RIFE - 5

Radioactivity in Food and the Environment, 1999

Food Standards Agency

SEPA
SCOTTISH ENVIRONMENT PROTECTION AGENCY

2000

FOOD STANDARDS AGENCY
SCOTTISH ENVIRONMENT PROTECTION AGENCY

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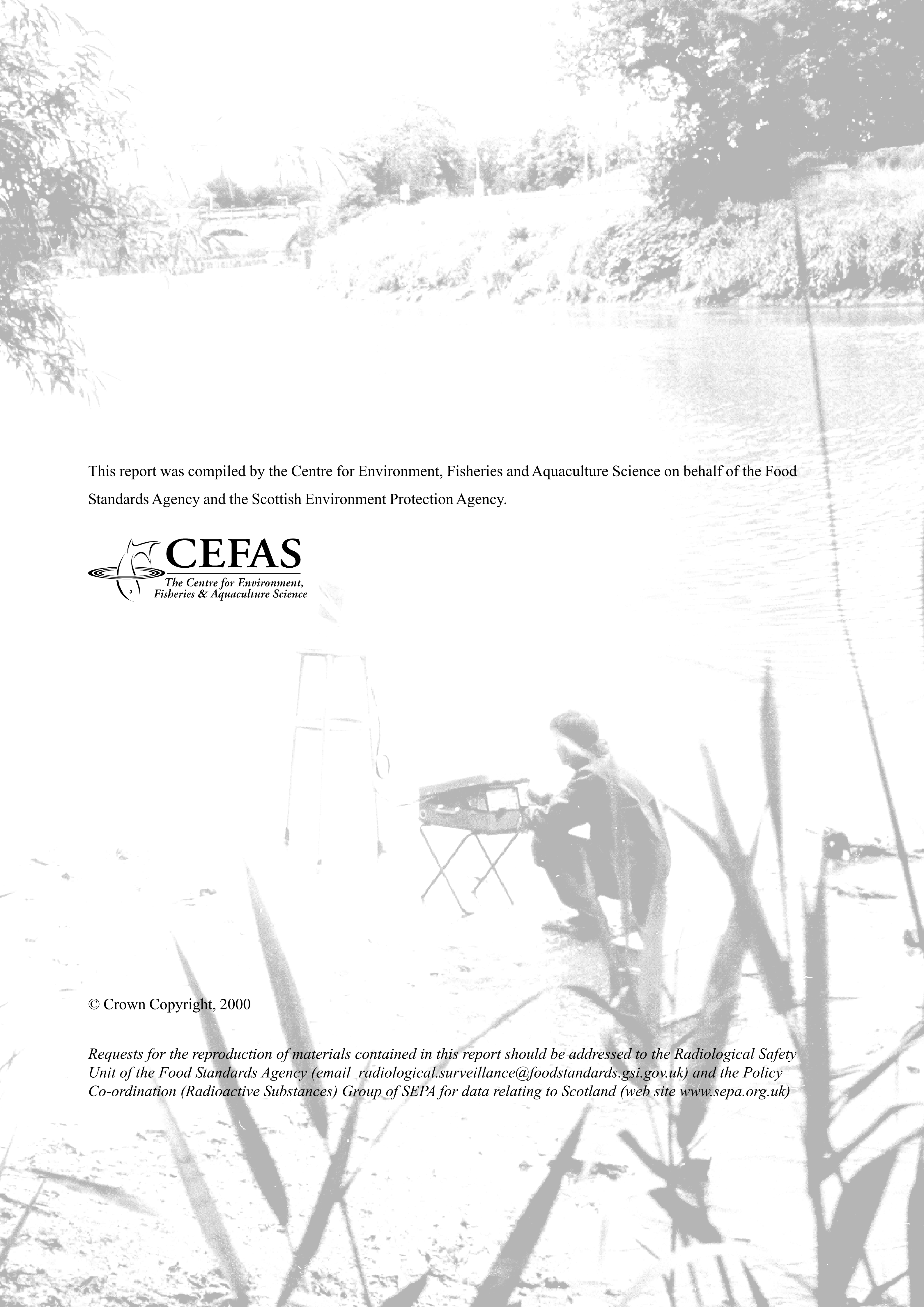
September 2000



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

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

FOREWORD

The safety of food and protection of the environment continue to be important issues on the Government's agenda. Radioactivity in food and the environment, a source of potential harm, therefore receives continuous surveillance to ensure that public safety targets and international commitments are met and ensure that the consumer and the environment are effectively protected. The Government makes the results of such surveillance widely available through publication of this report and through regular updates on the Food Standards Agency Web site. This technical report presents the scope and results of the radiological surveillance programmes for 1999. It is complemented by the Environment Agency's surveillance report on non-food pathways in England and Wales.

The Food Standards Agency and the Scottish Environment Protection Agency undertake measurements of radioactivity on a wide range of foodstuffs and in the environment around nuclear sites and other potential sources of elevated radioactivity throughout the United Kingdom. Measurements are also reported for the analysis of radioactivity in the national food supply.

This report demonstrates that the public is not exposed to unacceptable contamination of the foodchain. We remain committed to ensuring that a proper and rigorous surveillance programme is continued to ensure that this remains the case.

Professor Sir John Krebs
Chairman, Food Standards Agency

Mr Ken Collins,
Chairman, Scottish Environment Protection Agency (SEPA)

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EXECUTIVE SUMMARY

Radiation Safety – Food and the Environment at Nuclear Sites

This report combines data from both the Scottish Environment Protection Agency's (SEPA's) and the Food Standards Agency's* monitoring programmes for radioactivity in food and the environment in 1999. Both programmes demonstrate that, in terms of radioactive contamination, terrestrial foodstuffs and seafood produced in and around the United Kingdom are considered safe to eat. Exposure of consumers to artificially produced radioactivity via the food chain remained well below the statutory United Kingdom principal annual dose limit to members of the public of 1 mSv (millisievert) for all artificial sources of radiation (except medical sources), EU limits and Government targets.

In Scotland SEPA's monitoring programme also sets out to determine levels of man-made radioactivity within the environment by using a number of environmental indicators. The foodstuffs collected as part of SEPA's programme act both as indicators of the health of the environment and to verify that the levels of radioactivity present within foodstuffs have low radiological significance.

The highest doses were received by a group of high-rate consumers of fish and shellfish in Cumbria. The doses contain contributions from liquid discharges from both Sellafield and from the Rhodia Consumer Specialties Ltd. (formerly Albright and Wilson) Plant at Whitehaven. The dose to these high-rate consumers from Sellafield discharges were estimated to be 0.21 mSv in 1999 as compared with 0.20 mSv in 1998 (MAFF and SEPA, 1999). This small increase was largely due to changes in the habits of high-rate consumers of seafood. This critical group also received an estimated dose of 0.44 mSv from enhanced levels of natural radioactivity due to operations at the Rhodia Consumer Specialties Ltd. works at Whitehaven. As these doses are for the critical group by definition others will receive lower doses.

Within Scotland the highest doses were also attributable to liquid discharges from Sellafield and were received by a group of high-rate fish and shellfish consumers in the Dumfries and Galloway area. The estimated dose was 0.028 mSv, less than the 0.048 mSv estimated for 1998 (MAFF and SEPA, 1999). The reduction was largely due to a general decline in radionuclide concentrations in Scottish seafood consumed by the critical group.

The highest food doses arising from gaseous discharges were also calculated to be from the Sellafield site. High-rate terrestrial food consumers received an estimated dose of 0.044 mSv, similar to the dose in 1998. The assessment covered consumption of milk, vegetables, fruit and meat.

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 around 8% of the dose to the Sellafield seafood consumers.

Heysham high-rate seafood consumers are estimated to receive 0.071 mSv but most of this was attributed to Sellafield discharges. Therefore the nuclear site of next importance, with regard to public exposures from site discharges, was Nycomed Amersham in Cardiff where radiochemicals for research, medicine and industry are produced. Doses to high-rate seafood consumers at Cardiff were estimated to be 0.053 mSv in 1999. Most of the dose to Cardiff high-rate seafood consumers was due to tritium and carbon-14 in fish from the Bristol Channel. Research is underway to determine the mechanisms whereby tritium from this site accumulates in seafood. Such accumulation has not been observed to the same extent at other sites in the United Kingdom. Some sea-to-land transfer of tritium is taking place at Cardiff but the resulting exposures are substantially less than those of direct consumption of seafood.

Assessed doses at all major sites in the United Kingdom are shown in Figure S and are detailed in the Table overleaf.

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* *The Food Standards Agency began operation in April 2000. It is responsible for food safety issues in the UK. Previously MAFF was responsible for the RIFE programme. This responsibility thus now lies with the Food Standards Agency. For simplicity in this report we have referred to the pre-existing MAFF studies as being those of the Food Standards Agency.*

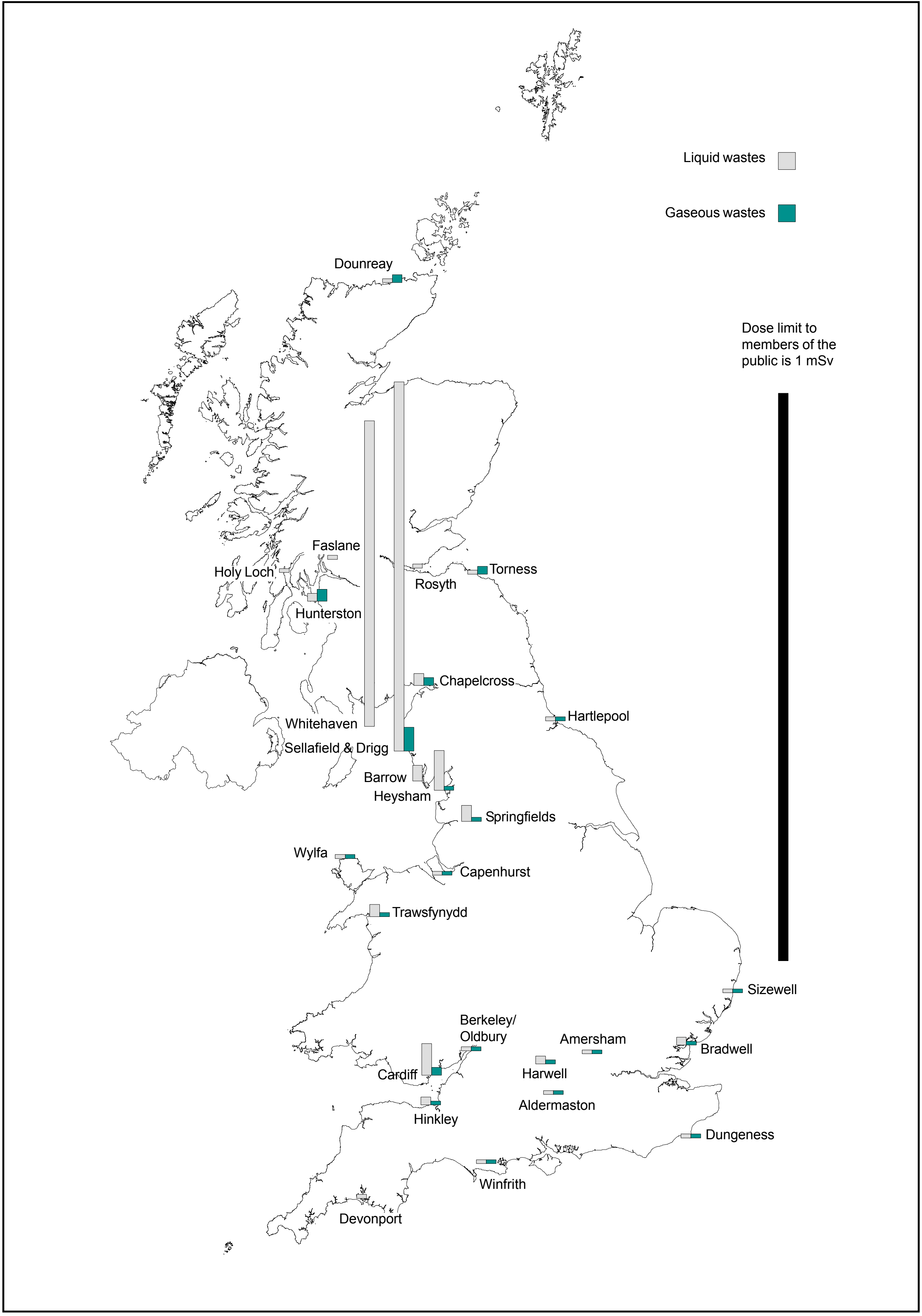

Figure S. ***Radiation exposures in the UK due to radioactive waste discharges, 1999 - Food Standards Agency and SEPA surveillance (Exposures at Whitehaven and Sellafield include the effects of artificial and enhanced natural nuclides from nuclear and non-nuclear industries)***

Summary Table: Radiation doses due to discharges of radioactive waste in the United Kingdom, 1999[k]

Establishment	Radiation exposure pathway	Critical group	Exposure, mSv[a]	Contributors[c]
British Nuclear Fuels plc[h]				
Sellafield and Drigg[b]	Fish and shellfish consumption and external	Local fishing community	0.21	$^{239/240}Pu$ ^{241}Am
	Terrestrial foods	Local consumers at Sellafield	0.044	^{90}Sr ^{106}Ru
	Terrestrial foods	Local consumers at Drigg	0.020	^{90}Sr ^{106}Ru
	Terrestrial foods	Local consumers at Ravenglass	0.026	^{60}Co ^{106}Ru
	External	Farmers	0.081	Ext
	External (skin)	Anglers	0.18[d]	Beta
	Handling of fishing gear	Local fishing community	0.11[d]	Beta
	Porphyra/laverbread consumption	Consumers in South Wales	<0.005	^{106}Ru ^{241}Am
	Trout consumption	Local consumers at Sellafield	<0.005	^{137}Cs ^{241}Am
	Seaweed/crops	Local consumers at Sellafield	0.032	^{99}Tc ^{241}Am
Springfields	External	Farmers	0.024	Ext
	External (skin)	Local fishermen	0.81[d]	Beta
	Fish and shellfish consumption and external	Local fishing community	0.026	Ext ^{137}Cs
	Terrestrial foods	Local consumers[j]	<0.005[f]	^{90}Sr ^{232}Th
Capenhurst	Inadvertent ingestion of water and sediment	Local community	<0.005	U ^{241}Am
	Terrestrial foods	Local consumers	<0.005	^{3}H U
Chapelcross	Fish and shellfish consumption and external	Local fishing community	0.021	Ext ^{137}Cs
	External	Wildfowlers	0.012	Ext
	Terrestrial foods	Local consumers	0.017	^{3}H ^{35}S
United Kingdom Atomic Energy Authority				
Dounreay	Fish and shellfish consumption	Local fishing community	<0.005	^{99}Tc ^{106}Ru
	External	Local community	<0.005	Ext
	Terrestrial foods	Local consumers[j]	0.016	^{90}Sr ^{129}I
Harwell	Fish consumption and external	Anglers	0.012	Ext ^{137}Cs
	Terrestrial foods	Local consumers	<0.005	^{3}H
Winfrith	Fish and shellfish consumption	Local fishing community	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods	Local consumers	<0.005	^{3}H
Electricity Companies[h]				
Berkeley and Oldbury	Fish and shellfish consumption and external	Local fishing community	<0.005	Ext ^{3}H
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Bradwell	Fish and shellfish consumption and external	Houseboat dwellers	0.014	Ext ^{241}Am
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Dungeness	Fish and shellfish consumption and external	Bait diggers	0.010	Ext ^{241}Am
	Terrestrial foods	Local consumers[g]	0.005	^{14}C ^{137}Cs
Hartlepool	Fish and shellfish consumption and external	Local fishing community	<0.005	Ext ^{241}Am
	Terrestrial foods	Local consumers	0.006	^{14}C ^{35}S
Heysham	Fish and shellfish consumption and external	Local fishing community	0.071	Ext ^{241}Am
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Hinkley Point	Fish and shellfish consumption and external	Local fishing community	0.011[i]	Ext ^{3}H
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Hunterston	Fish and shellfish consumption and external	Local fishing community	0.015	^{137}Cs ^{241}Am
	Terrestrial foods	Local consumers	0.019	^{35}S ^{90}Sr
Sizewell	Fish and shellfish consumption and external	Local fishing community	<0.005	^{14}C ^{241}Am
	Terrestrial foods	Local consumers	<0.005	^{35}S ^{137}Cs

