.g. Ould-Dada, 2000). A summary of all the research and development undertaken by the Environment Agency between 1996 and 2001 was published in 2002 (Environment Agency, 2002e).

A list of related projects completed in 2002 is presented in Table 12.1. 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 Radiological Protection and Research Management Division, Aviation House, 125 Kingsway, London WC2B 6NH. Further information on studies funded by SEPA and the Scotland and Northern Ireland Forum for Environmental Research is available from SEPA, Erskine Court, The Castle Business Park, Stirling FK9 4TR. Environment Agency reports are available from www.eareports.com. A charge may be made to cover costs. Table 12.1 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.

Assessment of UK laboratory performance: tritium in fish and milk - R02012

Whilst formal accreditation schemes such as that operated by the United Kingdom Accreditation Service offer a measure of reassurance that laboratories are performing to high standards, proficiency testing is an essential component of good laboratory practice. Seven laboratories participated in this study. Tritiated thymidine was added to powdered fish and milk and the samples were analysed independently (Toole, 2003).

The results indicate that the determinations are difficult to reproduce and that the homogeneity of the samples may have been variable. Consequently there was a wide spread in laboratory performance.

Only two and three laboratories provided results, which were consistent with the assigned values for milk and fish respectively. Most results exhibited varying degrees of negative bias indicating incomplete recovery of the tritium following oxidation. A wet chemical oxidation method showed that it can perform at least as well as the dry combustion methods, although one laboratory using this method had erratic results. One laboratory using a dry combustion method showed a large excess of tritium indicating a potential contamination problem.

Surveillance of farmed fish - R02015

An earlier study on radioactivity in fishmeal fed to fish had suggested from a theoretical standpoint that farmed fish may contain enhanced levels of naturally-occurring radionuclides as a result of the fishmeal they were fed (Smith and Jeffs, 1999). This project sought to test this thesis by monitoring farmed fish directly (Smith, 2002b).

Atlantic salmon and rainbow trout are the main farmed fish species consumed in the UK, and a representative cross-section of 11 fish farms in England, Scotland and Wales were sampled during 2001. Farmed fish were found to contain low levels of radioactivity. Many gamma radionuclides were undetectable and caesium-137 concentrations ranged from 0.23 to 0.53 Bq kg^{-1}. Concentrations of carbon-14 ranged from <16 to 50 Bq kg^{-1}, lead-210 ranged from <0.010 to 0.27 Bq kg^{-1} and polonium-210 ranged from 0.016 to 0.29 Bq kg^{-1}. Many of the samples had concentrations of carbon-14, lead-210 and polonium-210 at what may be considered natural rather than enhanced levels. Unusually, a number of fish samples had $^{210}Po/^{210}Pb$ quotients which were less than 1. Technetium-99 was measured in one set of Scottish salmon and fish feed samples and the results were 0.24 Bq kg^{-1} and 1.3 Bq kg^{-1}, respectively.

As a consequence of the low concentrations, estimated doses to high-rate consumers of farmed fish were also low, ranging from 0.017 mSv y^{-1} for adults to 0.038 mSv y^{-1} for 1-year-old infants. Most of these doses were due to naturally-occurring lead-210 and polonium-210.

Tritium and carbon-14 in seafood - R03014

Relatively large concentrations of tritium and carbon-14 have been found in seafood from routine monitoring around UK nuclear sites. This three year study sought to extend the available data on tritium and carbon-14 in seafood by establishing the extent of bioaccumulation of tritium. Samples of fish and shellfish were taken from waters throughout the UK near known tritium discharge points. The results of total tritium and organically bound tritium analyses were reported in previous issues of the RIFE report series and were collated by Swift and Hughes (2003). Whilst bioaccumulation of tritium was observed at several sites in the UK, the scale at sites other than at Cardiff was minor. Carbon-14 results showed rapidly decreasing concentrations with distance from Cardiff and Sellafield.

Dry cloth airborne radioactivity programme - RA104

The Atomic Energy Branch of the Food Sciences Division of the Ministry of Agriculture, Fisheries and Food first considered airborne particulate radioactivity monitoring in 1965. A study was made to determine the best method to be deployed around UK nuclear sites. Initially rainwater monitoring was considered but dismissed due to the inherent unreliability of the method. In view of the wide coverage required, passive methods of dust collection requiring no power supplies or frequent supervision were investigated and the ‘dry cloth’ airborne radioactivity programme began.

The programme was designed to provide a fast system to monitor airborne radioactivity around the major UK nuclear establishments that might deposit on agricultural land, leading to accumulation by crops or livestock and subsequent public exposure through consumption of agricultural products. Since its introduction, more direct methods of determining radionuclide levels in the foodchain have been introduced and the frequency of accidental releases from UK nuclear sites has been shown to be very small. The 'dry cloth' programme therefore ended in 2001. This study was the seventh and final report of a series covering the results of the dry cloth programme (Swift, 2002b).

Natural radionuclides in food from the wild - R03009

Previous surveys have shown that people can collect and eat large quantities of foods from the wild. These foods include blackberries, mushrooms, nuts and elderberries and they may be stored or frozen to eat throughout the rest of the year. Given the relatively large amounts of these particular foods that may be eaten, there is the potential that even small concentrations of radioactivity might result in significant doses to consumers. A previous study carried out for the Food Standards Agency around nuclear power stations (Green *et al*. 1999) showed that levels of artificially-produced radionuclides in these foods was very low, but recommended that a follow-up study should examine levels of naturally-occurring radionuclides. This survey was carried out well away from nuclear industry sites but in areas known to have high levels of naturally-occurring radionuclides in the soil.

400 people were identified and between them they collected 54 different types of food from the wild (Green, *et al*., 2002). Polonium-210 and lead-210 were the most radiologically significant radionuclides. In areas with average levels of naturally-occurring radionuclides, the increase in dose due to consumption of wild foods was small relative to estimates for whole diet from the Total Diet Study (see Section 11). However, in areas of elevated levels of naturally-occurring radionuclides in soil, doses from wild foods were similar to those from the Total Diet Study.

Radioactivity in cranberry products

The Food Standards Agency carried out a survey to determine the level of caesium-137 in a small number of cranberry products (Food Standards Agency, 2002c). The results are shown in Table 12.2. Most products contained very low levels of radioactivity although two had slightly elevated levels. The survey followed the finding of elevated levels of radioactivity in a consignment of concentrated cranberry juice exported from Germany. The consignment was returned to Germany and did not enter the UK foodchain.

An assessment showed that the dose from consumption of large amounts of these products would give less than 0.075 mSv. Therefore no advice to consumers to avoid cranberries or products containing cranberries was given by the Food Standards Agency.

Radioactivity in farmed salmon

In March-May 2003, the Food Standards Agency, in conjunction with SEPA, carried out a survey of radioactivity in farmed salmon from the west and north coast of Scotland and Northern Ireland. The survey compared the radioactivity, particularly technetium-99, in farmed and wild fish.

Results from the survey showed similar levels of radionuclides in farmed and wild fish and that consumption of these fish posed no threat to the health of consumers. Details and results of this survey can be found on the Food Standards Agency's website (Food Standards Agency, 2003b)

Development of TRAMS database - R03017

Geographical methods for presenting information from monitoring programmes offer powerful tools for assessors to use in routine and emergency situations. The Food Standards Agency sponsored this study to interface their terrestrial monitoring data in a Microsoft Access database with a Geographical Information System written in ArcView. Typical queries include the location of all sampling locations within a given distance of a nuclear site or a town centre, or all sampling results for a certain foodstuff. The system is undergoing testing within the Food Standards Agency and it will be used to identify any trends in the data and also as a guide to direct future monitoring programmes.