Summary Table: continued

Establishment	Radiation exposure pathway	Critical group	Exposure, mSv[a]	Contributors[c]
Electricity Companies *continued*				
Torness	Fish and shellfish consumption	Local fishing community	<0.005	^{137}Cs ^{241}Am
	External	Local community	<0.005	Ext
	Terrestrial foods	Local consumers	0.015	^{35}S ^{90}Sr
Trawsfynydd	Fish consumption and external	Local fishing community	0.021	Ext ^{137}Cs
	Terrestrial foods	Local consumers[j]	<0.005	^{90}Sr ^{137}Cs
Wylfa	Fish and shellfish consumption and external	Local fishing community	0.007	^{137}Cs ^{241}Am
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Defence Establishments				
Aldermaston	Fish consumption and external	Anglers	<0.005	^{3}H ^{137}Cs
	Terrestrial foods	Local consumers	<0.005[f]	^{3}H U
Barrow	External	Local community	0.025	Ext
Devonport	Fish and shellfish consumption and external	Local community	0.009	Ext ^{241}Am
Faslane	Fish and shellfish consumption and external	Local community	<0.005	^{137}Cs ^{241}Am
Holy Loch	External	Local community	0.005	Ext
Rosyth	External	Local community	<0.005	Ext
Nycomed Amersham plc				
Amersham	Fish consumption and external	Anglers	<0.005	Ext ^{241}Am
	Terrestrial foods	Local consumers	0.008	^{75}Se ^{131}I
Cardiff	Fish and shellfish consumption and external	Local fishing community	0.053	^{3}H ^{14}C
	Terrestrial foods	Local consumers	0.015	^{3}H ^{14}C
Rhodia Consumer Specialties Ltd				
Whitehaven[e]	Fish and shellfish consumption	Local fishing community	0.47	^{210}Po ^{210}Pb

[a] *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. All exposures for terrestrial pathways include a component from radionuclides which were found to be below the limits of detection. Unless stated otherwise, the critical group for terrestrial pathways is represented by the 1 year old age group*

[b] *The estimates for marine pathways include the effects of liquid discharges from Drigg, but exclude the effects of natural radionuclides. The contribution due to Drigg is negligible. The exposure due to enhanced concentrations of natural radionuclides for seafood consumers in 1999 was* 0.44 *mSv*

[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] *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)*

[e] *These estimates include the effects of enhanced concentrations of natural radionuclides but exclude a small contribution from the effects of artificial radionuclides from other sites. They assume a gut uptake factor of 0.8 for polonium which is based on studies of seafood consumption (see section 3). The exposure due to artificial radionuclides in 1999 was 0.064 mSv*

[f] *Includes a component due to natural sources of radionuclides*

[g] *Adults*

[h] *Some power stations are operated by Magnox Electric (a wholly owned subsidiary of BNFL plc)*

[i] *Excludes the effects of direct radiation from the site*

[j] *15 y old*

[k] *The Environment Agency publish supplementary information for some non-food pathways in England and Wales*

Radioactivity levels at nuclear sites

No significant changes in radioactive contamination of food or external dose rates were observed in 1999. Levels of technetium-99 in lobsters from the vicinity of Sellafield were again above those specified in the EU Directive setting post-accident intervention levels* but there has been some decline in levels as a result of reduced discharges to sea. The assessed dose to the most exposed group of seafood consumers from technetium-99 discharges was less than 2% of the principal dose limit for members of the public of 1 mSv. Sea-to-land transfer of technetium-99 occurred on a small scale via the harvesting of seaweed for use as a soil conditioner and fertiliser.

Site incidents and non-routine sampling

In February 1998, MAFF was informed of contaminated feral pigeons near the Sellafield site. Remedial measures, including a substantial cull of pigeons in the area, have been taken by BNFL. Nevertheless 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 Sellafield site. This advice is still current and has been confirmed by the Food Standards Agency.

The Waste Vitrification Plant at Sellafield was evacuated in January 1999. At the same time an unusual gaseous release of caesium-137 took place. Grass samples were collected and sent for analysis as a precaution. No increase above the normal Sellafield environmental background was detected.

In 1999 a further four fuel fragments were recovered from Sandside Bay near to the Dounreay site. The fishing restrictions under the Food and Environment Protection Act 1985 (United Kingdom Parliament, 1985) are still in force.

Remediation of a small beach in front of the Dounreay Fast Reactor was carried out at Dounreay by UKAEA resulting in the generation of 200 m^3 of radioactive waste. SEPA carried out independent monitoring before and after the remediation to confirm the success of the exercise.

Special sampling was carried out at Chapelcross in 1999 to investigate a localised area of contamination on the nuclear site associated with the liquid discharge route and the possibility of runoff from the site into adjacent surface water courses. In both cases no significant risk to the public was found.

Radiation doses and levels at other locations in the UK

Analyses of food throughout the United Kingdom in the general diet demonstrated that natural radionuclides were by far the most significant source of exposure from radiation to communities in areas remote from nuclear sites. Monitoring of artificial radioactivity on the Isle of Man and in Northern Ireland showed that doses were all less than 3% of the 1 mSv limit. A survey on the Channel Islands confirmed that doses due to discharges from the French reprocessing plant at La Hague and other local sources were less than 1% of the limit.

Concentrations of natural radionuclides in fish and shellfish near Whitehaven Works (Rhodia Consumer Specialties Ltd.) continued to be enhanced above normal levels. Making maximising assumptions about the level of enhancement, doses to high-rate seafood consumers, including the effects of artificial radionuclide discharges from the Sellafield site nearby, were estimated to be 0.54 mSv for the most exposed group at Whitehaven.

* *These levels apply only after an accident and do not cover routine discharges. It is worth noting that two other radionuclides with relatively low dose coefficients, comparable to that of technetium-99 (tritium and carbon-14) are exempted from these intervention levels. Government policy is explained in Section 3.5.*

The programme of monitoring the effects of discharging gaseous wastes at other non-nuclear industrial sites continued. Significant enhancement of tritium and carbon-14 was found in grass near Blychem Ltd., Billingham. Other sites discharge radioactive waste in the Billingham area. An initial estimate of dose to hypothetical high rate consumers near the site was 0.094 mSv. Further sampling in this area is planned in 2000. There was no evidence for enhancement of radionuclides near other non-nuclear industrial sites discharging gaseous wastes.

Tritium was found in leachate from some landfill sites but the radiological significance of the levels was negligible.

The surveillance programmes

The programmes involved the collaboration of four 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 SEPA, the Food Standards Agency and CEFAS. The programme includes monitoring undertaken on behalf of the Scottish Executive, Channel Island States, MAFF, the Environment and Heritage Service for Northern Ireland, the Manx Government and the National Assembly for Wales. This year's programmes required the collection of 2000 food samples and 3100 other samples as indicators of environmental levels. 21000 analyses or dose rate measurements were completed.

Results of samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries on the Internet (www.foodstandards.gov.uk). Further details of all programmes described in this report can be obtained by telephoning the Food Standards Agency on **020 7238 6177** or SEPA on **01786 457 700**.

Research

The surveillance programme is underpinned by applied research to improve analytical and assessment methods, to check for unusual or changing exposure pathways and to ensure that all sources of exposure are being addressed. Links to the results of the research are provided in the report.

1. INTRODUCTION

1.1 Background

This report contains the results of foodstuff and dose rate monitoring throughout the United Kingdom, the Channel Islands and the Isle of Man. In April 2000 the Food Standards Agency was formed, taking over the responsibilities previously held by the Ministry of Agriculture, Fisheries and Food (MAFF), Department of Health (DoH) and the National Assembly for Wales in relation to food safety. In Scotland, the Scottish Environment Protection Agency (SEPA) has continued to be responsible for environmental protection matters. This report is published jointly by the Food Standards Agency and SEPA.

The data in this report cover the calendar year of 1999. The results of the programmes have been assessed by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) on behalf of and agreed with the Food Standards Agency, SEPA, MAFF, the National Assembly for Wales, the Environment and Heritage Service (Northern Ireland), the Manx Government and the Channel Island States.

The purpose of the programme is to determine that the levels of radioactivity in foodstuffs are not unacceptable, and that public radiation exposure from the consumption of these foods is also not unacceptable and within United Kingdom and internationally accepted limits. In Scotland, SEPA has a broader responsibility (under the Environment Act 1995 (United Kingdom - Parliament, 1995a)) for protecting (and determining general levels of pollution in) the environment and the data reported here are also used to assess environmental impact.

The monitoring is independent of similar programmes carried out by nuclear site operators as a condition of their authorisations to discharge radioactive wastes. This monitoring can also include the analysis of radioactivity in foods as well as environmental indicators. The majority of the report concerns the local effects of disposals from nuclear sites in the United Kingdom. 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 in areas of the United Kingdom remote from nuclear sites, is included. For Scotland, all monitoring of the environment that is carried out is also included in this report. 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 Cotter *et al*. (1992).

To set the monitoring results from the programme in context, radioactive waste disposals from nuclear establishments in the United Kingdom for 1999 are first addressed in section 1.2. Before the results 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. A glossary of terms and abbreviations is provided in Appendix 3.

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from nuclear sites

Data on United Kingdom radioactive waste discharges (disposals) are published annually by the Department of Environment, Transport and the Regions (DETR, 1998), the latest available publication being for the year 1996. Details of the disposals from individual sites are available from public records held by SEPA and the Environment Agency. These agencies are responsible for authorising discharges in Scotland, and in England and Wales respectively under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993). A summary of 1999 disposals is included in Appendix 1 which enables the results of monitoring presented in this report to be considered in the context of the relevant disposals.

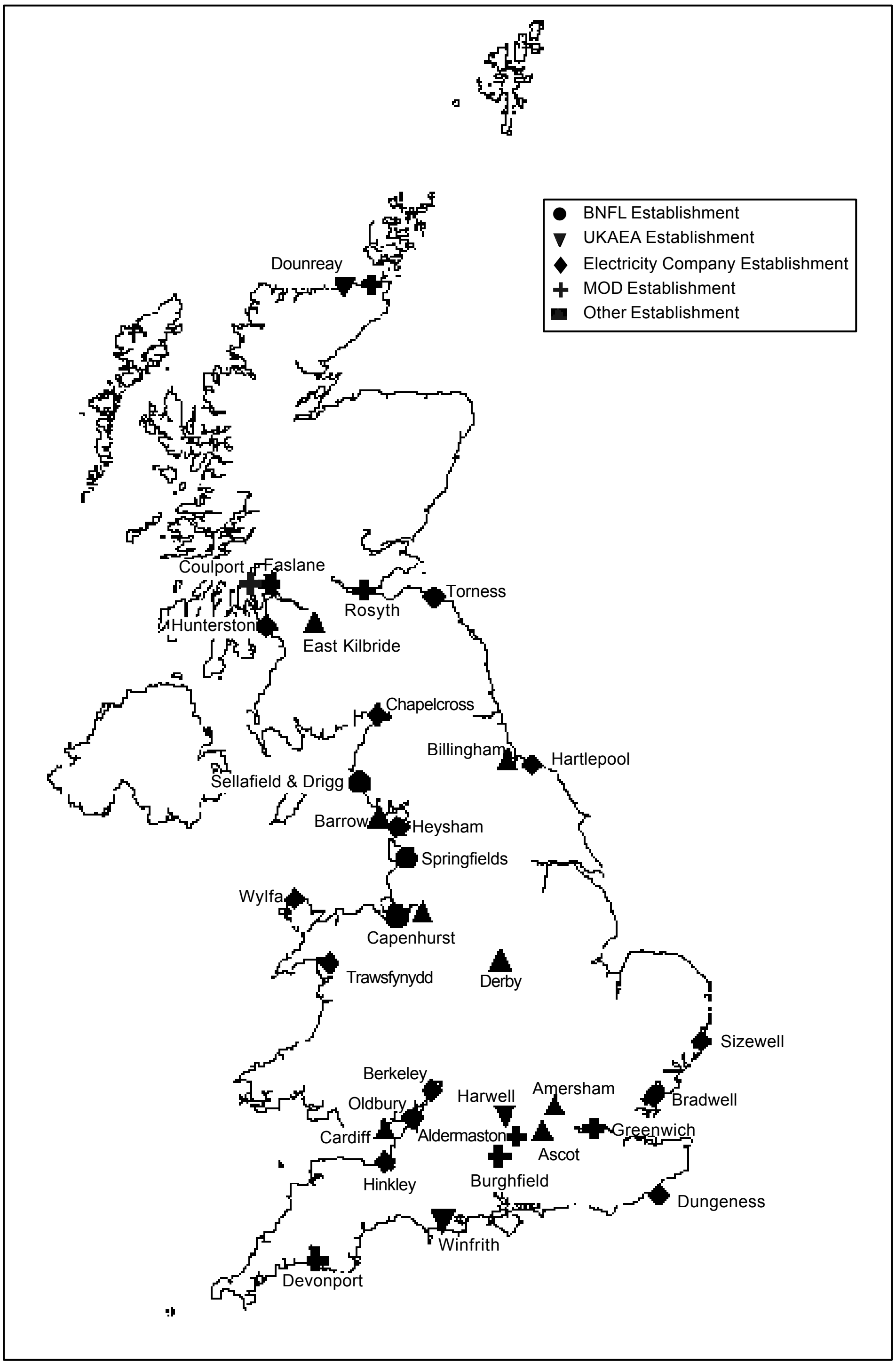

Figure 1.1. Principal sources of radioactive waste disposal in the UK

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 disposals of radioactive waste are also authorised under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993) from other sites such as hospitals, chemical works and research establishments. Occasionally the impact of such disposals 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. The non-nuclear licensed sites are not subject to the additional controls provided for by the Nuclear Installations Act 1965 (United Kingdom - Parliament, 1965). As noted in Figure S and the Summary Table there is a significant impact from the non-nuclear site at Whitehaven although in general disposals from non-nuclear are considered insignificant and as such environmental monitoring of their effects is often not required. However, this situation is reviewed from time to time and small surveys are included in the programme where relevant.

Appendix 1 presents the principal disposals of liquid, gaseous and solid radioactive waste respectively from nuclear establishments in the United Kingdom during 1999. The tables also list the 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 an exposure equivalent to the dose limits which are recommended by the International Commission on Radiological Protection (ICRP), and embodied in national policy (United Kingdom - Parliament, 1995b). The percentages of the authorised (or agreed) limits taken up in 1999 are also stated in the tables.

Where changes in the rates of disposal in 1999 have affected the levels of radioactivity in the environment, this is addressed in the relevant part of the subsequent text.

The Government regards it as important that there should be progressive and substantial reductions in the discharges of radioactive waste to sea. In July 1998 the Government signed the Sintra Statement which included the following commitment (OSPAR, 1998):

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

In achieving this objective the following issues should be taken into account:

- legitimate uses of the sea
- technical feasibility
- radiological impacts to man and biota

During 2000 the DETR published the draft National Discharge Strategy (NDS) for consultation (DETR, 2000). The NDS discusses the implementation of the requirements for progressive reductions in discharges.

1.2.2 Past disposals of solid radioactive waste at sea

In the past, there have also been disposals of packaged solid waste of low specific activity, mainly to an area of the deep Atlantic Ocean. The last such disposal was in 1982. The Government formally announced that the cessation of disposal of such material at sea was permanent at the OSPAR Ministerial meeting 1998 (OSPAR, 1998) when all Contracting Parties agreed that there would no longer be any exception to a prohibition on the dumping of radioactive substances, including wastes. The environmental impact of the deep ocean disposals is predicted by detailed mathematical modelling and has been shown to be negligible (OECD (NEA), 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 1999 are presented in Section 11.3, which confirms that the radiological impact of these disposals was insignificant.

MAFF issues licences to operators for the disposal of dredge spoil 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 spoil may contain radioactivity, assessments are undertaken where appropriate for assurance that there is no significant foodchain or other risk from the disposal. In 1999, a specific assessment of the disposal of spoil from a harbour at Whitehaven in Cumbria was carried out. Whitehaven harbour is known to contain measurable quantities of enhanced natural and artificial radionuclides. Samples of the material were taken and analysed and the results are given in Appendix 7. The assessment showed that the input of radioactivity associated with the disposal operation did not give cause for concern since it was small compared to other sources of radioactivity in the marine environment. In addition, surveillance near the dredge spoil disposal area after disposal had taken place has shown no increase in radioactivity. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA, 1999).