‘Monitoring of radiological discharges’ research seminar, 3 December 2002 – UKRSR04

The Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) hosted a research seminar primarily to disseminate the findings from the SNIFFER-Environment Agency funded project which investigated the past, current and future radiological impacts of Sellafield marine discharges on the people living in coastal communities surrounding the Irish Sea. Speakers from EHS, SEPA and the Environment Agency for England and Wales provided an overview of how the UK agencies monitor radiological discharges.

Solid speciation and remobilisation of radionuclides in the Northern Irish Sea and SW coast of Scotland - AIR(99)01

SNIFFER has commissioned this study which seeks to carry out a detailed examination of the solid speciation of plutonium-239+240, caesium-137 and americium-241in the sediment column of the Northern Irish Sea and the Solway Firth to determine the key process governing their release from the sediment into the overlying water column. The final report is due to be published in August 2003 and will be available from SNIFFER’s website at www.sniffer.org.uk.

Devonport marine survey

A supplementary survey of the marine environment near Devonport was undertaken in the summer of 2001 to support the Environment Agency’s review of the DML authorisation (Environment Agency, 2002f). The results of the survey are summarised in Section 7.

Solubility of particles in simulated gastric fluids

This study investigated the *in vitro* leaching of ‘hot’ radioactive particles recovered from the Dounreay area. The particles were placed in solutions that simulated the conditions found in the human stomach and small intestine. The amounts of radioactive elements released from the particles were quantified (Scottish Environment Protection Agency, 2003b). The results from this study will be used in the NRPB study assessing the dose implications of the radioactive particles (outlined in Section 5.1).

Table 12.1. Extramural projects

Topic	Reference	Further details	Target completion date
Surveillance of farmed fish	R02015	F	Complete
Assessment of UK laboratory performance: tritium in fish and milk	R02012	F	Complete
Development of TRAMS database	R03017	F	Complete
Natural radionuclides in wildfood	R03009	F	Complete
Microscale variation in estuaries	P3-057	E	Complete
Multiple source dose assessment	P3-070	E	Complete
Organic forms of tritium	P3-059	E	Complete
Monitoring research seminar	UKRSR04	S	Complete
Drinking water screening levels	Q5158	E	Complete
Dry cloth airborne radioactivity programme	RA104	F	Complete
Modelling the combined impact of radionuclide discharges reaching rivers	P3-068	E	Complete
Modelling the dispersion of radionuclides following short duration releases to rivers	P3-074	E	Complete
Development of a mobile emergency monitoring facility	C05014	F	Complete
Information management	C05024	F	Complete
Tritium and carbon-14 in seafood	R03014	F	Complete
Devonport marine survey 2001	TR/2002/006	E	Complete
Partitioning of radionuclides with sewage sludge and transfer along terrestrial foodchain pathways	R01046	F	Complete
Model for assessing the radiological impact of radionuclides in sewage sludge	R01057	F	Complete
A computer based tool to identify areas affected by discharges from more than one site	R01042	F	Complete
Modelling approach for estimating actinide uptake by fruit crops	R01052	F	Complete
RIFE Trend studies	R03011	F	Ongoing
Enhancement to Optimon-T software	R02004	F	Ongoing
Bottled waters	R03021	F	Ongoing
Data relevant to the assessment of radioactive waste discharges into inland waters	R01041	F	Ongoing
Presentation of probabilistic dose estimates: Extension of stage 1 pilot study to cover uncertainty	R01058	F	Ongoing
Soil and herbage survey	UKRSR01	S	Jun-03
Solid speciation and remobilisation of radionuclides in the Northern Irish Sea and the SW coast of Scotland	AIR (99) 01	S	Aug-03
Assessing the suitability of controlled landfills to accept radioactive waste	UKRSR03	S	Sep-03
Development of a regulatory framework to assess the application of best practicable means for the management of radioactive wastes	UKRSR05	S	Oct-03
European calibration and co-ordination of mobile and airborne gamma spectrometry (ECCOMAGS)	UKRSR02	S	Nov-03
Dietary and occupancy surveys	230/2350	S	Mar-04
Total diet studies	R03019	F	Mar-04
Industrial site surveillance	R03020	F	Mar-04
International Radionuclide Flux Database (RADFLUX)	R01051	F	Mar-04
Accumulation and remobilisation of Tc-99 in Eastern Irish Sea sediments	R01055	F	Mar-04
The feasibility, effectiveness and response implications of presenting the results of a prospective dose assessment to the public	R01056	F	Mar-04
Assessment of organically bound tritium (OBT) in the environment	R01034	F	Nov-04
Canteen meals	R03022	F	Mar-05
Recovery handbook - response to nuclear incidents	C05032	F, E, S	Dec-05

E Environment Agency
F Food Standards Agency
S Scotland and Northern Ireland Forum for Environmental Research or SEPA

Table 12.2. Concentrations of radiocaesium in cranberry products, 2002

Product	Purchase location	Mean radioactivity concentration (wet), Bq kg^{-1}
		^{137}Cs
Juice drink	Woking, Surrey	<5.0
Juice drink	Woking, Surrey	<5.0
Sauce	Woking, Surrey	<5.0
Sauce	Weybridge, Surrey	<5.0
Juice drink	Farnborough, Hampshire	<5.0
Cranberry vodka	Farnborough, Hampshire	<5.0
Juice drink	Brooklands, Surrey	<5.0
Juice drink	Brooklands, Surrey	<5.0
Sauce	Brooklands, Surrey	<5.0
Juice drink	Woking, Surrey	<5.0
Juice drink	Woking, Surrey	<5.0
Presse	Woking, Surrey	<5.0
Organic cordial	Woking, Surrey	<5.0
Wild cranberry sauce	Woking, Surrey	3.6
Cranberry tablets	Grayshot, Surrey	4.2
Cranberry Breezer	Guildford, Surrey	<5.0
Cranberry concentrate powder	Pocklington, York	56
Cranberry jelly	Brompton Road, London	110
Cranberry jelly	Brompton Road, London	9.5
Cranberry jelly	Brompton Road, London	<5.0
Cranberry jelly	Brompton Road, London	110
Juice drink	NA	<5.0

NA Not available

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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, 2002

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002 TBq[a]	% of limit[b]
British Nuclear Fuels plc				
Capenhurst[r] (Rivacre Brook)	Tritium[r]	78	0.125	<1
	Uranium	0.02	0.00124	6.2
	Uranium daughters	0.02	<0.00110	<5.5
	Non-uranic alpha	0.003	$6.4\ 10^{-6}$	<1
	Technetium-99	0.1	0.00110	1.1
Chapelcross	Alpha	0.1	$1.05\ 10^{-4}$	<1
	Beta[e]	25	0.123	<1
	Tritium	5.5	0.280	5.1
Drigg (sea pipeline)	Alpha	0.1	$7.42\ 10^{-5}$	<1
	Beta[e]	0.3	0.00119	<1
	Tritium	120	0.339	<1
Drigg (stream[f])	Alpha	$9.0\ 10^{4}$	192	<1
	Beta[e]	$1.2\ 10^{6}$	776	<1
	Tritium	$6.0\ 10^{8}$	$3.89\ 10^{4}$	<1
Sellafield[u] (sea pipelines)	Alpha	1	0.350	35
	Beta	400	112	28
	Tritium	$2.5\ 10^{4}$	3320	13
	Carbon-14	20.8	13.0	62
	Cobalt-60	13	0.90	6.9
	Strontium-90	48	19.8	41
	Zirconium-95+Niobium-95	9	0.410	4.6
	Technetium-99	90	85.4	95
	Ruthenium-106	63	6.02	9.6
	Iodine-129	1.6	0.730	46
	Caesium-134	6.6	0.490	7.4
	Caesium-137	75	7.69	10
	Cerium-144	8	0.970	12
	Plutonium alpha	0.7	0.340	49
	Plutonium-241	27	10.5	39
	Americium-241	0.3	0.04	13
	Uranium[d]	2040	440	22
Sellafield (factory sewer)	Alpha	0.0033	$5.40\ 10^{-5}$	1.6
	Beta	0.0135	$4.40\ 10^{-4}$	3.3
	Tritium	0.132	0.026	20
Springfields	Alpha	4	0.221	5.5
	Beta	240	106	44
	Technetium-99	0.6	0.0167	2.8
	Thorium-230	2	0.102	5.1
	Thorium-232	0.2	0.00250	1.3
	Neptunium-237	0.04	0.00140	3.5
	Uranium	0.15	0.0496	33

* *As reported to SEPA and the Environment Agency*

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002	
			TBq[a]	% of limit[b]
United Kingdom Atomic Energy Authority				
Dounreay	Alpha[c]	0.27	0.00196	<1
	Beta[e]	49	0.307	<1
	Tritium	30.8	0.0894	<1
	Cobalt-60	0.46	$4.45\ 10^{-4}$	<1
	Strontium-90	7.7	0.155	2.0
	Zirconium-95+Niobium-95	0.4	$3.93\ 10^{-4}$	<1
	Ruthenium-106	4.1	$8.46\ 10^{-4}$	<1
	Silver-110m	0.13	$1.37\ 10^{-4}$	<1
	Caesium-137	23	0.0144	<1
	Cerium-144	0.42	$5.58\ 10^{-4}$	<1
	Plutonium-241	2.3	$1.97\ 10^{-4}$	<1
	Curium-242	0.04	$5.61\ 10^{-7}$	<1
Harwell (pipeline)[w]	Alpha	0.001	$1.85\ 10^{-5}$	1.9
	Beta[e]	0.02	$5.80\ 10^{-4}$	2.9
	Tritium	4	0.154	3.9
	Cobalt-60	0.007	$1.39\ 10^{-5}$	<1
	Caesium-137	0.007	$7.53\ 10^{-5}$	1.1
Harwell (Lydebank Brook)[w]	Alpha	$5\ 10^{-4}$	$2.26\ 10^{-5}$	4.5
	Beta[e]	0.002	$2.43\ 10^{-4}$	12
	Tritium	0.1	0.0159	16
Winfrith (inner pipeline)	Alpha	0.3	$3.40\ 10^{-4}$	<1
	Tritium	650	5.90	<1
	Cobalt-60	10	0.0013	<1
	Zinc-65	6	$2.50\ 10^{-4}$	<1
	Other radionuclides	80	0.018	<1
Winfrith (outer pipeline)	Alpha	0.004	$6.30\ 10^{-5}$	1.6
	Tritium	1	0.00950	<1
	Other radionuclides	0.01	$1.60\ 10^{-4}$	1.6
Magnox Electric[h,v]				
Berkeley	Tritium	8	$6.20\ 10^{-4}$	<1
	Caesium-137	0.2	$2.10\ 10^{-4}$	<1
	Other radionuclides	0.4	$1.30\ 10^{-4}$	<1
Bradwell	Tritium	30	1.93	6.4
	Caesium-137	0.75	0.309	41
	Other radionuclides	1	0.132	13
Dungeness 'A' Station	Tritium	35	3.45	9.9
	Caesium-137	1.2	0.306	26
	Other radionuclides	1.4	0.194	14
Hinkley Point 'A' Station	Tritium	25	0.711	2.8
	Caesium-137	1.5	0.332	22
	Other radionuclides	1	0.0757	7.6
Hunterston 'A' Station	Alpha	0.04	$1.47\ 10^{-4}$	<1
	Beta	0.6	0.0287	4.8
	Tritium	0.7	$8.17\ 10^{-4}$	<1
	Plutonium-241	1.0	$2.19\ 10^{-4}$	<1
Oldbury	Tritium	25	0.419	1.7
	Caesium-137	0.7	0.543	78
	Other radionuclides	1.3	0.309	24

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002	
			TBq[a]	% of limit[b]
Sizewell				
'A' Station	Tritium	35	0.341	<1
	Caesium-137	1.0	0.536	54
	Other radionuclides	0.7	0.282	40
Trawsfynydd	Other radionuclides[e,i,j]	0.72	0.00215	<1
	Tritium	12	0.155	1.3
	Strontium-90	0.08	0.00198	2.5
	Caesium-137	0.05	0.00195	3.9
Wylfa	Tritium	40	4.93	12
	Other radionuclides	0.15	0.0682	46
British Energy Generation Ltd				
Dungeness				
'B' Station	Tritium	650	290	45
	Sulphur-35	2	0.359	18
	Cobalt-60	0.03	0.00156	5.2
	Other radionuclides	0.25	0.0274	11
Hartlepool	Tritium	1200	411	34
	Sulphur-35	3	1.56	52
	Cobalt-60	0.03	0.00480	16
	Other radionuclides	0.3	0.0157	5.2
Heysham				
Station 1	Tritium	1200	402	34
	Sulphur-35	2.8	0.278	9.9
	Cobalt-60	0.03	$9.23\ 10^{-4}$	3.1
	Other radionuclides	0.3	0.0232	7.7
Station 2	Tritium	1200	334	28
	Sulphur-35	2.3	0.0906	3.9
	Cobalt-60	0.03	$3.85\ 10^{-4}$	1.3
	Other radionuclides	0.3	0.0188	6.3
Hinkley Point				
'B' Station	Tritium	620	381	62
	Sulphur-35	5	0.530	11
	Cobalt-60	0.033	$1.5\ 10^{-4}$	<1
	Other radionuclides	0.235	0.0130	5.5
Sizewell				
'B' Station	Tritium	80	65.1	81
	Other radionuclides	0.2	0.0500	25
British Energy Generation (UK) Ltd				
Hunterston				
'B' Station	Alpha	0.001	$6.79\ 10^{-5}$	6.8
	Beta[e,g,p]	0.45	0.00593	1.3
	Tritium	800	448	56
	Sulphur-35	10	2.02	20
	Cobalt-60	0.03	$4.00\ 10^{-4}$	1.3
Torness	Alpha	0.001	$7.42\ 10^{-6}$	<1
	Beta[e,g,p]	0.45	$4.19\ 10^{-3}$	<1
	Tritium	800	250	31
	Sulphur-35	10	0.0184	<1
	Cobalt-60	0.03	$2.57\ 10^{-4}$	<1