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, release from overseas installations and the operation of nuclear powered submarines. Submarine berths in the United Kingdom are monitored by the Ministry of Defence (DRPS, 1999). General surveillance 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 1999. Small enhancements in environmental levels were detected in the Channel Islands due to discharges from the nuclear fuel reprocessing plant at La Hague. These are discussed further in Section 11.3.

2. SAMPLING AND MEASUREMENT

2.1 Sampling programme

The primary purpose of the Food Standards Agency programme is to monitor the safety of the food chain. In order to assess the total radiation dose received by a member of the public, for comparison with dose limits, samples from the environment are also taken. In this context the term sampling includes the collection of samples from the environment for laboratory analysis (which is mainly directed at food pathways), and also selective direct measurements in the environment of dose rates to assess external exposure pathways. Subsidiary objectives for the programme are: (i) to establish a baseline from which to judge the importance of accidental releases of radioactivity should they occur; (ii) to determine whether undeclared releases of radioactivity have occurred from sites; and (iii) to provide information on radioactivity in the diet of the general population and to aid calculation of collective radiation exposures to the population as a whole.

The primary purpose of the SEPA programme is to determine the levels of man-made radionuclides in the environment in order to assess the affects on human health as well as that of the environment. The programme also acts as an additional check for compliance with conditions in authorisations and provides a baseline dataset from which to judge the importance of accidental releases of radioactivity, should they occur. The programme also provides information on radioactivity in the environment and diet of the general Scottish population and aid calculation of collective radiation exposures to the population as a whole.

Sampling is focused on nuclear sites licensed by the Health and Safety Executive under the Nuclear Installations Act, 1965 (United Kingdom - Parliament, 1965). The programme also serves to provide information to assist the Environment Agency and SEPA 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 and the environment. Results from this sampling generate data that can be used as background levels to compare with results from around nuclear sites. Measurements can be affected by disposals of radioactive waste from nuclear sites abroad and show the legacy of atmospheric fallout from past nuclear weapon testing and the nuclear reactor accident at Chernobyl in the Ukraine.

The programmes 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 these sectors is summarised in Table 2.1 and described in the following sub-sections.

2.1.1 Nuclear sites

Nuclear sites are the prime focus of the programme as individually they are responsible for the largest disposals of radioactive waste. Monitoring is carried out close to each of the sites shown in Figure 1.1. Most food chain sampling and direct monitoring is conducted in the site's immediate vicinity. 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 relation to site incidents. The results of both routine and additional monitoring are included in this report.

2. Sampling and measurement

The main aim of the programme is to monitor the diet of consumers 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. The drinking water pathway is of interest for inland nuclear sites, which are found in England and Wales. This pathway is considered as part of the Environment Agency programme (Environment Agency, 1999). Inhalation of airborne activity and external exposure from airborne material and surface deposition are difficult to assess by direct measurement and are better assessed using environmental models. The main thrust of the monitoring is therefore directed at a wide variety of foodstuffs and measurements of external exposures on the shores of seas, rivers and lakes. It also includes some key environmental indicators, often where there is a database so that levels found in the environment can be put in an historic context.

The description of the work undertaken can be conveniently divided into two 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 disposals to the atmosphere.

From January 1998 onwards, the responsibility for the bulk of surveillance of external exposure from radioactive waste disposals in England and Wales passed to the Environment Agency who publish their results in a separate report. However, as part of SEPA's programme the RIFE report continues to provide external exposure information for Scotland. Where appropriate this report also contains external exposure data for England and Wales in order to give a holistic approach to high-rate consumers' protection and assurance for the farming and fishing communities.

The aquatic programme

The general scope of the aquatic programme in 1999 is summarised in Table 2.2. The main components were sampling and laboratory analysis of a wide range of seafood and indicator materials (see below) and selected direct measurements of external dose rates in areas of known or suspected contamination and where public occupation occurs or is likely to occur. In both cases the frequency of measurement depends on the level of environmental impact from the source under scrutiny, the intervals between measurements varying between 1 week and 1 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 indeed from year to year, according to local circumstances.Within England, Scotland and Wales large areas of sediment within the intertidal area are selected by SEPA and the EA to determine if there are any areas of unusual localised radioactivity which have not been detected by the monitoring programmes conducted by SEPA and the EA.

SEPA and the EA often measure indicator materials, such as sediments and seaweeds, which 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 (sometimes referred to as "environmental indicators"). In the case of sediments, there is an immediate use for activity concentration data in assessments. Such data can also be used to help distinguish contributions to the overall dose rates from artificial and natural radionuclides and different sources of artificial radioactivity using the characteristic radionuclide signatures.

Data from the aquatic programme are also used to aid the development of models for assessment of future (prospective) doses from planned discharges. This is important for deciding on the acceptability of revised or new discharge authorisations.

The terrestrial programme

The general scope of the terrestrial programme in 1999 is summarised in Table 2.2. The main focus of this programme is the sampling and analysis of foodstuffs that may be affected by disposals to atmosphere, although in some cases where food availability is limited, environmental indicator materials such as grass are monitored.

The types of foodstuff sampled are chosen on a site-by-site basis to reflect local availability, and to provide information on: (i) the main components of diet; 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 radioactivity, may also be sampled when available.

For monitoring purposes, cows' milk is generally the most important foodstuff as grass is an efficient collector of atmospheric contaminants, cows graze significant areas of grass and many of the more important radionuclides are rapidly passed from grass into milk. 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. In addition, cows graze a large area of pasture and therefore the monitoring of milk provides a method of carrying out surveillance of large areas. For most analyses of milk, weekly or monthly collections are combined (bulked) to provide four quarterly samples for analysis each year, although some analyses may be carried out more frequently, such as weekly iodine-131 analysis. Annual bulking of some samples is carried out for analysis of tritium, C-14 and caesium ratios. The frequency of analysis of other foodstuffs is generally annual. This allows for a wide range of sample types to be collected throughout the year. Samples are collected from locations as close to the sites as practicable as these are usually the most sensitive to the effects of disposals. In the case of milk, sampling may take place at several farms and these are labelled either as 'near' or 'far' in the tables of results depending on their distance from the site. The threshold for distinguishing between 'near' and 'far' farms is that 'near' farms are up to 8 km from the site, with 'far' farms 8-16 km from site.

'Dry cloth' detectors, positioned around the nuclear sites are analysed for airborne radionuclides that have become entrapped in the cloth. Further details are given in section 2.2.3.

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 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 sites considered in 1999 are shown in Figure 2.1.

Industrial sites are chosen because either they are known from previous research to have a measurable radiological impact on the food chain or they represent a type of industrial activity that has potential effects on the environment/food chain. These sites do not require licensing under the Nuclear Installations Act. In 1999, the industrial sites studied were:

- Whitehaven, Cumbria (a phosphate plant)
- Avonmouth, Avon (clinical waste incinerator)
- Basildon, Essex (hospital)
- Billingham, Cleveland (manufacture of radiochemicals)
- Plymouth, Devon (clinical waste incinerator)
- Redcar, Cleveland (steel works)
- Welwyn Garden City, Hertfordshire (manufacture of radiochemicals)

In the case of the Whitehaven site, the survey was directed at seafood and marine sampling and analysis. At the other sites monitoring of grass, soil or animals took place because the main interest was the terrestrial food chain.

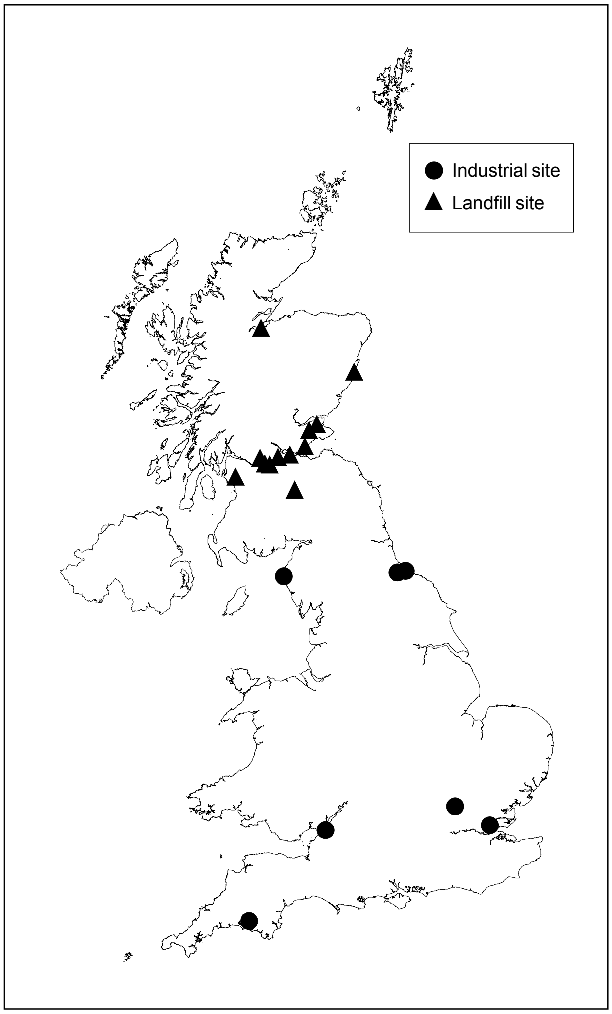

Figure 2.1. Industrial and landfill sites studied in 1999 (Landfill sites in England and Wales are monitored by the Environment Agency and are therefore not covered in this report)

Twelve landfill sites were monitored in Scotland. These sites are approved for disposal of very low levels of radioactivity. They are studied to assess the extent, if any, of the contamination leaching from the site and re-entering the terrestrial environment and hence the food chain. Monitoring of landfill sites in England and Wales was undertaken by the Environment Agency.

2.1.3 Chernobyl fallout

The main effort to monitor the effects of the 1986 Chernobyl accident was in relation to the continuing restrictions on the movement, sale and slaughter of sheep in Cumbria, north Wales and parts of Scotland and Northern Ireland. Monitoring of other foodstuffs is now at a much-reduced rate as levels have declined dramatically 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 United Kingdom, 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 Isle of Man and the Channel Islands;
- dietary surveys;
- sampling of milk, crops, bread and meat;
- drinking water and airborne particulates in Scotland;
- seawater surveys.

Isle of Man and the Channel Islands

The programmes for the Insular States are designed to complement that for the United Kingdom and to take account of the possibility of long-range transport of radionuclides.

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.

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 United Kingdom and French disposals into the English Channel and historic disposal of solid waste in the Hurd Deep.

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. Representative mixed diet samples are collected from regions throughout the United Kingdom. In England and Wales the samples are derived from the Food Standards Agency's Total Diet Study (TDS). Normal culinary techniques are used in preparing samples (e.g. removal of outer leaves) and samples are combined in amounts that reflect the relative importance of each food in the average United Kingdom diet. These samples are analysed for a range of contaminants including radionuclides. Part of this data is also supplied to the European Commission (EC) in support of the Euratom Treaty.

Specific foods, freshwater, 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 and airborne particulates in Scotland are also analysed to add to our 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 United Kingdom in 1999. Samples are taken monthly and some of the results are reported to the EU to allow comparison with those from other member states.

Other food sampling complements the regional dairy programme described above. Crop samples were taken from locations covering areas throughout the United Kingdom. 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.

Drinking water was sampled throughout Scotland. The results of monitoring of drinking water in England and Wales are summarised in the Environment Agency's Annual Report (Environment Agency, 1999). Airborne particulates are sampled monthly in Glasgow for SEPA.

Seawater surveys

Seawater surveys are carried out in the Irish Sea, Scottish waters and the North Sea on behalf of MAFF 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, 1993a) to which the United Kingdom is a signatory. 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 are collected from the environment and 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 methods. They are therefore only used when there is clear expectation that information is needed on specific radionuclides that are not detectable using gamma spectrometry.

Four 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 dry cloths and aquatic samples excluding those from Scotland
- VLA Veterinary Laboratory Agency,
  gamma spectrometry and radiochemistry (excluding total uranium analysis) of terrestrial samples excluding those from Scotland
- NRPB National Radiological Protection Board,
  gamma spectrometry and radiochemistry of Scottish samples, and diet and industrial samples from England and Wales
- IC Imperial College, University of London,
  total uranium analysis of terrestrial samples

Each laboratory operates a quality control procedure to the standards required by the Food Standards Agency or SEPA involving regular calibration of detectors and intercomparison exercises with other laboratories. 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 from their 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 reflect the effects of the normal cooking process for the foodstuff.

2.2.2 Measurement of dose rates

Measurements of gamma dose in air over intertidal areas are normally made at 1 m above the ground using Mini Instruments* environmental radiation meters type 6-80 with compensated Geiger-Muller tubes type MC-71. With 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 contamination monitors. These portable instruments are calibrated against recognised reference standards.

2.2.3 Dry Cloths

The dry cloth programme provides a simple and cheap method of sampling airborne radioactive contamination around some of the major nuclear licensed sites. The dry cloth assembly consists of a v-shaped, dust retentive cloth mounted to pivot on a 2-metre rod. The assembly is set up in a relatively exposed, but secure area and is free to turn in the wind to maximise collection. The cloths are changed each month and analysed for alpha, beta and gamma activity. Around 2000 cloths are analysed each year. Each set of results is carefully examined so that any unusual levels of activity can be followed up by further sampling or investigation at the site.

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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.*

2. Sampling and measurement

Table 2.1. Scope of the monitoring programmes

Programme	Sub-programme	Main purpose
Nuclear sites[a]		Support for RSA 93[c], food safety assessment of waste disposal
Industrial sites[b]	Chemical works	Support for RSA 93[c], food safety assessment of waste disposal
	Landfill sites[c]	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[b]	Milk, crops, bread and meat	General food safety, support for EURATOM Treaty[c]
	Diet	General food safety, support for EURATOM Treaty[d]
	Isle of Man	General food safety
	Northern Ireland	General food safety
	Channel Islands	General food safety
	Freshwater and air particulate[c]	Safety of drinking water and air, support for EURATOM Treaty
	Seawater	Support for OSPAR Convention

[a] *The terrestrial parts of this programme in England and Wales, excluding most grass and soil sampling and all drycloth sampling, are known as TRAMP (Terrestrial Radioactivity Monitoring Programme)*
[b] *The terrestrial parts of these programmes in England and Wales are known as FARM (Food and Agriculture Monitoring Programme)*
[c] *In Scotland*
[d] *In England and Wales*

Table 2.2. Scope of the nuclear site sampling in 1999

Measurement	Routine frequency of measurement	Analyses or measurements	Types of material	Detailed species/materials
Aquatic programme				
Analysis of foods	Annually to monthly	Total beta, gamma spectrometry, ^{3}H, organic ^{3}H, ^{14}C, ^{226}Ra, ^{90}Sr, ^{99}Tc, ^{147}Pm, $^{134/137}Cs$, Th, U, transuranics	Fish, crustaceans, molluscs, edible aquatic plants	Cod, plaice, grey mullet, bass, dab, ray, herring, flounder, sea trout, dogfish, whiting, whitebait, fish oil, salmon, sole, spurdog, mackerel, pollack, haddock, crabs, lobsters, squat lobsters, winkles, native oysters, mussels, limpets, whelks, cockles, elvers, *Nephrops*, pacific oysters, shrimps, prawns, squid, scallops, queens, ormers, toothed winkles, *Porphyra,* laverbread, samphire, pike, brown trout, rainbow trout, perch and spider crabs
Analysis of indicator materials	Annually to weekly	Total beta, gamma spectrometry, ^{3}H, ^{14}C, ^{226}Ra, ^{90}Sr, ^{99}Tc, ^{147}Pm, $^{134/137}Cs$, Th, U, transuranics	Water, sediments, salt marsh, seaweeds, aquatic plants and coarse fish	Fish meal, mud, sand, clay, salt marsh, turf, sludge, seawater, freshwater, *Fucus spp., Rhodymenia spp., Elodea canadensis, Nuphar lutea, Ascophyllum nodosum,* rudd and lugworm
Gamma dose rates	Annually to monthly		On beaches, harbours, marshes, riverbanks, lakesides and boats	
Beta dose rates	Annually to quarterly		On nets, pots, ropes, sediments and saltmarsh	
Contamination survey	Annually to monthly		On beaches	
Terrestrial programme				
Analysis of foods	Annually to monthly	Total alpha, beta and gamma, gamma spectrometry ^{3}H, organic ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{45}Ca, ^{55}Fe, ^{90}Sr, ^{99}Tc, Ru, ^{131}I, ^{129}I, ^{147}Pm, Cs, ^{210}Po, U, ^{210}Pb transuranics	Milk, crops and animals	Cows' and goats' milk, beef meat, kidney and liver, sheep meat and offal, pig meat and offal, chicken, duck, curlew, pintail, shelduck, teal, pheasant, rabbits, honey, mushrooms, hazelnuts, beetroot, wheat, barley, elderberries, apples, blackberries, strawberries, raspberries, cabbage, sea kale, lettuce, potatoes, runner beans, turnips, leeks, carrots, swede, sprouts, sprout tops, broad beans, kale, peas, cauliflower, pears, spinach, marrow, courgettes, onions, leaf beet, French beans, hares, pigeons, figs and rape oil
Analysis of indicator materials	Annually to monthly	Total alpha, beta and gamma, gamma spectrometry ^{3}H, organic ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{45}Ca, ^{55}Fe, ^{63}Ni, ^{90}Sr, ^{99}Tc, Ru, ^{131}I, ^{129}I, ^{147}Pm, Cs, ^{210}Po, U, ^{210}Pb transuranics	Grass, soil, faeces, dry cloths and animal food	Grass, soil, silage, animal faeces, rape, fodder beet, lucerne, rainwater and dry cloths