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002	
			TBq[a]	% of limit[b]
Ministry of Defence				
Aldermaston (River Thames)	Alpha	$6.0\ 10^{-5}$	$6.49\ 10^{-6}$	11
	Tritium	0.05	0.00599	12
	Plutonium-241	$2.4\ 10^{-4}$	$2.60\ 10^{-5}$	11
	Other radionuclides	$6.0\ 10^{-5}$	$5.51\ 10^{-6}$	9.2
Aldermaston (Silchester)	Alpha	$4.0\ 10^{-5}$	$2.21\ 10^{-6}$	5.5
	Beta	$1.2\ 10^{-4}$	$6.25\ 10^{-6}$	5.2
	Tritium	0.05	$4.42\ 10^{-4}$	<1
Aldermaston (stream)	Tritium	0.01	0.00168	17
Barrow[l]	Tritium	0.02	$1.25\ 10^{-4}$	<1
	Manganese-54	$2.5\ 10^{-7}$	$3.95\ 10^{-9}$	1.6
	Cobalt-58	$7.0\ 10^{-7}$	$5.15\ 10^{-10}$	<1
	Cobalt-60	$7.0\ 10^{-8}$	$2.49\ 10^{-9}$	3.6
	Tin-113	$2.5\ 10^{-7}$	$5.60\ 10^{-10}$	<1
	Antimony-124	$2.0\ 10^{-6}$	$5.19\ 10^{-10}$	<1
	Other radionuclides	$3.5\ 10^{-6}$	$4.67\ 10^{-10}$	<1
Derby[y]	Alpha[s]	0.00666	$4.18\ 10^{-4}$	6.3
	Alpha[t]	$1.85\ 10^{-4}$	$1.05\ 10^{-7}$	<1
	Beta[t]	0.0094	$3.39\ 10^{-5}$	<1
Devonport[m,n] (sewer)	Beta		$5.21\ 10^{-6}$	
	Tritium		$5.13\ 10^{-6}$	
	Cobalt-60		$3.67\ 10^{-7}$	
Devonport[o,k] (sewer)	Tritium	0.002	$1.33\ 10^{-4}$	6.7
	Cobalt-60	$3.5\ 10^{-4}$	$2.50\ 10^{-5}$	7.1
	Other radionuclides[e,p]	$6.5\ 10^{-4}$	$2.21\ 10^{-4}$	34
Devonport[o,k] (pipeline)	Tritium	0.7	0.0675	9.6
	Carbon-14	0.0017	$2.51\ 10^{-4}$	15
	Cobalt-60	$8.0\ 10^{-4}$	$2.72\ 10^{-5}$	3.4
	Other radionuclides[e,p,x]	$3.0\ 10^{-4}$	$2.31\ 10^{-5}$	7.7
Faslane	Alpha activity	$2.0\ 10^{-4}$	$2.05\ 10^{-6}$	1.0
	Beta activity[e,p]	$5.0\ 10^{-4}$	$3.50\ 10^{-5}$	7.0
	Tritium	1	0.0782	7.8
	Cobalt-60	$5.0\ 10^{-4}$	$9.31\ 10^{-6}$	1.9
Rosyth[q]	Alpha	$1\ 10^{-6}$	$3.70\ 10^{-8}$	3.7
	Beta[e,p]	$5\ 10^{-4}$	$8.79\ 10^{-5}$	18
	Tritium	0.04	0.00355	8.9
	Cobalt-60	0.005	$1.93\ 10^{-4}$	3.9
Amersham plc				
Amersham	Alpha	$3.0\ 10^{-4}$	$2.92\ 10^{-5}$	9.7
	Beta >0.4 MeV	0.1	0.00236	2.4
	Tritium	0.2	0.00215	1.1
	Iodine-125	0.2	$3.78\ 10^{-4}$	<1
	Caesium-137	0.005	$1.68\ 10^{-5}$	<1
	Other radionuclides	0.3	0.0186	6.2

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002	
			TBq[a]	% of limit[b]
Cardiff	Tritium	900	59.5	6.6
	Carbon-14	2	0.212	11
	Phosphorus-32/33	0.01	$6.29\ 10^{-7}$	<1
	Iodine-125	0.05	$7.20\ 10^{-4}$	1.4
	Others	$5.0\ 10^{-4}$	Nil	Nil
Minor sources				
Imperial College Reactor Centre Ascot	Tritium	$1.0\ 10^{-4}$	Nil	Nil
	Other radioactivity	$4.0\ 10^{-5}$	"	"
Imperial Chemical Industries plc Billingham	Beta/gamma	0.36	Nil	Nil
Scottish Universities Research and Reactor Centre East Kilbride	Total activity	0.00144	$1.10\ 10^{-7}$	<1

[a] *Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 3 significant figures except where fewer significant figures are provided in source documents*
[b] *Data quoted to 2 significant figures except when values are less than 1%*
[c] *Excluding curium-242*
[d] *The limit and discharge data are expressed in kg*
[e] *Excluding tritium*
[f] *Discharges and limits are expressed in terms of concentrations of activity in Bq m^{-3}*
[g] *Excluding sulphur-35*
[h] *Magnox Electric is a wholly owned subsidiary of BNFL plc*
[i] *Excluding caesium-137*
[j] *Excluding strontium-90*
[k] *Discharge authorisation at Devonport was revised with effect from 13th March 2002. Discharges quoted are for 13th March-31st December 2002*
[l] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[m] *Discharges were made by the Ministry of Defence*
[n] *The current authorisation includes limits on concentrations of total activity (MoD 2 10^{-6} TBq m^{-3}). At no time did the concentrations exceed the limits*
[o] *Discharges were made by Devonport Royal Dockyard Ltd*
[p] *Excluding cobalt-60*
[q] *Discharges were made by Rosyth Royal Dockyard Ltd*
[r] *Discharge limits depend on operational throughput*
[s] *Discharge limit is for Nuclear Fuel Production Plant*
[t] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[u] *Some limits are related to the throughput of plant and may thus vary from year to year*
[v] *Discharge authorisations at Magnox Electric sites were revised with effect from 18th December 2002. BNFL plc took over operation of Berkeley, Berkeley Centre and Trawsfynydd. Discharges quoted are for the whole year and the old limits have been assumed to apply throughout the year*
[w] *Discharge authorisation at Harwell was revised with effect from 1st May 2003*
[x] *Excluding carbon-14*
[y] *Discharges were made by Rolls Royce Marine Power Operations Ltd*

Table A1.2 Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2002

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002	
			TBq	% of limit
British Nuclear Fuels plc				
Capenhurst	Tritium	1600	0.00970	<1
	Uranium[d]		4.8 10^{-7}	
Chapelcross	Tritium	5000	763	15
	Sulphur-35	0.05	0.00733	15
	Argon-41	4500	1160	26
Sellafield[a,b]	Alpha	0.00246	4.62 10^{-5}	1.9
	Beta	0.341	9.24 10^{-4}	<1
	Tritium	1440	253	18
	Carbon-14	7.30	0.829	11
	Sulphur-35	0.21	0.0121	5.8
	Argon-41	3700	325	8.8
	Cobalt-60	9.2 10^{-4}	6.01 10^{-6}	<1
	Krypton-85	4.7 10^{5}	1.01 10^{5}	22
	Strontium-90	0.0094	4.68 10^{-5}	<1
	Ruthenium-106	0.056	0.00131	2.3
	Antimony-125	0.005	3.79 10^{-4}	7.6
	Iodine-129	0.069	0.0260	38
	Iodine-131	0.055	4.46 10^{-4}	<1
	Caesium-137	0.0183	4.26 10^{-4}	2.3
	Plutonium (alpha)	0.00122	1.89 10^{-5}	1.5
	Plutonium-241	0.0174	9.73 10^{-5}	<1
	Americium-241 and curium-242	7.40 10^{-4}	1.96 10^{-5}	2.6
Springfields	Uranium	0.006	8.60 10^{-4}	14
United Kingdom Atomic Energy Authority[h]				
Dounreay (Fuel Cycle Area)	Alpha[e]	9.8 10^{-4}	3.28 10^{-5}	3.3
	Beta[k]	0.045	2.21 10^{-4}	<1
	Tritium	2	0.233	12
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	4.03 10^{-4}	9.6
	Ruthenium-106	0.0039	6.38 10^{-6}	<1
	Iodine-129	0.0011	7.21 10^{-5}	6.6
	Iodine-131	1.5 10^{-4}	2.37 10^{-5}	16
	Caesium-134	8.4 10^{-4}	7.59 10^{-7}	<1
	Caesium-137	0.007	5.05 10^{-5}	<1
	Cerium-144	0.007	5.13 10^{-6}	<1
	Plutonium-241	0.0033	1.16 10^{-5}	<1
	Curium-242	2.7 10^{-4}	7.36 10^{-8}	<1
	Curium-244[i]	5.4 10^{-5}	4.77 10^{-8}	<1
Dounreay (Fast Reactor)	Alpha	10^{-5}	1.80 10^{-9}	<1
	Beta	0.0015	1.86 10^{-8}	<1
	Tritium	4.5	6.11 10^{-4}	<1
	Krypton-85	4.0 10^{-4}	2.26 10^{-4}	57
Dounreay (Prototype Fast Reactor)	Alpha	6 10^{-6}	3.69 10^{-8}	<1
	Beta	5.1 10^{-5}	1.25 10^{-6}	2.5
	Tritium	22.5	0.0577	<1
	Krypton-85	4	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002	
			TBq	% of limit
Dounreay (East minor sources)	Alpha[l]	$1.37\ 10^{-5}$	$2.10\ 10^{-7}$	1.5
	Beta[k]	$3.71\ 10^{-4}$	$3.33\ 10^{-7}$	<1
	Krypton-85	1	Nil	Nil
Dounreay (West minor sources)	Alpha[l]	$3\ 10^{-7}$	$1.38\ 10^{-10}$	<1
	Beta[k]	$7.5\ 10^{-5}$	$1.34\ 10^{-9}$	<1
	Tritium	$2.25\ 10^{-5}$	$2.85\ 10^{-6}$	13
Harwell[q]	Alpha	$7.0\ 10^{-6}$	$1.00\ 10^{-7}$	1.4
	Beta	$4.5\ 10^{-4}$	$3.83\ 10^{-6}$	<1
	Tritium	150	1.12	<1
Windscale	Alpha	$1.2\ 10^{-5}$	$1.63\ 10^{-7}$	1.4
	Beta	0.005	$3.18\ 10^{-6}$	<1
	Tritium	2.3	0.00790	<1
	Krypton-85	14	0.260	1.9
	Iodine-131	0.0012	$2.74\ 10^{-6}$	<1
Winfrith	Alpha	$2.0\ 10^{-6}$	$2.00\ 10^{-9}$	<1
	Beta	$2.5\ 10^{-5}$	$6.60\ 10^{-8}$	<1
	Tritium	5	0.0900	1.8
	Carbon-14	0.3	$4.0\ 10^{-4}$	<1
	Krypton-85	150	Nil	Nil
Magnox Electric[o,p]				
Berkeley	Alpha and beta[m]	$2.0\ 10^{-4}$	$3.68\ 10^{-7}$	<1
	Tritium	2	0.00421	<1
	Carbon-14	0.2	$2.64\ 10^{-4}$	<1
	Sulphur-35	0.006	Nil	Nil
Bradwell	Beta	0.001	$1.43\ 10^{-4}$	14
	Tritium	1.5	0.647	43
	Carbon-14	0.6	0.158	26
	Sulphur-35	0.2	0.0485	24
	Argon-41	1000	137	14
Dungeness 'A' Station	Beta	0.001	$2.50\ 10^{-4}$	25
	Tritium	3	0.460	15
	Carbon-14	5	3.5	70
	Sulphur-35	0.4	0.0390	9.8
	Argon-41	2000	1200	60
Hinkley Point 'A' Station	Beta	0.001	$2.63\ 10^{-6}$	<1
	Tritium	25	0.0357	<1
	Carbon-14	4	0.00256	<1
	Sulphur-35	0.2	$2.55\ 10^{-6}$	<1
	Argon-41	4500	Nil	Nil
Hunterston 'A' Station	Beta[j]	$6.0\ 10^{-5}$	$2.6\ 10^{-7}$	<1
	Tritium	0.02	0.00145	<1
	Carbon-14	0.002	$1.80\ 10^{-4}$	9.0
Oldbury	Beta	0.001	$1.20\ 10^{-4}$	12
	Tritium	5	2.79	56
	Carbon-14	6	4.48	75
	Sulphur-35	0.75	0.343	46
	Argon-41	500	284	57

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002 TBq	% of limit
Sizewell 'A' Station	Beta	0.001	$1.87\ 10^{-4}$	19
	Tritium	7	2.63	38
	Carbon-14	1.5	1.17	78
	Sulphur-35	0.6	0.133	22
	Argon-41	3000	1850	62
Trawsfynydd	Beta particulate	0.002	$4.63\ 10^{-7}$	<1
	Tritium	10	0.0483	<1
	Carbon-14	5	$9.0\ 10^{-4}$	<1
	Sulphur-35	0.4	Nil	Nil
	Argon-41	3500	"	"
Wylfa	Beta particulate	0.001	$2.93\ 10^{-5}$	2.9
	Tritium	20	3.81	19
	Carbon-14	2.4	1.54	64
	Sulphur-35	0.5	0.203	41
	Argon-41	120	31.9	27
British Energy Generation Ltd				
Dungeness 'B' Station	Beta particulate	0.001	$9.25\ 10^{-6}$	<1
	Tritium	15	4.90	33
	Carbon-14	5	0.638	13
	Sulphur-35	0.45	0.0463	10
	Argon-41	150	22.2	15
	Iodine-131	0.005	$1.96\ 10^{-6}$	<1
Hartlepool	Beta particulate	0.001	$5.37\ 10^{-6}$	<1
	Tritium	6	1.56	26
	Carbon-14	5	1.78	36
	Sulphur-35	0.16	0.110	69
	Argon-41	60	10.9	18
	Iodine-131	0.005	$3.90\ 10^{-5}$	<1
Heysham Station 1	Beta particulate	0.001	$8.34\ 10^{-6}$	<1
	Tritium	6	2.15	36
	Carbon-14	4	1.32	33
	Sulphur-35	0.12	0.0228	19
	Argon-41	60	12.8	21
	Iodine-131	0.005	$1.11\ 10^{-4}$	2.2
Heysham Station 2	Beta particulate	0.001	$9.38\ 10^{-6}$	<1
	Tritium	15	1.30	8.7
	Carbon-14	3	1.28	43
	Sulphur-35	0.3	0.0158	5.3
	Argon-41	85	19.5	23
	Iodine-131	0.005	$4.08\ 10^{-5}$	<1
Hinkley Point 'B' Station	Beta particulate	0.001	$3.18\ 10^{-5}$	3.2
	Tritium	30	5.02	17
	Carbon-14	8	1.07	13
	Sulphur-35	0.4	0.124	31
	Argon-41	300	10.7	3.6
	Iodine-131	0.005	$5.60\ 10^{-6}$	<1
Sizewell 'B' Station[a]	Noble gases	300	5.14	1.7
	Halogens	0.003	$1.89\ 10^{-4}$	6.3
	Beta particulate	0.01	$7.14\ 10^{-6}$	<1
	Tritium	8.0	0.858	11
	Carbon-14	0.6	0.194	32