Table 2.3. Analytical methods

Radionuclides	Sample type	Method of measurement
^{3}H ^{3}H (organic) ^{14}C ^{32}P ^{35}S ^{45}Ca ^{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
$^{103+106}Ru$ ^{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
Gamma	Dry cloths	Gamma counting by solid scintillation
^{51}Cr ^{54}Mn ^{57}Co ^{58}Co ^{60}Co ^{59}Fe ^{65}Zn ^{95}Nb ^{95}Zr ^{103}Ru ^{106}Ru ^{110m}Ag ^{125}Sb ^{134}Cs ^{137}Cs ^{144}Ce ^{154}Eu ^{155}Eu ^{241}Am ^{233}Pa ^{234}Th	All	Gamma spectrometry using germanium detectors
^{125}I ^{129}I	Terrestrial samples^{S}	Gamma spectrometry using germanium detectors
^{129}I ^{131}I	Aquatic samples	Gamma spectrometry using germanium detectors
U	Terrestrial samples	Activation and delayed neutron counting
^{210}Po ^{226}Ra* ^{234}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	Dry cloths	Alpha counting using thin window proportional detectors

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

3. PRESENTATION AND ASSESSMENT

Dose to members of the public from consumption of food is a function of the level of contamination of the foodchain, the rate of consumption, and the dose coefficient. This section explains how data are presented and how assessments of public dose are made, including non-food pathways where this is relevant.

3.1 Time averaging

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 or the random fluctuations expected in the environment.

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 contamination of seafood (see Section 3.6)

For milk samples, the most appropriate quantity for use in assessments is the arithmetic mean at the farm where the highest concentrations are observed. In most tables this is also labelled 'max' to distinguish it from the values which are averaged over a range of farms. However for Scottish sites bulking of milk samples across farms is carried out prior to analysis. In these cases the 'max' values are the maximum results from the analysis of the respective bulked samples.

For most 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 in 1999 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 Space averaging

In this report results are presented for each location or source of supply where a sample is taken or a measurement is made. These measurements form the basis of the dose calculations. Sample collectors are instructed to use the same location for obtaining samples 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 through concentration gradients in seawater 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. Soya meal based feeds can be used from overseas. 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 are sampled to provide information on activities in milk at nuclear sites in England and Wales are indicated in the tables of results. The bulking regimes are described in section 2.1.1. In Scotland, milk from all farms sampled around a site are bulked for each sampling period and the numbers in the tables refer to the number of bulked samples analysed at the site. 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 spectrometry. However, the results are 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 (LoD) or minimum reporting level (MRL). There are also a few results quoted as 'not detected' (ND) by the methods used. 'Less than' values are 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 1999.

Limits of detection are governed by various factors relating to the measurement method used and these are described in earlier reports (MAFF, 1995). The minimum reporting level 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. MAFF, 1995).

3.4 Additional information

The main aim of this report is to present all the results of routine surveillance from the programmes described previously. However it is necessary to carry out some averaging for clarity, and to exclude some basic data which may be of use only to those with particular research interests. Full details of the additional data are available from the Food Standards Agency and SEPA. Results of samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries through the Internet (www.foodstandards.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 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. As a first approximation, their concentrations can be taken to be the same as those of their respective parents.

A list of research studies underpinning the surveillance programme is given in Section 12.

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 subsection describes the dose standards that apply in ensuring protection of the public.

Current United Kingdom practice relevant to the general public is based on the recommendations of the International Commission on Radiological Protection (ICRP) as set out in ICRP Publication 60 (ICRP, 1991). The dose standards are embodied in national policy on radioactive waste (United Kingdom – Parliament, 1995b) and in guidance from the International Atomic Energy Agency (IAEA) in their Basic Safety Standards for Radiation Protection (IAEA, 1996). Legislative dose standards are contained in the Basic Safety Standards Directive 96/29/Euratom (CEC, 1996) and subsequently incorporated into United Kingdom law in the Ionising Radiations Regulations 1999 (United Kingdom – Parliament, 1999).

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. This is 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 individual dose limits apply to the mean dose received by the 'critical group'. This 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 often receive higher doses than adults because of their physiology, anatomy and dietary habits. Consequently we have assessed doses to different age groups and determined those most at risk.

Individual dose limits are to be 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 surveillance. 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).

Accidental releases may be judged against EU and ICRP standards in emergency situations (CEC, 1989 and ICRP, 1993). In addition it is Government policy that EU food intervention levels will be taken into account when setting discharge limits. Where appropriate intervention levels are used as an indicator for radioactive concentrations in this report.

3.6 Assessment methods and data

Calculations of exposures of members of the public from waste disposals are based on the environmental monitoring data for 1999. These data provide information on two main pathways: (i) ingestion of foodstuffs; and (ii) external exposure from contaminated materials in the aquatic environment. 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. There are three factors to consider in the assessment of the ingestion pathway: (i) the concentrations of radionuclides in foodstuffs; (ii) the amounts of food eaten; and (iii) the dose coefficients relating an intake of activity to a dose.

3.6.1 Radionuclide concentrations in foodstuffs

In nearly all cases, the activities in foodstuffs are determined by monitoring and are given later in this report. The Sellafield, Isle of Man and Scottish 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 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 appropriate, corrections for background concentrations of natural radionuclides are made in the calculations of dose.

For aquatic foodstuffs, the assessment is based on the mean concentrations from the areas where harvesting of seafood is known to take place near the site in question. For milk, the mean concentrations at a farm close to the site are taken where possible. The farm is chosen by reference to the data on concentrations such that the highest values of any farm are used in the assessment. This procedure accounts for the possibility that any farm close to a site can act as the sole source of supply of milk to high-rate consumers. For Scottish sites, results for individual farms are generally not available. In such cases, the maximum observed concentration in the bulk samples across farms is taken to provide an adequate degree of conservatism. 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 foodstuff from the site. Although this approach will produce a slight overestimation of dose, particularly at sites where levels are low, it ensures that estimated exposures are unlikely to be understated. Formally, as a consequence of including 'less than' concentrations in the dose assessments, dose values in this report should be preceded with the less than (<) symbol. However, for reasons of clarity, we have presented doses in the text without the symbol. The summary table does include less than symbols where appropriate.

3.6.2 Consumption rates

In the assessment of the effects of disposals of liquid effluents, the amounts of seafood consumed are determined by site-specific habits surveys. Data are collected primarily by direct interviews with potential high-rate consumers who are often found in fishing communities. Techniques have included the use of consumption logging sheets (Leonard *et al*., 1982; Leonard, 1984) and consumption rate data have been interpreted using techniques based upon ICRP recommendations (Hunt *et al*., 1982) to select appropriate groups of high-rate consumers. 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 four ages: adults, 15-year-old children, 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 these 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, D *et al*., 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.

The foodstuff consumption rates are given in Appendix 4. Dose estimates are based on the most up to date information available.

The assessment of terrestrial foodstuffs is based on the 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 are 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 (Day, pers comm.). 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 Summation of aquatic and terrestrial doses

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 influenced by liquid waste disposal and those by gaseous waste disposal. We have therefore calculated doses separately in these two cases. This information can form the basis for a formal comparison with dose limits. The simple 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. A given individual is unlikely to consume both aquatic and terrestrial foods at such high rates. Development of a method for calculating a combined aquatic and terrestrial dose is being undertaken and will be reported in future reports.

3.6.4 Dose coefficients

Dose calculations for intakes of radionuclides are based on dose coefficients taken from ICRP Publication 72 (ICRP, 1996a). These coefficients (often referred to as 'dose per unit intake') relate the committed dose received to the activity ingested. The dose coefficients used in this report are provided in Appendix 5 for ease of reference. In past reports (e.g. The Scottish Office 1996) the dose received by infants from the consumption of milk has been calculated using the dose per unit intake values appropriate to 3-month-old infants. In this report, for uniformity with the calculations carried out for England and Wales, the values appropriate to a 1-year-old have been used. This should be considered when comparing the dose estimates reported for Scottish sites with those reported previously.

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 which results in the highest predicted exposure. 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.

The current ICRP advice is that a gut uptake factor of 0.5 is appropriate for dietary intakes of polonium by adults (ICRP, 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 (NRPB, 1990) to be used when data for the specific circumstances under consideration is 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. 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).

3.6.5 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 (ICRP, 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 exposure of gonads to beta radiation is assessed using the methods described by Hunt (Hunt, 1992). 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.

3.6.6 Subtraction of 'background' levels

When assessing the man-made effect on external exposures to gamma radiation and internal exposures due to ingestion of carbon-14 and radionuclides in the uranium and thorium decay series in seafood, estimates of dose rates and concentrations, as appropriate, 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 were 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 has been 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.

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* *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 volume of air.*

4. BRITISH NUCLEAR FUELS PLC (BNFL)

BNFL's main business interests are the design and production of fuel for nuclear reactors, fuel reprocessing and the generation of electricity. 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 and Drigg, Cumbria

Operations and facilities at Sellafield include fuel element storage, the Magnox and oxide fuel reprocessing plants, mixed oxide fuel manufacture, decommissioning of some nuclear facilities, and the Calder Hall Magnox nuclear power station. Radioactive waste disposals include a very minor contribution from the adjoining UKAEA Windscale site which includes facilities operated by AEA Technology. The most significant disposals are made from the BNFL fuel element storage ponds and the reprocessing plants, which handle irradiated Magnox and oxide fuel from the United Kingdom nuclear power programme, and some fuel from abroad. The authorised limits for disposals were revised with effect from 1 January 2000. Small disposals of liquid and gaseous radioactivity are made from the Drigg site, as a result of the solid waste management practices. Historically disposals from Sellafield have had the greatest impact on food and the environment of the United Kingdom. Current surveillance 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

Liquid radioactive wastes from both Sellafield and Drigg are discharged under separate authorisations effectively to the same body of water on the Irish Sea coastline. The sites are therefore considered together for the purpose of aquatic environmental monitoring.

Disposals from the Sellafield pipelines during 1999 are summarised in Appendix 1. Total alpha and beta disposals were 0.133 and 110 TBq respectively (1998: 0.174 and 85.9 TBq respectively). In terms of individual radionuclides, there were increases in discharges of carbon-14 and strontium-90, whilst there were decreases for cobalt-60 and ruthenium-106. Technetium-99 discharges in 1999 were up on 1998 (68.8 TBq for 1999 compared to 52.7 TBq for 1998) but were lower than discharges in 1994-1997, which ranged from 72 TBq in 1994 to 192 TBq in 1995 (Camplin, 1995; MAFF, 1996; MAFF and SEPA, 1997; MAFF and SEPA, 1998). All disposals were within the limits set in the authorisations.

The main function of the Drigg site is to receive low level solid radioactive wastes from Sellafield and other United Kingdom sites and to dispose of them in engineered trenches or vaults on land. The authorisation for disposals 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 disposals are small compared with those discharged from the Sellafield site. Marine monitoring of the Drigg site is subsumed within the Sellafield programme that is described in the remainder of this sub-section. The contribution to exposures due to Drigg disposals is negligible compared with that attributable to Sellafield and any effects of Drigg disposals could not be detected in 1999 above those due to Sellafield. Regulatory monitoring of the Drigg Stream is carried out by the Environment Agency.

Regular monitoring of the marine environment near Sellafield continued during 1999. 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 are kept under review. In 1999, 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 general review of radioactivity in the Irish Sea has been compiled by Kershaw *et al.* (1992). In addition, Hunt (1995) has provided a reconstruction of exposures due to Sellafield liquid disposals from the beginning of operations in 1952 through to 1993. A recent review of changes in disposals and effects from the site is given by Smith, B. *et al*. (2000).

The fish and shellfish consumption pathway

Concentrations of radioactivity

Time trends of activity concentrations of carbon-14, technetium-99, caesium-137, plutonium-239/240 and americium-241 are shown in Figures 4.1-4.5 respectively.

Concentrations of beta/gamma activity in fish from the vicinity of the Irish Sea and from further afield are given in Table 4.1. Concentrations in 1999 were generally similar to those in 1998. 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 disposals 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 most exposed 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, because significant reductions in disposals have been achieved. There is therefore a greater contribution from historical sources. Radiocaesium in fish from the Baltic is not due to Sellafield disposals but is substantially from the Chernobyl accident (Aakrog *et al.,* 1991). 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 and Celtic Seas are similar. In the Irish Sea, the ratios of caesium-137 to caesium-134 were generally higher than those in recent disposals from Sellafield, even allowing for residence time in the water and uptake into fish; this suggests that a significant contribution from aged radiocaesium is present, due to remobilisation from the sediment of the Irish Sea. Data for cod from the 'Offshore Area' typify the time trends in concentrations in fish (Figure 4.3).

A sample of rainbow trout from a small lake near Sellafield was again collected this year. Stocking had taken place and the caesium-137 concentration in the sample, 17 Bq kg^{-1}, was much less than in 1998 (180 Bq kg^{-1}); however the variability of activities in samples of freshwater fish is known to be high (Camplin *et al.,* 1989). Although the evidence is not conclusive, the source of activity in this lake is likely to be Sellafield.

Concentrations of other beta/gamma emitting radionuclides in fish tend to be lower. However, with an expected natural carbon-14 concentration being about 25 Bq kg^{-1}, the data suggest there is a local enhancement of carbon-14 due to discharges from the site. The highest concentrations of radioactivity in fish are found for tritium at about 200 Bq kg^{-1}. Concentrations of tritium in local seawater at St Bees are less than 20 Bq l^{-1} (Table 11.12) suggesting that some bioaccumulation of tritium in the Sellafield vicinity may be taking place. This is being investigated further in 2000. However the radiotoxicity of tritium is very low, and the radiological importance of these concentrations, as determined later in this report, is much less than that of other radionuclides.

For shellfish, a wide range of radionuclides contribute 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 most exposed 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.