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002 TBq	% of limit
British Energy Generation (UK) Ltd				
Hunterston 'B' Station	Beta[j]	0.002	5.43 10^{-5}	2.7
	Tritium	20	6.8	34
	Carbon-14	3	2.23	74
	Sulphur-35	0.8	0.0692	8.7
	Argon-41	220	38.6	18
Torness	Beta[j]	0.002	1.81 10^{-5}	<1
	Tritium	20	3.25	16
	Carbon-14	3	0.511	17
	Sulphur-35	0.8	0.0208	2.6
	Argon-41	220	4.68	2.1
Ministry of Defence				
Aldermaston[a,n]	Alpha	4.5 10^{-7}	1.12 10^{-7}	25
	Other beta and gamma emitters[f]	5.0 10^{-6}	8.64 10^{-8}	1.7
	Tritium	170	16.8	9.9
	Krypton-85	1.0	2.00 10^{-3}	<1
	Plutonium-241	1.68 10^{-6}	3.80 10^{-7}	23
Barrow[g]	Tritium	3.2 10^{-6}	Nil	Nil
	Argon-41	0.08	"	"
Burghfield[a,n]	Uranium	2.0 10^{-8}	6.80 10^{-10}	3.4
	Tritium	0.05	Nil	Nil
Coulport	Tritium	0.05	0.00294	5.9
Derby[s]	Alpha	[d]	1.60 10^{-6}	
Devonport[r]	Beta/gamma	3.0 10^{-7}	2.96 10^{-8}	9.9
	Tritium	0.004	6.28 10^{-4}	16
	Carbon-14	0.043	4.69 10^{-4}	1.1
	Argon-41	0.015	2.20 10^{-4}	1.5
Dounreay (Vulcan)	Alpha[j]	10^{-6}	4.68 10^{-8}	4.7
	Beta[j]	10^{-4}	1.2 10^{-6}	1.2
	Noble gases	0.027	1.86 10^{-4}	<1
	Iodine-131	3.7 10^{-4}	2.60 10^{-5}	7.0
Rosyth[c]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	2.32 10^{-4}	<1
Amersham plc				
Amersham	Alpha	2.0 10^{-6}	1.0 10^{-7}	5.0
	Other (penetrating)	0.05	7.40 10^{-5}	<1
	Other (non-penetrating)	0.5	0.0069	1.4
	Tritium	40	Nil	Nil
	Selenium-75	0.03	2.80 10^{-4}	<1
	Iodine-125	0.1	0.00230	2.3
	Iodine-131	0.05	5.10 10^{-4}	1.0
	Radon-222	10	2.4	24
Cardiff	Soluble tritium	400	74.1	19
	Insoluble tritium	1000	327	33
	Carbon-14	6	1.87	31
	Phosphorus-32/33	2.0 10^{-4}	3.95 10^{-6}	2.0
	Iodine-125	5.0 10^{-4}	9.92 10^{-5}	20
	Other activity	0.04	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2002	
			TBq	% of limit
Minor sources				
AEA Technology				
Harwell	Alpha	$7.0\ 10^{-7}$	Nil	Nil
	Beta	$3.0\ 10^{-5}$	$8.00\ 10^{-7}$	2.7
	Tritium	$2.0\ 10^{-4}$	Nil	Nil
Winfrith	Alpha	$2.0\ 10^{-7}$	Nil	Nil
	Beta	$2.5\ 10^{-5}$	$6.46\ 10^{-6}$	32
	Tritium	10	3.57	36
Imperial College Reactor Centre				
Ascot	Tritium	$5.0\ 10^{-4}$	$6.79\ 10^{-5}$	14
	Argon-41	2.5	0.505	25
Imperial Chemical Industries plc				
Billingham	Tritium, argon-41, krypton-85 and xenon-133	2.3	Nil	Nil
	Thorium	$3.0\ 10^{-5}$	"	"
Ortho-Clinical Diagnostics Ltd				
Cardiff	Iodine-125	$4.0\ 10^{-4}$	$4.20\ 10^{-5}$	<1
	Other activity	$5.0\ 10^{-4}$	Nil	Nil
Scottish Universities Research and Reactor Centre				
East Kilbride	Beta	$5.0\ 10^{-7}$	$5.66\ 10^{-8}$	11
	Tritium	0.05	0.00973	19
Urenco (Capenhurst) Ltd				
Capenhurst	Uranium	$2.5\ 10^{-6}$	$1.16\ 10^{-7}$	4.6

[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] *Some limits are related to the operation of plant and may thus vary from year to year*
[c] *Discharges were made by Rosyth Royal Dockyard Ltd*
[d] *There are no numerical limits for this discharge. However, the authorisation stipulates that the Best Practicable Means should be used to control the discharge*
[e] *Excluding curium-242 and 244*
[f] *Excluding tritium and plutonium-241*
[g] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges were made by BAE SYSTEMS Marine Ltd*
[h] *Data includes contributions from tenants*
[i] *Data includes any curium-243 present*
[j] *Particulate activity*
[k] *Excluding tritium and krypton-85*
[l] *Excluding radon and daughter products*
[m] *Combined data for Berkeley Power Station and Berkeley Technology Centre*
[n] *Discharges were made by AWE plc*
[o] *Magnox Electric is a wholly owned subsidiary of BNFL plc*
[p] *Discharge authorisations at Magnox Electric sites were revised with effect from 18th December 2002. BNFL plc took over operation of Berkeley, Berkeley Centre and Trawsfynydd. Discharges quoted are for the whole year and the old limits have been assumed to apply throughout the year*
[q] *Discharge authorisation at Harwell was revised with effect from 1st May 2003*
[r] *Discharges were made by Devonport Royal Dockyard Ltd*
[s] *Discharges were made by Rolls Royce Marine Power Operations Ltd*

Table A1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2002

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 2002	
			TBq	% of limit
Drigg	Tritium	10	1.80	18
	Carbon-14	0.05	0.0130	26
	Cobalt-60	2	0.190	9.5
	Iodine-129	0.05	$4.00\ 10^{-5}$	<1
	Radium-226 plus thorium-232	0.03	$1.40\ 10^{-3}$	4.7
	Uranium	0.3	0.016	5.3
	Other alpha[a]	0.3	0.030	10
	Others[a,b]	15	2.40	16
Dounreay[c]	Alpha		$4.17\ 10^{-6}$	
	Beta/gamma		$2.12\ 10^{-5}$	