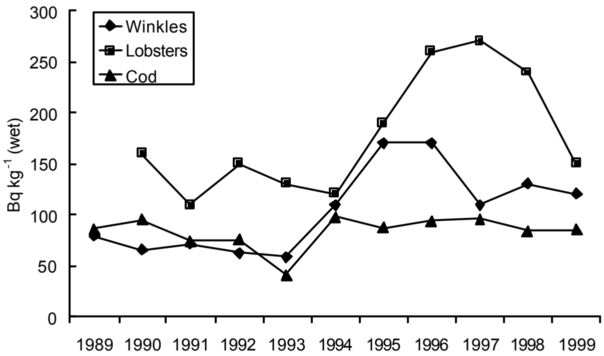

Figure 4.1. Carbon-14 concentrations in cod, lobsters and winkles from Sellafield

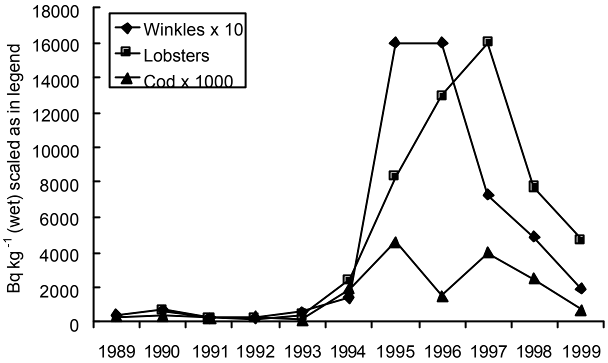

Figure 4.2. Technetium-99 concentrations in cod, lobsters and winkles from Sellafield

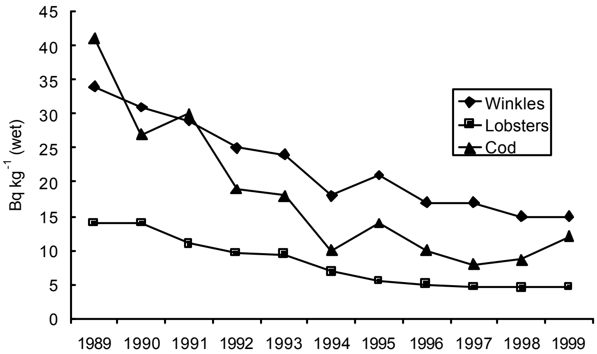

Figure 4.3. Caesium-137 concentrations in cod, lobsters and winkles from Sellafield

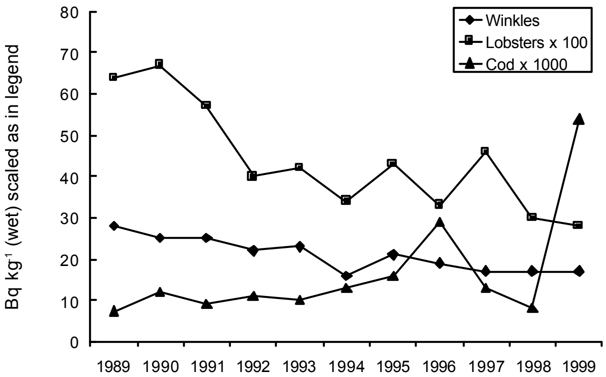

Figure 4.4. Plutonium-239/240 concentrations in cod, lobsters and winkles from Sellafield

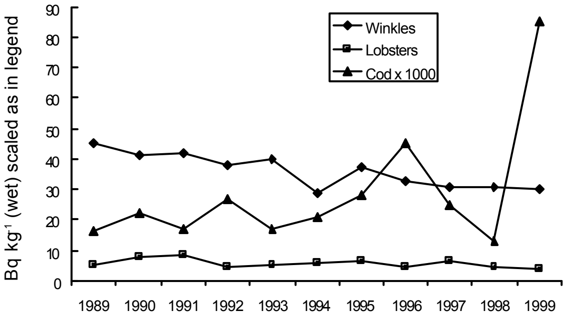

Figure 4.5. Americium-241 concentrations in cod, lobsters and winkles from Sellafield

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)). 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 1998 and 1999 data across a wide range of sampling locations and shellfish species, few significant changes in concentrations were found. Some decreases in ruthenium-106 concentrations were apparent and these probably reflect the reduction in discharges. Technetium-99 levels generally continued to reduce.

As a general rule, the concentrations observed in shellfish are largely due to discharges, past and present, from Sellafield. Occasionally, increases above this Sellafield background are observed and this was the case in 1999 for tritium in shrimps from the Wirral and for carbon-14 in crabs from the English Channel. The source of tritium near the Wirral is unclear though discharges from Capenhurst are a possibility. In the Channel the main direct nuclear industry source of carbon-14 is the French reprocessing plant at Cap de la Hague.

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, was analysed for transuranic nuclides. The data for 1999 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 as compared to fish, and a rapid reduction with distance from Sellafield in concentrations of transuranics, particularly in shellfish. Concentrations in shellfish in 1999 were similar to or less than those in 1998 (Figures 4.4 and 4.5). Those in samples from the northeastern Irish Sea remain the highest levels of such nuclides to be found in foodstuffs in the United Kingdom. There was an anomalous increase in concentrations in cod caught offshore of Sellafield in 1999. No such increase was observed in cod caught in the coastal area.

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 1999 from artificial radionuclides in fish and shellfish. The dose to the local most exposed group of consumers was 0.21 mSv. This includes a contribution due to external exposure. The small increase in dose from 0.20 mSv reported for 1998 (MAFF and SEPA, 1999) is largely due to changes in the assumed habits of high-rate consumers of shellfish. The changes, which were based on the results of a local habits survey, included increased consumption of molluscs. 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 8% 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.

Data for natural radionuclides in fish and shellfish are discussed in Section 10; however, the effects on the Sellafield most exposed group from controlled disposals of natural radionuclides from another west Cumbrian source, Rhodia Consumer Specialties Ltd., Whitehaven, are considered here to enable the total dose to be compared to the limit of 1 mSv. The increase in natural radionuclide concentrations is difficult to determine above a variable background. However using maximising assumptions, the dose to the local group of seafood consumers due to the enhancement of concentrations of natural radionuclides in the Sellafield area in 1999 was estimated to be 0.44 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. This gives a total dose to this group of less than 0.65 mSv which was less than 65% of the principal dose limit for members of the public of 1 mSv. These doses may be compared with an average dose rate of approximately 2.2 mSv year^{-1} to members of the United Kingdom public from all natural sources of radiation (NRPB, 1999a).

Exposures of groups representative of the wider fishing communities associated with fisheries in Whitehaven, Dumfries and Galloway, the Morecambe Bay area, Fleetwood, Northern Ireland and the Isle of Man have been kept under review (Table 4.4). Another group, covering the North Wales coast, was added this year due to interest from the local population. 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 1998 (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 principal dose limit for members of the public of 1 mSv.

In the case of the Dumfries and Galloway group, this pathway has the highest attributed dose of all the identified aquatic critical pathways in Scotland. As indicated in Table 4.4, the 1999 dose is significantly lower than that for the previous year. This is due to general reductions in technetium-99, plutonium-239/ 240 and americium-241 radionuclide concentrations in Scottish seafood and also due to reduced external dose rates over intertidal areas with high occupancies on the Dumfries and Galloway coast.

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. The dose in 1999 was 0.002 mSv, the same as that for 1998 (MAFF and SEPA, 1999).

Seafood doses from artificial radionuclides in the Irish Sea		
Group	Dose, mSv	
	1998	1999
Northern Ireland	0.014	0.013
Dumfries and Galloway	0.048	0.028
Whitehaven	0.023	0.038
Sellafield	0.20	0.21
Isle of Man	0.010	0.010
Morecambe Bay	0.074	0.071
Fleetwood	0.027	0.021
North Wales	Not assessed	0.006

The review of seafood consumption rates at Sellafield undertaken in 1999 revealed that consumption of material caught as by-catches of fishing in the local area, as reported in the 1998 report (MAFF and SEPA, 1999), was no longer taking place. A single family had been involved. The material included species that are not normally eaten, for example, sea mice, sea urchins (*Echinoidea*), brittle stars (*Ophiuroidea*), common shore crabs (*Carcinus maenas*), and hermit crabs (*Eupagurus spp*.). We will continue to monitor this pathway at Sellafield, and have begun a research project to investigate these uncommon foods at United Kingdom nuclear sites.

The potential exposure of consumers of trout from a tarn at a local farm was also considered in 1999. Their dose was less than 0.005 mSv which was less than 0.5% of the principal dose limit to members of the public of 1 mSv. This includes a contribution due to Chernobyl and weapons test fallout. Current evidence indicates that no such consumption is taking place.

External exposure

A further important pathway leading to radiation exposure as a result of Sellafield disposals 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 local consumers, a programme of direct measurements has therefore been maintained. 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 radioactivity 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 Food Standards Agency and SEPA 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 disposals, are given later in this report. Further data are available from the Environment Agency. Variations in sediment type from place to place account for the quite marked fluctuations in dose rate, superimposed on a general decrease with increasing distance from Sellafield. Dose rates over intertidal areas throughout the Irish Sea in 1999 were similar to those data for the same locations in 1998 (MAFF and SEPA, 1999).

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, in most cases at the same locations as the dose rate measurements, are given in Table 4.6. Concentrations in sediments vary for reasons similar to those causing variation in dose rates, and comparison with results for 1998 (MAFF and SEPA, 1999) shows similar amounts of radioactivity. Kershaw *et al*. (1999a) have published a review of plutonium and americium in Irish Sea sediments.

The external dose to seafood consumers in western Cumbria is included in their assessment noted earlier in this report. Boats in Whitehaven harbour are no longer on mud at low tide since the commissioning of new lock gates. Occupancy of seafood consumers on such boats is therefore of no radiological significance. In terms of occupancy over tide-washed pasture, farmers are representative of those most exposed. In northern Cumbria their dose was unchanged at 0.081 mSv. The Environment Agency considers other groups exposed to external gamma radiation, including houseboat dwellers in the Ribble estuary who represented those who received the highest external exposures from the effects of disposals from Sellafield in 1998 (MAFF and SEPA, 1999).

Inhalation of resuspended beach sediments and inadvertent ingestion of the same material give rise to only minor radiation exposures to the public compared with the external radiation pathway considered in this section (Wilkins *et al.,* 1994). In areas of salt marsh and sea-washed pastures such as the Ravenglass estuary, exposures from pathways other than those due to external radiation need consideration. Earlier assessments of pathways including external radiation in such areas found that doses were well within the principal dose limit for members of the public of 1 mSv (Wilkins *et al.,* 1994). This would also have been the case in 1999 because, in general, concentrations of activity and dose rates in such areas have reduced. However, in order to investigate the effects of recent increases in technetium-99 discharges from Sellafield, additional research was undertaken. This is reported in sub-section 4.1.4.

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 portable beta dosimeters. Results for 1999 are presented in Table 4.7. Measured dose rates were generally greater than those for 1998. 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 1999, including a component due to natural radiation, was 0.11 mSv, which was less than 1% of the appropriate dose limit. Handling of fishing gear is therefore a minor pathway of radiation exposure.

4.1.2 The terrestrial monitoring programme

Because of the proximity of the sites, environmental monitoring at Sellafield and Drigg are considered together in this sub-section. In addition, the programme around the Ravenglass estuary approximately 10 km south of the Sellafield is included. The purpose of that programme is primarily to investigate contamination of sea-washed land resulting from disposals of liquid waste from Sellafield.

Sellafield

Disposals of gaseous wastes from Sellafield are summarised in Appendix 1. There were small increases in the overall discharges of alpha and beta activities from the site and changes for particular radionuclides. However, none of these were of sufficient magnitude such that substantial changes in environmental levels were to be expected. Over and above routine sampling, special sampling was undertaken to investigate an unusual release of caesium-137 from the waste vitrification plant in January 1999 (see below).

The routine sampling programme for terrestrial foods in the vicinity of Sellafield was the most extensive of those for the nuclear sites in the United Kingdom 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, honey, 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 disposals. The analyses undertaken included gamma 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 1999 are presented in Table 4.8. The concentrations of all radionuclides were low and there was no indication of widespread contamination from the site. However, small enhancements of some radionuclides were found close to the site. The ratio of the mean concentration in milk collected from near and far farms was close to 1 for all radionuclides though positive determinations of strontium-90 and radiocaesium indicated a factor nearer 2. Some evidence for a site-related effect was also found by examination of the maximum concentrations at single farms (a factor of five). For example, the carbon-14 concentration was 28 Bq l^{-1} at one farm, which is in excess of that expected due to natural sources (18 Bq l^{-1}). Concentrations in milk were generally similar to those in 1998 (MAFF and SEPA, 1999).

Levels of activity in bovine and ovine meat and offal continued to be analysed in 1999. In addition, chickens, hare, pheasants and pigeons were collected. Concentrations of radionuclides were generally low, with limited evidence of the effects of Sellafield derived activity in data for tritium, carbon-14, sulphur-35 and strontium-90. Plutonium concentrations, whilst much lower than those found in seafood, gave isotopic ratios ((239 + 240)/238) less than 20. With a ratio of about 40 expected for background weapon test fallout, these data demonstrate a site source. The level of sulphur-35 found in a sample of hare meat was unusually high at 30 Bq kg^{-1}, but is negligible in terms of radiological significance.

The fruit and vegetables that were sampled in 1999 included apples, cabbage, carrots, cauliflower, french beans, mushrooms, potatoes, runner beans, 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 disposals was found in data for tritium, carbon-14, sulphur-35 and strontium-90. Concentrations of transuranic radionuclides were very low and did not produce as distinct a Sellafield signal in the plutonium isotopic ratio as some other food groups.

Barley was sampled as being representative of cereals in 1999. It was a particularly good indicator of the effects of Sellafield with relatively high values of most radionuclides compared with other terrestrial foodstuffs.

The dose received by the most exposed group of terrestrial food consumers was calculated using the methods and data presented in Section 3. The results are presented in Table 4.9. Calculations were performed for four ages (adults, 15y, 10y and 1y) and the doses received by 1-year-olds were found to be the highest, at 0.044 mSv (Adult: 0.022; 15y: 0.028: 10y: 0.026). The most significant contributions to this dose were from carbon-14, sulphur-35, cobalt-60, strontium-90 and ruthenium-106. The most important foodstuff was milk that accounted for more than 60% of the dose. The exposure is likely to be an upper estimate of the effects of Sellafield disposals 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 nuclides 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 doses in 1999 were similar to those in 1998 (1y: 0.042 mSv). The dose received by a typical adult consumer obtaining food from the vicinity of Sellafield, 0.013 mSv, was much less than this.

The previous report in this series 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 was found up to 0.11 MBq kg^{-1}. This is far in excess of the EU Food Intervention Levels. Consuming the breast meat of 20 birds contaminated at the highest level would have resulted in a dose of 1 mSv, the annual dose limit for members of the public. Remedial measures, including a substantial cull of pigeons in the area, have been taken by BNFL. Nevertheless the advice issued by MAFF on 14th February 1998 remains in place as a precaution. People are advised not to handle, slaughter or consume pigeons within a 10 miles radius of the site. A full review of the incident was published in 1999 (CBC *et al*, 1999).

Special sampling was undertaken in January 1999 in relation to an unusual release of caesium-137 from the Sellafield waste vitrification plant (WVP). Several 'beta in air' alarms in the WVP operating area had gone off when shield doors had been open for the transfer of materials. Later in the day the WVP stack went into alarm and the building was evacuated.

The estimated source term was 30 MBq of caesium-137 or about 15% of the expected discharge from similar stacks in a whole year. As a precaution, samples of grass were collected and sent for analysis. The results, given in Table 4.8, are typical of levels to be found in the Sellafield area and are equivalent to exposures through foodchain pathways of the order of 0.001 mSv which was 0.1% of the principal dose limit for members of the public of 1 mSv.

The WVP also released enhanced disposals of ruthenium-106 in November 1997. MAFF sampling at the time showed that there was no significant risk to consumers of local foodstuffs (MAFF and SEPA, 1998). In February 1999 barley was repeat sampled. Levels, reported in Table 4.8, were below the limit of detection and those detected in 1997.

4.1.3 Drigg

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

Results for 1999 are given in Table 4.10. Low concentrations of tritium that may have leached from the site were found in sheep and potatoes; however they were of negligible radiological significance. Other than this there was no direct evidence to suggest migration of activity from the site was taking place. In general concentrations of other radionuclides detected were similar to, or lower than those found near Sellafield. Levels of technetium-99 in foodstuffs and actinides in sheep meat may have been due to sea-to-land transfer. The radiation dose to the most exposed group, including a component due to Chernobyl and weapon test fallout, was 0.020 mSv which was 2% of the principal dose limit for members of the public of 1 mSv (Table 4.9). This compares with 0.017 mSv in 1998.

4.1.4 Other Surveys

Contact dose-rate monitoring of intertidal areas

A routine programme of measurements of beta dose rates on contact with shoreline sediments continued in 1999 in order to establish the contribution to effective dose made by exposures of seafood consumers, such as bait diggers, who handle sediments regularly, and to estimate their exposures for comparison with the skin dose limit of 50 mSv. This dose is set out in the Ionising Radiations Regulations (United Kingdom - Parliament, 1999). The results of the measurements made using contamination monitors are presented in Table 4.11.

The skin dose to anglers who dig bait, based on a time handling sediment of 950 h $year^{-1}$, was 0.18 mSv in 1999 which was less than 1% of the appropriate dose limit.

Ravenglass

The main purpose of the monitoring of terrestrial foodstuffs in the Ravenglass area is to determine whether there is 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 are collected and analysed for radionuclides which are released in liquid effluent disposals from Sellafield. In addition analyses for sulphur-35 are also undertaken for comparison with results for the immediate area around Sellafield.

The results of measurements in 1999 are presented in Table 4.12. In general, the data are similar to those for 1998 (MAFF and SEPA, 1999) and show lower concentrations than are found in the Sellafield vicinity. The observed higher levels of tritium in cabbage and carrots are unexpected. However the levels are of little radiological significance. Evidence for sea-to-land transfer is limited. Technetium-99 concentrations in all materials were very low. A small amount of promethium-147 (0.2 Bq kg^{-1}) was detected in cabbage from Ravenglass though the concentrations in grass were similar to those found at Drigg. Concentrations of plutonium isotopes in some samples indicated a local source in that the plutonium-239/240 to plutonium-238 ratio was substantially less than that expected due to weapon test fallout. Taken together these observations suggest that some sea-to-land transfer of radionuclides takes place to a limited extent though the effect is minor.

The only other indication of the effects of Sellafield disposals is the low concentrations of sulphur-35 detected in some samples. These may have been due to gaseous disposals from the site.

The exposure due to consumption of terrestrial foods from Ravenglass in 1999 is given in Table 4.9. The 1-year-old age group received the highest exposures. Their dose, including contributions from Chernobyl and weapon test fallout, was 0.026 mSv which was less than 3% of the principal dose limit for members of the public of 1 mSv. This compares with 0.028 mSv for 1998 (MAFF and SEPA, 1999). From this evidence, sea-to-land transfer in this area is not having a major effect on the terrestrial food chain.

Research and other surveys

In addition to the monitoring described above, which is related to the most significant radiation exposure pathways as a consequence of Sellafield disposals, a number of further investigations are undertaken. Some of these are of a research nature; however, they also enable pathways of lower radiological significance to be kept under review.

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 4.13 presents the results of measurements in 1999 on marine plants 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 disposals of technetium-99 from Sellafield in recent years, though at a reduced level compared with 1998. Such seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a continuing research study in 1999. The results are shown in Table 4.14.

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,* in press). In 1999 seaweed harvesting in the Sellafield area continued to be rare. However, three plots of land fertilised by seaweed were identified and were investigated further. Samples of soil were analysed by gamma spectrometry and for technetium-99, the radionuclide of main interest. The soil data show enhanced levels of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Various vegetable samples that had been grown in the soils from these plots were obtained. The technetium-99 concentrations in vegetables ranged from about 0.28 to 480 Bq kg^{-1} in the edible parts. The higher concentrations were found in leaf beet. 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 as well as their consumption of local seafood. Based on pessimistic assumptions, the maximum dose received by the consumers was estimated to be 0.032 mSv, most of which was due to the seafood component of their diet. The highest dose due to technetium-99 in vegetables was 0.01 mSv. Whilst the doses due to consumption of seafood and external radiation from sediments remain more important, further studies of the seaweed/vegetable pathway will be undertaken in 2000.

Recent investigations have shown that seaweed in the vicinity of Sellafield is not used in the production of alginate. The species harvested for this purpose are not those associated with high levels of technetium, therefore this is not a significant pathway.

The potential transfer of technetium-99 to milk, meat and offal from animals grazing tide-washed pasture was considered in the report for 1997 (MAFF and SEPA, 1998). The maximum potential dose was calculated to be 0.009 mSv at that time. Follow up sampling at Newton Arlosh, Cumbria and Hutton Marsh, Lancashire in 1999 suggests that this dose estimate remains valid. (Table 4.14). 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.

No harvesting of *Porphyra* in west Cumbria, for consumption after being made into laverbread, was reported in 1999; this pathway has therefore remained essentially dormant. However, monitoring 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 United Kingdom shorelines of the Irish Sea. Results of analyses for 1999 are presented in Table 4.13. Samples of laverbread from the major manufacturers are regularly collected from markets in South Wales and analysed. Results for 1999 are also presented in Table 4.13. 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.

Research into the distribution of radionuclides in seawater is considered in Section 11.8.

4.2 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 disposals are made by pipeline to the Ribble estuary. Disposals of beta emitting radionuclides, which result in the greatest contribution to the radiological impact, were similar in 1999 (128 TBq) to 1998 (150 TBq) as rates of processing of uranium ore concentrate were maintained. Disposals of gaseous effluents remained very low at a similar level to those for 1998.

Public radiation exposure in this vicinity, as a result of site disposals, is relatively low; there is, however, a contribution in the estuary due to Sellafield disposals. The most important marine pathway is external exposure, due to adsorption of radioactivity on the muddy areas of river banks and in salt marshes. Assessments of the external exposure critical group are provided by the Environment Agency. However habits surveys have also identified consumers of seafood, particularly fish and shrimps, and they are considered as a potential critical group in this report. Locally obtained fish, shellfish and samphire continued to be sampled and a limited programme of gamma and beta dose rates monitoring was continued. A study (Rollo *et al.,* 1994) has shown that exposures due to airborne radionuclides that may have come from disposals to the estuary are negligible.

Monitoring of terrestrial foods included sampling of milk, fruit and vegetables. Indicator materials including dry cloths, grass, soil and animal faeces were also sampled.

Results for 1999 are shown in Tables 4.15(a) and (b). Radionuclides detected which were partly or wholly due to Springfields disposals were isotopes of thorium, uranium and their decay products. Natural sources also contributed to these activities. Artificial radionuclides present were mainly from Sellafield.

Concentrations of radionuclides in seafood and measurements in other materials from the estuary were similar to those for 1998. Seafood consumption was dominated by fish and shrimps though small quantities of cockles and samphire were also taken into account, as indeed was external exposure over the outer parts of the estuary while fishing. The dose to seafood consumers was 0.026 mSv in 1999. Most of this was due to Sellafield disposals with only a small percentage attributable to Springfields. This compares with 0.036 mSv for 1998 (MAFF and SEPA, 1999).

Skin irradiation of fishermen handling nets was 0.81 mSv in 1999. This is less than 2% of the relevant dose limit for members of the public. Whole body doses of farmers working over marshes bordering the estuary were assessed as being 0.024 mSv, similar to the value of 0.019 mSv appropriate to 1998.

The most exposed group of terrestrial food consumers were children aged 15 consuming vegetables at high rates. Their dose in 1999, including a contribution due to weapons testing and Chernobyl fallout and natural sources, was less than 0.005 mSv, a significant part of which was due to thorium radionuclides. In 1998 the estimated dose was also calculated as being less than 0.005 mSv.

4.3 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 of tritium, uranium and its daughter products, and technetium-99 and neptunium-237 from recycled fuel, are minor; in 1999 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 is carried out related to the pathways that could be of radiological significance due to all disposal routes. Plants, rain water, animal faeces, soil and dry cloths are also sampled as indicator materials.

Results for 1999 are presented in Table 4.16. Concentrations of radionuclides in materials from the land and from the Rivacre Brook were generally similar to those for 1998. There was a decrease in the tritium concentration in water from the Brook but this observation is based on very few measurements. There was a single sample of shrimps containing tritium at a level of 240 Bq kg^{-1}, well in excess of the limit of detection. No reason was noted for this level of activity in shrimps. However the radiotoxicity of tritium is very low and the radiological significance of the observation is correspondingly small. The concentrations of other artificial radionuclides in marine samples are consistent with values expected at this distance from Sellafield. The hypothetical most exposed group for liquid disposals from the site is considered to be people who may inadvertently ingest water and sediment from the Brook. Taking pessimistic assumptions about their ingestion rates, the dose to the group was very low, at less than 0.005 mSv in 1999. The dose to the most exposed group of terrestrial food consumers was also low, at less than 0.005 mSv in 1999.

4.4 Chapelcross, Dumfries and Galloway

At this establishment, BNFL operates a nuclear power station with four Magnox-type reactors. 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. Terrestrial monitoring comprises sampling and analysis of milk and grass. Habits surveys have been used to investigate aquatic exposure pathways. These have established that two groups of people could receive radiation exposures of potential importance. The first of these groups comprises of fishermen who consume local seafood and are exposed to external radiation whilst tending stake nets. The second group consists of wildfowlers who are exposed whilst on salt marshes. The scope of aquatic monitoring reflects these pathways. Samples of sea water and *Fucus vesiculosus*, as useful indicators, are also analysed.

The results of routine monitoring in 1999 are presented in Tables 4.17(a) and (b). Additional monitoring is presented in 4.17(c). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to Sellafield disposals, and the general levels of nuclides are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides, such as technetium-99 due to Sellafield, in 1999 remained at the levels detected in recent years. Samples taken to represent seawater in 1999 were collected incorrectly. Measurements of the salinity of these samples at this location indicated that they were not seawater samples. SEPA have investigated the sampling procedure at this location and have instructed the contractor to make arrangements to ensure that in the future seawater samples are collected. As a consequence there are no results for the analysis of seawater from this location in 1999.

The whole-body dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.021 mSv in 1999 which was less than 3% of the principal dose limit for members of the public of 1 mSv. Measurements of the contact beta dose-rate received whilst handling nets, were below the limit of detection. The estimated dose to wildfowlers 0.012 mSv which was less than 2% of the principal dose for members of the public of 1mSv. A consideration of the disposals from Chapelcross indicates that the contribution was a very small fraction of the total dose to the local population, a greater proportion of the dose was attributed to Sellafield's disposals.

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 continued, although work carried out by the operator in recent years has led to a decline in these particles being found in the environment. SEPA has requested the operator to consider further improvements to the effluent management system to prevent further release of such particles. During 1998 and 1999 improvements were made to the operation of the effluent management system and in 1999 there was a substantial reduction in the number of particles found compared to 1998.

Concentrations of radionuclides in milk and grass were similar to those in 1998. The effects of the power station were detected by observation of positive values for tritium in terrestrial samples, but the radiological significance of this radionuclide is low. The dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon test and Chernobyl fallout, was estimated to be 0.017 mSv which was less than 2% of the principal dose limit for members of the public of 1 mSv. This estimate includes a contribution due to consumption of vegetables (Appendix 2).

Table 4.1. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 1999

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}											
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Sellafield coastal area	Cod	5			0.67		<0.31	<0.57		<0.77	<0.16	14	<0.38	160
Sellafield coastal area	Plaice	4	230		0.34		<0.31	<0.47		<0.76	<0.08	8.0	<0.38	150
Sellafield coastal area	Grey mullet	1			<0.12		<0.27	<0.28		<0.97	<0.10	12	<0.47	
Sellafield coastal area	Bass	1			<0.16		<0.61	<0.80		<1.6	<0.17	13	<0.63	
Sellafield offshore area	Cod	1		85	<0.12	0.036	<0.24	<0.23	0.72	<0.86	<0.10	12	<0.36	
Sellafield offshore area	Plaice[c]	2		140	0.26	0.18	<0.10	<0.08	17	<0.41	<0.05	7.0	<0.21	
Sellafield offshore area	Dab	2			0.37		<0.21	<0.23		<0.71	<0.08	8.5	<0.31	
Sellafield offshore area	Whiting	2			<0.08		<0.21	<0.24		<0.62	<0.07	12	<0.30	
Sellafield offshore area	Herring	1			<0.16		<0.50	<0.58		<1.6	<0.16	2.7	<0.62	
Sellafield offshore area	Spurdog	2			<0.09		<0.26	<0.37		<0.73	<0.07	9.5	<0.34	
Ravenglass	Cod	4			0.33		<0.26	<0.38		<0.69	<0.08	10	<0.32	150
Ravenglass	Plaice	4	210		<0.20		<0.31	<0.52		<0.74	<0.08	6.5	<0.34	
Whitehaven	Cod	4		75	<0.20	0.037	<0.16	<0.13		<0.75	<0.09	11	<0.36	
Whitehaven	Plaice	4			<0.10	0.042	<0.18	<0.16		<0.76	<0.09	5.3	<0.36	
Whitehaven	Ray	2			<0.07		<0.19	<0.19		<0.64	<0.07	4.7	<0.36	
Parton	Cod	4			<0.12		<0.20	<0.22		<0.68	<0.08	12	<0.35	
Morecambe Bay (Flookburgh)	Flounder	4		77	<0.09		<0.25	<0.28		<0.85	<0.09	17	<0.37	
Morecambe Bay (Morecambe)	Plaice	4	37		<0.08	0.042	<0.20	<0.19	16	<0.75	<0.08	7.1	<0.38	
Morecambe Bay (Morecambe)	Bass	2			<0.12		<0.34	<0.40		<1.2	<0.12	15	<0.49	
Morecambe Bay (Sunderland Point)	Whitebait	1			0.30	0.15	<0.14	<0.16		<0.44	<0.05	6.4	<0.23	
Calder Farm	Rainbow trout	1			<0.06		<0.18	<0.18		<0.62	<0.06	17	<0.35	
River Duddon	Sea trout	1			<0.09		<0.32	<0.41		<0.77	<0.09	6.4	<0.34	
River Derwent	Sea trout	1			<0.06		<0.22	<0.28		<0.66	<0.07	6.4	<0.42	
Fleetwood	Cod	4		47	<0.06	0.032	<0.14	<0.13	0.51	<0.52	<0.06	5.7	<0.27	
Fleetwood	Plaice	4			<0.08		<0.13	<0.12		<0.53	<0.06	6.0	<0.27	
Ribble Estuary	Flounder	1			<0.07		<0.20	<0.21		<0.71	<0.07	8.4	<0.33	
Ribble Estuary	Salmon	1			<0.11		<0.31	<0.29		<1.1	<0.12	0.27	<0.69	
Ribble Estuary	Bass	1			<0.07		<1.0	*		<0.79	<0.08	12	<0.36	
Ribble Estuary	Sea trout	1			<0.09		<0.23	<0.24		<0.73	<0.09	15	<0.33	
Isle of Man	Cod	3			<0.08		<0.17	<0.16		<0.61	<0.07	3.6	<0.34	
Isle of Man	Herring	1			<0.14		<0.72	<1.3		<1.3	<0.13	1.1	<0.61	
Inner Solway	Flounder[d]	3	73	47	<0.11	<0.10	<0.26	<0.34	2.1	<0.65	<0.10	26	<0.42	
Inner Solway	Salmon	1	9.4		<0.10		<0.12	<0.10		<0.44	<0.10	0.26	<0.34	
Kirkcudbright	Plaice[e]	4			<0.10		<0.21	<0.19		<0.65	<0.10	2.8	<0.43	
Kirkcudbright	Sole	1			<0.13		<0.53	<0.72		<1.5	<0.15	3.2	<0.78	
North Anglesey	Plaice	1		23	<0.07		<0.27	<0.32		<0.73	<0.08	0.52	<0.29	
North Anglesey	Ray	2			<0.13		<0.34	<0.37		<1.1	<0.12	1.0	<0.50	
Northern Ireland	Cod	7		28	<0.06		<0.18	<0.20		<0.54	<0.06	2.7	<0.29	
Northern Ireland	Whiting[f]	8	<25		<0.10		<0.30	<0.36		<0.98	<0.10	4.9	<0.44	
Northern Ireland	Herring	1			<0.07		<0.49	<1.3		<0.73	<0.07	1.6	<0.35	
Northern Ireland	Spurdog	8			<0.08		<0.30	<0.44		<0.74	<0.08	3.6	<0.33	
Sound of Mull	Salmon	1			<0.04		<0.12	<0.12		<0.37	<0.04	0.17	<0.19	