[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	^{144}Ce	^{147}Pm	^{241}Pu
Milk	Sellafield	a	$1.52\ 10^{-4}$	b	b	$7.89\ 10^{-6}$
	Ravenglass	a	$2.60\ 10^{-4}$	$2.75\ 10^{-3}$	b	$1.53\ 10^{-5}$
	Drigg	a	$3.90\ 10^{-4}$	b	$3.21\ 10^{-2}$	$2.08\ 10^{-5}$
	Isle of Man	a	$5.03\ 10^{-4}$	$3.81\ 10^{-3}$	$1.39\ 10^{-3}$	$1.27\ 10^{-5}$
Beef	Sellafield	a	$1.52\ 10^{-1}$	b	b	a
	Ravenglass	a	$2.60\ 10^{-1}$	$1.38\ 10^{-1}$	b	a
Lamb	Sellafield	a	$1.76\ 10^{-1}$	b	b	$3.64\ 10^{-4}$
	Ravenglass	a	$3.00\ 10^{-1}$	$1.59\ 10^{-1}$	b	$7.06\ 10^{-4}$
	Drigg	a	$4.50\ 10^{-1}$	b		$9.60\ 10^{-4}$
Beef offal	Sellafield	a	$1.52\ 10^{-1}$	b	b	a
	Ravenglass	a	$2.60\ 10^{-1}$	a	b	a
Lamb offal	Sellafield	a	$1.76\ 10^{-1}$	b	b	a
	Ravenglass	a	$3.00\ 10^{-1}$	a	b	$5.29\ 10^{-2}$
	Drigg	a	$4.50\ 10^{-1}$	b	b	$7.20\ 10^{-2}$

[a] *Positive result used, or LOD result used because modelling result greater than LOD*
[b] *No grass or leafy green vegetable or sample LOD data available*

A2.2 Air

For some sites, in particular the steel pressure vessel power stations, non-food exposure pathways are significant. For these types of power stations, discharges of argon-41 to air are significant whilst the reactors are operating. Argon-41 is a noble gas with a short radioactive half-life of about 1.8 h. It does not become incorporated into food produce, but people working or living within the plume may be exposed to external radiation from argon-41 as it disperses downwind of the discharge point. The dose from argon-41, along with the dose from the inhalation of other radionuclides released to air, has been assessed.

The power stations considered for this assessment are Bradwell, Chapelcross, Dungeness A, Oldbury, Sizewell A and Calder Hall at Sellafield. The additional radionuclides discharged to air from the Sellafield site have been included in the assessment, with the assumption that all argon-41 and sulphur-35 are released by the Calder Hall reactors and the other radionuclides are released from THORP. An assessment has also been made of discharges from the Cardiff site. The Gaussian plume model within the assessment code PC CREAM (Mayall *et al*., 1997) has been used to derive air concentrations at the locations of nearest habitation around these sites from the reported discharges of radionuclides to air. Site-specific meteorological data have been used in the assessment and other key modelling assumptions (ie discharge height, exposure location) are shown in Table A2.3.

PC CREAM has also been used to calculate the external radiation doses from radionuclides in the plume and internal radiation doses from inhalation of discharged radionuclides. Doses have been assessed for three age groups: infants (1 y), children (10 y) and adults. The inhalation and occupancy rates assumed in this assessment are shown in Table A2.4. Adults and infants are assumed to have year-round occupancy at the nearest habitation, whilst children are assumed to spend time away at school.

Allowance has been made for time spent indoors and outdoors. During the time people are assumed to be indoors, the standard assumption that the dose from radionuclides in the plume will be reduced by 80 per cent (ie shielding factor of 0.2) has been made.

The predicted concentrations of radioactivity in air are given in Tables A2.5 and A2.6.

Table A2.3 Air concentration modelling assumptions

Nuclear site	Stack height, m	Exposure location	Distance to exposure location, m	Bearing to exposure location
Bradwell	14	Dwelling	300	225°
Cardiff	20	Dwelling	400	270°
Chapelcross	30	Farm	800	30°
Dungeness A	17	Dwelling	300	70°
Oldbury	20	Farm	700	90°
Sizewell A	18	Dwelling	300	180°
Sellafield (argon-41 and sulphur-35 from Calder Hall)	25	Farm	500	100°
Sellafield (other radionuclides from THORP)	92.5	Farm	1200	90°

Table A2.4 Inhalation and occupancy data for dose assessment of discharges to air

Age group, y	Inhalation rates, $m^3\ h^{-1}$	Occupancy at exposure location, $h\ y^{-1}$	Fraction of time indoors
Bradwell, Cardiff, Dungeness A and Sizewell A (dwellings)			
1	0.22	8760	0.9
10	0.63	7500	0.8
Adult	0.83	8760	0.7
Chapelcross, Oldbury and Sellafield (farm locations)			
1	0.22	8760	0.9
10	0.63	7500	0.8
Adult	0.83	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
Bradwell	$5.0\ 10^{-2}$	$1.2\ 10^{-2}$		$3.8\ 10^{-3}$	11	$1.1\ 10^{-5}$	
Cardiff	10	0.18	$3.7\ 10^{-7}$				$9.3\ 10^{-6}$
Chapelcross	24			$2.3\ 10^{-4}$	36		
Dungeness A	$8.7\ 10^{-2}$	0.67		$7.4\ 10^{-3}$	$2.3\ 10^{2}$	$4.7\ 10^{-5}$	
Oldbury	0.16	0.26		$2.0\ 10^{-2}$	16	$7.0\ 10^{-6}$	
Sizewell A	0.17	$7.6\ 10^{-2}$		$8.6\ 10^{-3}$	$1.2\ 10^{2}$	$1.2\ 10^{-5}$	

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

Radionuclide	Radioactivity concentration in air, $Bq\ m^{-3}$
Tritium	0.52
Carbon-14	$1.7\ 10^{-3}$
Sulphur-35	$4.3\ 10^{-4}$
Argon-41	11
Cobalt-60	$1.2\ 10^{-8}$
Krypton-85	$2.1\ 10^{2}$
Strontium-90	$9.6\ 10^{-8}$
Ruthenium-106	$2.7\ 10^{-6}$
Antimony-125	$7.8\ 10^{-7}$
Iodine-129	$5.3\ 10^{-5}$
Iodine-131	$9.1\ 10^{-7}$
Caesium-137	$8.8\ 10^{-7}$
Plutonium-239	$3.9\ 10^{-8}$
Plutonium-241	$2.0\ 10^{-7}$
Americium-241	$4.0\ 10^{-8}$

APPENDIX 3. ABBREVIATIONS

AEA	Atomic Energy Authority
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BNFL	British Nuclear Fuels plc
BNS	Babcock Naval Services
CBC	Copeland Borough Council
CEC	Commission of the European Communities
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
DML	Devonport Royal Dockyard Ltd
DoENI	Department of Environment Northern Ireland
DoH	Department of Health
DPAG	Dounreay Particles Advisory Group
DSTL	Defence Science and Technology Laboratory
EA	Environment Agency
EC	European Commission
EHS	Environment and Heritage Service
EU	European Union
FEPA 85	Food and Environment Protection Act 1985
FSA	Food Standards Agency
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IC	Imperial College
ICRP	International Commission on Radiological Protection
MAFF	Ministry of Agriculture, Fisheries and Food
MOD(N)	Ministry of Defence (Navy)
MRL	Minimum reporting level
ND	Not detected
NEA	Nuclear Energy Agency
NII	Nuclear Installations Inspectorate
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NRTE	Nuclear reactor test establishment
OBT	Organically bound tritium
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Commission
RIFE	Radioactivity in Food and the Environment
RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
TDS	Total Diet Study
THORP	Thermal Oxide Reprocessing Plant
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VLA	Veterinary Laboratories Agency
WELL	Winfrith Environmental Level Laboratory
WHO	World Health Organisation
YP	Ystradyfodwg and Pontpridd