Table 4.1. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Minch	Cod	4			<0.05		<0.24	<0.35	<0.52	<0.06	0.48	<0.29	
Minch	Plaice	4			<0.05		<0.21	<0.30	<0.50	<0.05	0.52	<0.31	
Minch	Haddock	4			<0.04		<0.18	<0.28	<0.41	<0.04	0.36	<0.25	
Minch	Herring	1			<0.04		<0.12	<0.11	<0.38	<0.04	0.62	<0.18	
Minch	Mackerel	2		31	<0.09	<0.023	<0.32	<0.45	<0.80	<0.09	0.16	<0.50	
Shetland	Fish meal[g]	4			<0.18	0.038	<0.39	<0.31	<1.6	<0.19	0.77	<0.85	
Shetland	Fish oil[g]	4			<0.10		<0.30	<0.31	<0.96	<0.11	<0.10	<0.56	
Northern North Sea	Cod	3			<0.04	<0.027	<0.18	<0.34	<0.41	<0.05	0.44	<0.24	
Northern North Sea	Plaice	3			<0.05		<0.20	<0.32	<0.46	<0.05	0.30	<0.28	
Northern North Sea	Haddock	2		28	<0.06		<0.16	<0.16	<0.53	<0.06	0.42	<0.24	
Northern North Sea	Herring	2			<0.06		<0.33	<0.76	<0.62	<0.07	0.41	<0.34	
Northern North Sea	Mackerel	1			<0.06		<0.21	<0.22	<0.60	<0.07	0.15	<0.42	
Mid-North Sea	Cod	3		24	<0.04	<0.023	<0.10	<0.11	<0.34	<0.04	0.47	<0.20	
Mid-North Sea	Plaice	3		26	<0.06	<0.025	<0.12	<0.10	<0.51	<0.06	0.25	<0.27	
Mid-North Sea	Herring	2			<0.10		<0.66	<0.08	<0.95	<0.10	0.56	<0.43	
Southern North Sea	Cod	2			<0.04	0.021	<0.08	<0.06	<0.33	<0.04	0.29	<0.19	
Southern North Sea	Plaice	2			<0.04	<0.025	<0.08	<0.06	<0.39	<0.04	0.38	<0.22	
Southern North Sea	Herring	2			<0.06		<0.17	<0.18	<0.58	<0.06	0.41	<0.30	
English Channel-East	Cod	3			<0.05	<0.024	<0.10	<0.08	<0.42	<0.05	0.28	<0.23	
English Channel-East	Plaice	4			<0.06	<0.025	<0.15	<0.14	<0.53	<0.06	<0.10	<0.25	
English Channel-East	Whiting	1			<0.06		<0.26	<0.36	<0.59	<0.06	0.33	<0.38	
English Channel-West	Plaice	4		26	<0.06	<0.024	<0.16	<0.16	<0.53	<0.06	0.16	<0.26	
English Channel-West	Mackerel	4			<0.08		<0.24	<0.26	<0.77	<0.09	0.35	<0.44	
English Channel-West	Whiting	4			<0.05	<0.026	<0.11	<0.11	<0.41	<0.05	0.34	<0.25	
Gt Yarmouth (retail shop)	Cod	4			<0.04		<0.08	<0.06	<0.34	<0.04	0.22	<0.19	
Gt Yarmouth (retail shop)	Plaice	4			<0.05		<0.10	<0.07	<0.44	<0.05	0.49	<0.20	
Skagerrak	Cod	4			<0.05		<0.22	<0.44	<0.43	<0.05	0.42	<0.24	
Skagerrak	Herring	4			<0.07		<0.24	<0.31	<0.67	<0.07	0.66	<0.40	
Iceland area	Cod	1			<0.06		<0.22	<0.28	<0.54	<0.06	0.19	<0.28	
Icelandic processed	Cod	2		20	<0.04		<0.07	<0.05	<0.31	<0.04	0.19	<0.15	
Barents Sea	Cod	4			<0.07		<0.52	<0.23	<0.67	<0.07	0.29	<0.33	
Baltic Sea	Cod	2			<0.06		<0.32	<0.58	<0.61	0.17	13	<0.33	
Baltic Sea	Herring	2			<0.08		<0.44	<0.82	<0.78	<0.09	8.9	<0.40	
Celtic Sea	Cod	4		19	<0.05	<0.024	<0.13	<0.14	<0.42	<0.05	0.40	<0.21	
Celtic Sea	Plaice	4			<0.08		<0.23	<0.24	<0.74	<0.08	0.30	<0.32	

* *Not detected by method used*
[a] *Sampling area or landing point*
[b] *See section 3 for definition*
[c] *The concentration of ^{147}Pm was 0.055 Bq kg^{-1}*
[d] *The concentration of organic ^{3}H was 16 Bq kg^{-1}*
[e] *The concentration of ^{65}Zn was 0.21 Bq kg^{-1}*
[f] *The concentration of organic ^{3}H was <25 Bq kg^{-1}*
[g] *Concentrations refer to weight as supplied*

Table 4.2. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 1999

Location[a]	Material	No. of sampling observ- ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag
Sellafield coastal area	Crabs[c]	8		120	4.4	1.6	<0.40	<0.69	53	<1.2	<2.4
Sellafield coastal area	Lobsters	8		150	3.9	0.70	<0.48	<0.84	4700	<1.4	4.4
Sellafield coastal area	*Nephrops*	1			0.77		<0.52	<0.66	990	<1.6	<0.30
Sellafield coastal area[d]	Winkles	4		110	25	4.7	<0.54	<0.56	290	19	9.1
Sellafield coastal area[d]	Mussels	4			14	2.0	<0.25	<0.20		20	<0.22
Sellafield coastal area[d]	Limpets	4		58	6.2	6.1	<0.17	<0.17	990	9.9	4.8
Sellafield coastal area	Whelks	2		98	3.4	0.15	<0.30	<0.56	120	2.3	2.4
Sellafield offshore area	Whelks	2			4.1		<0.22	<0.24		6.2	3.6
St Bees	Winkles[e]	4		130	19	8.3	<0.21	<0.22	200	15	7.2
St Bees	Mussels	4			13		<0.22	<0.19		14	<0.29
St Bees	Limpets	4			7.0		<0.21	<0.21		12	4.6
Nethertown	Winkles	12	52	120	25	5.9	<0.32	<0.30	190	25	10
Nethertown	Mussels	4		180	16		<0.28	<0.23	860	26	<0.26
Whitriggs	Prawns	1			1.4		<0.60	<0.81		<1.7	0.73
Drigg	Winkles	4		180	26		<0.37	<0.40	850	25	13
Ravenglass	Crabs	4			5.1	1.1	<0.50	<1.0	38	<1.4	3.3
Ravenglass	Lobsters	4			2.8	0.31	<0.42	<0.96	4400	<0.94	4.4
Ravenglass	Winkles	2			12		<0.22	<0.21		11	7.5
Ravenglass	Cockles	4		140	36	2.5	<0.23	<0.16	58	14	<0.32
Ravenglass	Mussels	4	92		8.4		<0.18	<0.13	920	12	<0.18
Tarn Bay	Winkles	2			14		<0.25	<0.23		11	6.0
Saltom Bay	Winkles	4			12		<0.27	<0.25		9.2	2.3
Whitehaven	*Nephrops*	4		52	<0.13	0.13	<0.40	<0.57	280	<1.2	<0.21
Whitehaven	Whelks	3		100	2.7	0.32	<0.20	<0.20		<2.4	2.0
Silloth	Mussels	4	<25		1.1		<0.48	<0.55		<1.7	<0.27
Parton	Crabs	4			1.8		<0.25	<0.30		<0.88	1.5
Parton	Lobsters	4			0.97		<0.19	<0.19		<0.73	1.3
Parton	Winkles	4			9.2		<0.25	<0.22		8.3	2.1
Haverigg	Cockles	2			8.2		<0.18	<0.13		2.7	<0.17
Millom	Mussels	2			2.0		<0.09	<0.07		2.2	<0.08
Morecambe Bay (Flookburgh)	Shrimps	4		75	<0.11		<0.20	<0.22	3.8	<0.74	<0.13
Morecambe Bay (Morecambe)	Mussels	4	87	72	0.81		<0.22	<0.21	190	<1.0	<0.15

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	Total beta
Sellafield coastal area	Crabs[c]	8	<0.27	<0.11	2.8	<0.50	0.39	<0.27	<0.22	170
Sellafield coastal area	Lobsters	8	<0.29	<0.12	4.6	<0.60	0.63	<0.32	<0.26	3200
Sellafield coastal area	*Nephrops*	1	<0.36	<0.15	9.3	<0.60		<0.44	<0.23	
Sellafield coastal area[d]	Winkles	4	<1.1	<0.23	8.6	<1.0	1.5	<0.61	<0.46	
Sellafield coastal area[d]	Mussels	4	<0.68	<0.12	4.5	<0.75		<0.39	<0.24	
Sellafield coastal area[d]	Limpets	4	1.6	<0.08	12	<0.60		<0.28	<0.21	
Sellafield coastal area	Whelks	2	<0.22	<0.08	1.7	<0.38		<0.23	<0.15	
Sellafield offshore area	Whelks	2	<0.37	<0.10	2.3	<0.51		<0.28	<0.24	
St Bees	Winkles[e]	4	<1.1	<0.09	14	<0.67	1.9	<0.30	<0.18	
St Bees	Mussels	4	0.78	<0.11	4.3	<0.46		<0.27	<0.23	
St Bees	Limpets	4	2.2	<0.10	9.9	<0.52		<0.29	<0.25	
Nethertown	Winkles	12	<1.5	<0.17	15	<0.86	4.4	<0.50	<0.36	410
Nethertown	Mussels	4	1.1	<0.14	4.7	<1.4		<0.35	<0.33	670
Whitriggs	Prawns	1	<0.36	<0.15	3.6	<0.61		<0.43	<0.23	
Drigg	Winkles	4	<1.3	<0.18	8.8	<0.85	2.2	<0.42	<0.33	800
Ravenglass	Crabs	4	<0.28	<0.10	2.5	<0.45		<0.25	<0.18	130
Ravenglass	Lobsters	4	<0.22	<0.09	3.5	<0.49		<0.24	<0.22	2700
Ravenglass	Winkles	2	<0.61	<0.12	9.6	<0.52		<0.34	<0.26	
Ravenglass	Cockles	4	<0.48	<0.12	7.6	<1.2		0.61	<0.25	200
Ravenglass	Mussels	4	0.56	<0.09	2.6	<0.40		<0.27	<0.18	
Tarn Bay	Winkles	2	0.79	<0.13	12	<0.62		<0.35	0.31	
Saltom Bay	Winkles	4	1.9	<0.13	11	<0.66		<0.33	<0.33	
Whitehaven	*Nephrops*	4	<0.28	<0.12	3.6	<0.54		<0.35	<0.23	280
Whitehaven	Whelks	3	<0.20	<0.08	2.1	<0.32		<0.24	<0.15	250
Silloth	Mussels	4	<0.38	<0.15	4.7	<0.68		<0.41	<0.31	
Parton	Crabs	4	<0.22	<0.08	2.4	<0.46		<0.23	<0.21	
Parton	Lobsters	4	<0.18	<0.08	3.6	<0.31		<0.22	<0.15	
Parton	Winkles	4	<1.1	<0.13	9.7	<0.52		<0.34	<0.26	
Haverigg	Cockles	2	<0.33	<0.10	6.3	<0.40		<0.27	<0.19	
Millom	Mussels	2	<0.15	<0.05	2.2	<0.23		<0.14	<0.11	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.20	<0.08	6.2	<0.42		<0.21	<0.19	
Morecambe Bay (Morecambe)	Mussels	4	<0.33	<0.09	4.8	<0.40		<0.24	<0.19	

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag
Morecambe Bay (Flookburgh)	Cockles	4		63	2.2	0.49	<0.15	<0.17	37	<0.96	<0.09
Morecambe Bay (Middleton sands)	Cockles	2			2.5		<0.13	<0.11		<0.95	<0.11
Fleetwood	Lobsters	2			0.41		<0.17	<0.18	2100	<0.53	0.68
Fleetwood	Squid	1			<0.07		<0.26	<0.37		<0.61	<0.12
Fleetwood	Whelks	4		27	0.34	0.022	<0.13	<0.12	27	<0.53	<0.21
Wirral	Shrimps	2	<130		<0.06		<0.11	<0.08	2.9	<0.48	<0.09
Wirral	Cockles	4			0.30		<0.16	<0.15	35	<0.68	<0.11
Liverpool Bay	Mussels	2	<25								
Mersey Estuary	Mussels	2	<25								
Ribble Estuary	Shrimps	2		47	<0.06		<0.13	<0.10	1.5	<0.57	<0.10
Knott End	Cockles	1			4.2		<0.14	<0.10		1.2	<0.12
Isle of Man	Lobsters	3			<0.09		<0.25	<0.29	260	<0.87	<0.16
Isle of Man	Scallops	4			<0.06		<0.29	<0.18		<0.50	<0.11
Inner Solway	Shrimps[i]	4	10		<0.12	<0.10	<0.18	<0.19	5.5	<0.56	<0.10
Southerness	Winkles	4	8.8		1.9		<0.14	<0.12	380	<0.99	0.64
Kirkcudbright	Scallops	7			<0.13		<0.09	<0.09		<0.30	<0.13
Kirkcudbright	Queens	8			<0.17		<0.13	<0.12		<0.46	<0.09
North Solway coast	Crabs	8		68	<0.50	<0.20	<0.21	<0.22	16	<0.68	0.41
North Solway coast	Lobsters[j]	8		57	<0.18	<0.096	<0.26	<0.26	640	<0.86	<0.27
North Solway coast	Winkles[k]	8			1.8		<0.14	<0.12		<1.1	0.78
North Solway coast	Cockles[l]	8	8.5	69	2.1	0.99	<0.13	<0.12	18	1.2	<0.10
North Solway coast	Mussels	8	8.1	62	0.78	0.48	<0.10	<0.09	270	<1.3	<0.09
Conwy	Mussels	2			<0.06		<0.13	<0.09		<0.57	<0.10
Northern Ireland	Lobsters	8			<0.12		<0.48	<0.84	180	<1.4	<0.27
Northern Ireland	*Nephrops*	8			<0.12		<0.51	<0.84	71	<1.2	<0.22
Northern Ireland	Winkles	4			<0.08		<0.17	<0.20		<0.48	<0.10
Northern Ireland	Mussels[f]	2	<25		<0.15		<0.57	<0.78	34	<1.6	<0.27
Minch	*Nephrops*	4			<0.10		<0.40	<0.57	23	<1.1	<0.19
Northern North Sea	*Nephrops*	3			<0.11		<0.41	<0.61	9.4	<1.1	<0.20
Mid North Sea	Mussels[g]	2			<0.05		<0.09	<0.07		<0.41	<0.08
Southern North Sea	Cockles	2			<0.04		<0.08	<0.06		<0.39	<0.07
Southern North Sea	Cockles[h]	2			0.06		<0.07	<0.06	0.20	<0.31	<0.06
Southern North Sea	Mussels	4			<0.10		<0.31	<0.38	3.0	<1.1	<0.18
English Channel-East	Scallops	4		29	<0.18		<0.16	<0.19		<0.52	<0.10
English Channel-West	Crabs	4		120	<0.07		<0.19	0.21		<0.59	<0.12
English Channel-West	Lobsters	3			<0.06		<0.15	<0.16	0.29	<0.56	<0.11
English Channel-West	Scallops	3		25	<0.04		<0.10	<0.09		<0.39	<0.08