APPENDIX 4. CONSUMPTION, INHALATION, HANDLING AND OCCUPANCY RATES

This appendix gives the consumption, handling and occupancy rate data used in the assessment of exposures from terrestrial consumption and aquatic pathways. Consumption rates for terrestrial foods are based on Byrom *et al*. (1995) and are given in Table A4.1. These are based on 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. Data used for 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 [b]
Amersham (1991)		1 kg y^{-1} pike 1600 h y^{-1} over riverbank
Berkeley and Oldbury (2001)		18 kg y^{-1} salmonids and other fish 2.3 kg y^{-1} shrimps 520 h y^{-1} over mud
Bradwell	A (1999)	44 kg y^{-1} fish 3.1 kg y^{-1} crustaceans 6.5 kg y^{-1} molluscs 2900 h y^{-1} over mud
	B (NA)	300 h y^{-1} over sediment
Capenhurst (NA)	10 year old children	500 h y^{-1} over sediment 5 10^{-3} kg y^{-1} sediment by inadvertent ingestion 20 l y^{-1} water by inadvertent ingestion
Cardiff	A (1998)	34 kg y^{-1} fish 1.4 kg y^{-1} prawns 990 h y^{-1} over mud and sand
	B (NA)	500 h y^{-1} over bank of the River Taff 2.5 10^{-3} kg y^{-1} sediment by inadvertent ingestion 35 l y^{-1} water by inadvertent ingestion
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

Table A4.2. continued

Site	Group[a]	Rates
Chapelcross (2000)	A	20 kg y^{-1} salmonids (80%) and other fish (20%)
		12 kg y^{-1} shrimps
		3.0 kg y^{-1} mussels
		1000 h y^{-1} over mud and sand
	B	500 h y^{-1} over salt marsh
	C	1100 h y^{-1} handling nets
Culham (NA)		600 l y^{-1} water
Derby (NA)		600 l y^{-1} water
Devonport (1992)		14 kg y^{-1} salmonids
		13 kg y^{-1} fish
		5 kg y^{-1} crustaceans
		2000 h y^{-1} over mud
Dounreay (1999)	A	1800 h y^{-1} handling pots
	B	19 kg y^{-1} fish
		14 kg y^{-1} crab and lobster
		2.2 kg y^{-1} winkles
	C	430 h y^{-1} over sand and rock
	D	25 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
		1400 h y^{-1} over mud and sand
Hartlepool (2002)		32 kg y^{-1} fish
		15 kg y^{-1} crab and lobster
		12 kg y^{-1} winkles and whelks
		910 h y^{-1} over mud
Harwell (1991)		1 kg y^{-1} pike
		650 h y^{-1} over river bank
Heysham (2001)		36 kg y^{-1} fish
		18 kg y^{-1} shrimps
		19 kg y^{-1} cockles and other molluscs
		1200 h y^{-1} over mud and sand
Hinkley Point (2000)		43 kg y^{-1} fish
		9.8 kg y^{-1} shrimps and prawns
		1.8 kg y^{-1} whelks
		960 h y^{-1} over mud
Holy Loch (1989)		900 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	1100 h y^{-1} over mud and sand
Sellafield	A (Sellafield fishing community) (2002)	51 kg y^{-1} cod (40%) and other fish (60%)
		16 kg y^{-1} crab (50%), lobster (30%) and *Nephrops* (20%)
		29 kg y^{-1} winkles (60%) and mussels (40%)
		1200 h y^{-1} over mud and sand
	B (Fishermen's nets and pots) (1998)	1200 h y^{-1} handling nets and pots
	C (Bait diggers) (1998)	950 h y^{-1} handling sand

Table A4.2. continued

Site	Group[a]	Rates
Sellafield (cont.)	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 1998-2002) (NA)	40 kg y^{-1} fish 13 kg y^{-1} crabs 6.0 kg y^{-1} lobsters 2.2 kg y^{-1} Nephrops 10 kg y^{-1} winkles 10 kg y^{-1} mussels 1100 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 2.49 10^{-5} kg y^{-1} mud and sand by resuspension and inhalation
	P (Typical beach user) (NA)	30 h y^{-1} over sand
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)	3000 h y^{-1} over mud 0.015 kg y^{-1} mud by inadvertent ingestion 2.49 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 490 h y^{-1} over sand
	B	1800 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 (1987)		77 kg y^{-1} cod 26 kg y^{-1} crab 39 kg y^{-1} whelks 300 h y^{-1} over sediment

Table A4.2. continued

Site	Group[a]	Rates
Wylfa (1988)		94 kg y^{-1} fish 23 kg y^{-1} crab 1.8 kg y^{-1} molluscs 370 h y^{-1} over sand

[a] *Where more than one group exists at a site the groups are denoted A, B, etc. Year of habits survey is given where appropriate*
[b] *Not assessed in this report for 2002*
NA not applicable

APPENDIX 5. DOSIMETRIC DATA [ICRP 72]

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

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 (0.0030-0.55)	0.02 (0.013-2.4)	0.24 (0.043-0.76)	0.080 (0.02-0.79)	1.2 (0.18-6.8)	1.5 (0.69-2.6)	1.6 (0.68-6.8)	0.94 (0.59-1.3)	0.39 (0.18-0.61)	1.5 (0.68-4.9)
Polonium-210	0.82 (0.18-4.4)	9.1 (1.1-35)	19 (4.1-35)	5.3 (1.9-10)	17 (1.2-69)	13 (6.1-25)	42 (19-69)	18 (11-36)	6.5 (1.2-11)	8.4 (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. CONCENTRATIONS OF RADIONUCLIDES IN SEDIMENT FROM HEYSHAM APPROACHES, LANCASHIRE, 2002

Location		Radioactivity concentration (dry), Bq kg^{-1}									
Lat	Long	^{40}K	^{60}Co	^{106}Ru	^{137}Cs	^{212}Pb	^{214}Bi	^{226}Ra	^{228}Ac	^{234}Th	^{241}Am
54 00.93' N	2 56.70' W	350	0.86	<2.5	34	9.3	6.0	7.9	8.1	*	31
54 00.98' N	2 56.86' W	330	0.82	5.2	28	8.1	5.9	7.4	7.2	*	27
54 01.08' N	2 56.78' W	330	0.78	<2.6	30	8.8	6.0	7.7	8.1	*	27
54 01.03' N	2 56.57' W	340	<0.27	<2.6	20	7.7	5.4	6.9	6.6	*	18
54 00.96' N	2 56.68' W	340	0.59	<2.6	29	8.3	5.6	7.3	7.9	*	29
54 01.04' N	2 56.61' W	340	0.62	<2.5	27	8.3	5.7	7.3	7.4	*	25

* *Not detected by the method used*

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