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	Total beta
Morecambe Bay (Flookburgh)	Cockles	4	<0.18	<0.05	5.2	<0.25	<0.13	<0.11	
Morecambe Bay (Middleton sands)	Cockles	2	<0.15	<0.06	4.6	<0.25	<0.17	<0.13	
Fleetwood	Lobsters	2	<0.14	<0.06	2.6	<0.35	<0.15	<0.17	1400
Fleetwood	Squid	1	<0.16	<0.07	1.4	<0.29	<0.20	<0.12	
Fleetwood	Whelks	4	<0.13	<0.06	1.1	<0.25	<0.16	<0.13	
Wirral	Shrimps	2	<0.14	<0.06	2.5	<0.28	<0.17	<0.15	
Wirral	Cockles	4	<0.18	<0.07	1.3	<0.40	<0.18	<0.20	
Liverpool Bay	Mussels	2							
Mersey Estuary	Mussels	2							
Ribble Estuary	Shrimps	2	<0.16	<0.06	3.8	<0.32	<0.17	<0.16	
Knott End	Cockles	1	<0.19	<0.07	4.4	<0.39	<0.16	<0.19	
Isle of Man	Lobsters	3	<0.21	<0.09	0.61	<0.41	<0.27	<0.18	190
Isle of Man	Scallops	4	<0.12	<0.05	0.47	<0.32	<0.16	<0.15	
Inner Solway	Shrimps[i]	4	<0.17	<0.10	7.0	<0.36	<0.10	<0.19	
Southerness	Winkles	4	<0.33	<0.10	1.9	<0.36	<0.10	<0.17	
Kirkcudbright	Scallops	7	<0.09	<0.07	<0.36	<0.20	<0.10	<0.11	
Kirkcudbright	Queens	8	<0.12	<0.07	0.54	<0.25	<0.12	<0.12	
North Solway coast	Crabs	8	<0.17	<0.09	1.4	<0.36	<0.16	<0.18	
North Solway coast	Lobsters[j]	8	<0.22	<0.11	1.9	<0.40	<0.23	<0.19	
North Solway coast	Winkles[k]	8	<0.33	<0.09	2.0	<0.32	<0.16	<0.17	
North Solway coast	Cockles[l]	8	<0.16	<0.07	5.0	<0.26	<0.13	<0.13	
North Solway coast	Mussels	8	<0.12	<0.07	2.7	<0.23	<0.12	<0.12	
Conwy	Mussels	2	<0.16	<0.06	0.34	<0.37	<0.17	<0.19	
Northern Ireland	Lobsters	8	<0.30	<0.13	<0.41	<0.72	<0.35	<0.27	
Northern Ireland	*Nephrops*	8	<0.27	<0.12	1.2	<0.58	<0.36	<0.25	
Northern Ireland	Winkles	4	<0.12	<0.05	0.40	<0.23	<0.15	<0.10	
Northern Ireland	Mussels[f]	2	<0.34	<0.15	0.89	<0.64	<0.40	<0.26	
Minch	*Nephrops*	4	<0.23	<0.10	0.59	<0.41	<0.30	<0.16	
Northern North Sea	*Nephrops*	3	<0.24	<0.11	0.21	<0.47	<0.32	<0.19	
Mid North Sea	Mussels[g]	2	<0.11	<0.05	<0.05	<0.20	<0.13	<0.10	20
Southern North Sea	Cockles	2	<0.10	<0.04	0.20	<0.21	<0.12	<0.11	
Southern North Sea	Cockles[h]	2	<0.08	<0.04	0.13	<0.15	<0.09	<0.07	
Southern North Sea	Mussels	4	<0.27	<0.11	<0.21	<0.58	<0.30	<0.28	
English Channel-East	Scallops	4	<0.13	<0.06	<0.06	<0.32	<0.18	<0.16	
English Channel-West	Crabs	4	<0.15	<0.06	<0.06	<0.35	<0.18	<0.17	
English Channel-West	Lobsters	3	<0.14	<0.06	<0.06	<0.26	<0.18	<0.11	
English Channel-West	Scallops	3	<0.10	<0.04	<0.06	<0.20	<0.14	<0.09	

[a] *Landing point or sampling area.*
[b] *See section 3 for definition*
[c] *The concentration of ^{129}I was <1.0 Bq kg^{-1}*
[d] *Samples collected by Consumer 116*
[e] *The concentration of ^{129}I was <0.60 Bq kg^{-1}*
[f] *The concentration of organic ^{3}H was <25 Bq kg^{-1}*
[g] *Landed in Denmark*
[h] *Landed in Holland*
[i] *The concentration of ^{65}Zn was 0.14 Bq kg^{-1}*
[j] *The concentration of ^{65}Zn was <0.28 Bq kg^{-1}*
[k] *The concentration of ^{65}Zn was <0.18 Bq kg^{-1}*
[l] *The concentration of ^{65}Zn was <0.14 Bq kg^{-1}*

Table 4.3. Transuranic radioactivity in fish and shellfish from the Irish Sea vicinity and further afield, 1999

Location[a]	Material	No. of sampling observ-ations[b]	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		0.00090	0.0044		0.0073	<0.00022	<0.000073
Sellafield coastal area	Plaice	1		0.0038	0.024		0.032	0.000089	0.000049
Sellafield coastal area	Grey mullet	1					<0.29		
Sellafield coastal area	Bass	1					<0.14		
Sellafield coastal area	Crabs	2	0.0044	0.070	0.34	4.0	1.6	<0.0030	0.0036
Sellafield coastal area	Lobsters	2	0.021	0.059	0.28	3.1	3.8	*	0.0088
Sellafield coastal area	*Nephrops*	1		0.083	0.43		2.7	0.0022	0.0031
Sellafield coastal area	Winkles[c]	1	0.027	2.3	11	120	12	*	0.024
Sellafield coastal area	Mussels[c]	1		2.0	9.8	120	19	*	0.045
Sellafield coastal area	Limpets[c]	1		2.3	11	130	20	*	0.037
Sellafield coastal area	Whelks	1		0.35	1.7	19	4.3	*	0.0070
Sellafield offshore area	Cod	1		0.010	0.054		0.085	0.000031	0.00013
Sellafield offshore area	Plaice	1	0.0011	0.017	0.080		0.14	*	0.00033
Sellafield offshore area	Dab	2					0.26		
Sellafield offshore area	Herring	1					<0.13		
Sellafield offshore area	Spurdog	2					<0.08		
Sellafield offshore area	Whiting	2					<0.12		
Sellafield offshore area	Whelks	1		0.51	2.6	29	5.7	*	0.011
St Bees	Winkles	1	0.027	2.6	14	150	26	0.081	0.047
St Bees	Mussels	2		1.7	8.3	96	27	*	0.075
St Bees	Limpets	1		2.0	10		20	0.043	0.037
Nethertown	Winkles	4	0.037	3.4	17	190	30	*	0.057
Nethertown	Mussels	4		1.9	9.1		17	<0.018	0.046
Whitriggs	Prawns	1					<0.12		
Drigg	Winkles	4	0.034	2.7	13	150	30	<0.018	<0.047
Ravenglass	Cod	1		0.00068	0.0035		0.0039	*	0.000011
Ravenglass	Plaice	1		0.0017	0.0082		0.014	*	0.000023
Ravenglass	Crabs	1		0.052	0.26	3.1	1.5	0.0014	0.0032
Ravenglass	Lobsters	1		0.054	0.25	2.7	3.1	*	0.0088
Ravenglass	Winkles	2					21		
Ravenglass	Cockles	1		2.3	12	130	33	*	0.048
Ravenglass	Mussels	1		1.2	5.8	68	13	*	0.021
Tarn Bay	Winkles	1		2.6	13	140	23	*	0.070
Saltom Bay	Winkles	4					18		
Whitehaven	Cod	1		0.0014	0.0075		0.013	*	*
Whitehaven	Plaice	1		0.0022	0.011		0.021	*	*
Whitehaven	Ray	1		0.00060	0.0028		0.0049	*	*
Whitehaven	*Nephrops*	1		0.021	0.12		0.43	*	0.00060
Whitehaven	Whelks	1		0.46	2.3	26	4.7	0.0036	0.0082
Silloth	Mussels	1		0.59	3.1		5.9	0.0099	0.0084
Parton	Cod	4					<0.14		
Parton	Crabs	4					1.3		
Parton	Lobsters	4					1.3		
Parton	Winkles	1		1.4	7.1	79	12	*	0.017
Haverigg	Cockles	1		1.4	7.2		21	*	0.031
Millom	Mussels	2					4.0		
Morecambe Bay (Flookburgh)	Flounder	1		0.0012	0.0063		0.012	*	0.000021
Morecambe Bay (Morecambe)	Plaice	1		0.00023	0.0012		0.0022	*	*
Morecambe Bay (Morecambe)	Bass	2					<0.15		
Morecambe Bay (Sunderland Point)	Whitebait	1		0.066	0.35	3.6	0.59	*	0.00083

Table 4.3. continued

Location[a]	Material	No. of sampling observ-ations[b]	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)	Shrimps	1	0.0046	0.027	0.70	0.046	*	0.00013
Morecambe Bay (Morecambe)	Mussels	1	0.36	2.0		3.6	*	0.0038
Morecambe Bay (Flookburgh)	Cockles	1	0.48	2.5	27	6.9	0.013	0.017
Morecambe Bay (Middleton Sands)	Cockles	1	0.39	2.2		5.1	*	0.0073
Calder Farm	Rainbow trout	1				<0.22		
River Duddon	Sea trout	1				<0.15		
River Derwent	Sea trout	1				<0.17		
Fleetwood	Cod	1	0.000066	0.00032		0.00076	*	*
Fleetwood	Plaice	1	0.00037	0.0021		0.0042	*	0.000014
Fleetwood	Lobsters	2				1.0		
Fleetwood	Squid	1				0.10		
Fleetwood	Whelks	1	0.093	0.49		0.63	*	0.0013
Ribble Estuary	Flounder	1				<0.08		
Ribble Estuary	Salmon	1				<0.55		
Ribble Estuary	Bass	1				<0.06		
Ribble Estuary	Sea trout	1				<0.08		
Ribble Estuary	Shrimps[g]	1	0.0025	0.012		0.023	*	0.000048
Wirral	Shrimps	2				<0.17		
Wirral	Cockles	1	0.14	0.79		2.1	*	0.0028
Knott End	Cockles	1	0.42	2.3		5.7	*	0.0084
Isle of Man	Cod	1	0.00014	0.00087		0.0016	*	0.000011
Isle of Man	Herring	1	0.000093	0.00051		0.00072	*	*
Isle of Man	Lobsters	3				<0.15		
Isle of Man	Scallops	1	0.018	0.10		0.038	*	0.000046
Inner Solway	Flounder	1	0.0070	0.028		0.079	*	*
Inner Solway	Salmon	1	0.0025	0.0030		<0.00052		
Inner Solway	Shrimps	1	0.0036	0.013		0.036	*	*
Southerness	Winkles	1	0.018	0.91		1.6		
Kirkcudbright	Plaice	1	0.0034	0.016		0.084		
Kirkcudbright	Sole	1				<0.29		
Kirkcudbright	Scallops	2	0.022	0.11		0.13	0.000086	0.00011
Kirkcudbright	Queens	2	0.015	0.081		0.066	0.00011	0.000077
North Solway coast	Crabs	2	0.014	0.069	0.66	0.46	*	0.00033
North Solway coast	Lobsters	2	0.014	0.072	0.70	0.37	*	0.00052
North Solway coast	Winkles	2	0.19	0.95	9.9	2.1	*	0.0033
North Solway coast	Cockles	5	0.52	2.7	28	6.8	*	0.014
North Solway coast	Mussels	2	0.41	2.2	28	4.2	*	0.010
Conwy	Mussels	1	0.022	0.12		0.22	*	0.00040
North Anglesey	Plaice	1				<0.15		
North Anglesey	Rays	1	0.000031	0.00021		0.00029	*	*
Northern Ireland	Cod	7				<0.19		
Northern Ireland	Whiting	1	0.00026	0.0015		0.0019	*	*
Northern Ireland	Herring	1				<0.06		
Northern Ireland	Spurdog	8				<0.10		
Northern Ireland	Lobsters	8				<0.28		
Northern Ireland	*Nephrops*	1	0.0050	0.026		0.075	*	*
Northern Ireland	Winkles	1	0.030	0.16		0.13	*	0.00035
Northern Ireland	Mussels	2				<0.29		

Table 4.3. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}				
			^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$
South of Mull	Salmon	1			<0.11		
Minch	Cod	1	0.000039	0.00033	0.00045	*	*
Minch	Plaice	4			<0.17		
Minch	Haddock	1	0.00081	0.0049	0.0076	0.000031	0.000027
Minch	Herring	1			<0.05		
Minch	Mackerel	1	0.000093	0.00058	0.00073	*	*
Minch	*Nephrops*	1	0.00057	0.0031	0.0095	*	0.000012
Shetland	Fish meal[d]	1	0.00013	0.0010	0.00056	*	*
Shetland	Fish oil[d]	4			<0.13		
Northern North Sea	Cod	1	0.00014	0.00073	0.00051	*	*
Northern North Sea	Plaice	3			<0.16		
Northern North Sea	Haddock	1	0.00010	0.00055	0.00058	*	*
Northern North Sea	Herring	2			<0.16		
Northern North Sea	Mackerel	1			<0.18		
Northern North Sea	*Nephrops*	1	0.0011	0.0045	0.0023	*	0.000027
Mid North Sea	Cod	3			<0.08		
Mid North Sea	Plaice	3			<0.10		
Mid North Sea	Herring	2			<0.18		
Mid North Sea	Mussels[e]	1	0.00031	0.0028	0.0028	*	*
Southern North Sea	Cod	2			<0.11		
Southern North Sea	Plaice	2			<0.15		
Southern North Sea	Herring	2			<0.10		
Southern North Sea	Cockles	1	0.0020	0.012	0.0064	*	0.000021
Southern North Sea	Cockles[f]	1	0.0026	0.011	0.013	*	0.00093
Southern North Sea	Mussels	1	0.0034	0.022	0.0093	*	*
English Channel-East	Cod	3			<0.14		
English Channel-East	Plaice	4			<0.14		
English Channel-East	Whiting	1			<0.25		
English Channel-East	Scallops	1	0.00090	0.0034	0.0021	0.00012	0.00013
English Channel-West	Plaice	4			<0.10		
English Channel-West	Mackerel	4			<0.22		
English Channel-West	Whiting	4			<0.18		
English Channel-West	Crabs	1	0.00018	0.0015	0.0019	0.000043	0.00014
English Channel-West	Lobsters	3			<0.07		
English Channel-West	Scallops	1	0.00021	0.0032	0.00077	*	*
Gt. Yarmouth (retail shop)	Cod	4			<0.10		
Gt. Yarmouth (retail shop)	Plaice	4			<0.07		
Skagerrak	Cod	4			<0.13		
Skagerrak	Herring	4			<0.23		
Iceland Area	Cod	1			<0.15		
Icelandic processed	Cod	1	0.00014	0.00063	0.0011	*	*
Barents Sea	Cod	4			<0.12		
Baltic Sea	Cod	2			<0.07		
Baltic Sea	Herring	2			<0.13		
Celtic Sea	Cod	4			<0.09		
Celtic Sea	Plaice	4			<0.13		

* *not detected by the method used*
[a] *Sampling area or landing point*
[b] *See section 3 for definition*
[c] *Samples collected by Consumer 116*
[d] *Concentrations refer to weight as supplied*
[e] *Landed in Denmark*
[f] *Landed in Holland*
[g] *The concentration of* ^{237}Np *was 0.0020 Bq kg*$^{-1}$

Table 4.4. Individual radiation exposures due to consumption of Irish Sea fish and shellfish, 1999

Exposed population[b]	Foodstuffs	Exposure mSv[a]												
		Total	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Others	External
Sellafield fishing community	Plaice and cod Crabs and lobsters Winkles and other molluscs	0.21[f]	0.005	0.002	0.005	0.016	0.003	0.009	0.008	0.046	0.010	0.082	<0.002	0.023
Whitehaven commercial fisheries	Plaice and cod *Nephrops* Whelks	0.038	0.002			0.002		0.005	0.002	0.009	0.002	0.015	<0.002	
Dumfries and Galloway	Plaice, cod and salmon Crabs, Lobster and *Nephrops* Winkles and mussels	0.028[c]	0.002			0.005		0.005		0.002		0.005	<0.001	0.009
Morecambe Bay	Flounders and plaice Shrimps Cockles and mussels	0.071[d]	0.003			0.002		0.012	0.002	0.012	0.003	0.023	<0.001	0.013
Fleetwood	Plaice and cod Shrimps Whelks	0.021	0.002					0.010		0.003		0.004	<0.002	
Isle of Man	Fish and shellfish[e]	0.010				0.003		0.003					<0.004	
Northern Ireland	Fish and shellfish[e]	0.013				0.002		0.005				0.003	<0.003	
North Wales	Fish and Shellfish[e]	0.006						0.002				0.002	<0.002	
Typical member of the fish eating public consuming fish landed at Whitehaven and Fleetwood	Plaice and cod	0.002						0.001					<0.001	

[a] *Due to artificial radionuclides: see text for exposures due to natural radionuclides. Blank data indicate a dose of less than 1 µSv. 'Others' comprises data for all radionuclides with doses below 1 µSv.*
[b] *Representative of people most exposed unless stated otherwise*
[c] *Including exposure due to 1000 h year^{-1} occupancy over intertidal sediments*
[d] *Including exposure due to 900 h year^{-1} occupancy over intertidal sediments*
[e] *Local habits surveys have not been undertaken in these areas; representative species are adopted for fish, crustaceans and molluscs*
[f] *Including exposure due to 1000 h year^{-1} occupancy over intertidal sediments*

Table 4.5. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 1999

Location	Ground type	No. of sampling observations[a]	Mean gamma dose rate in air at 1 m, $\mu Gy\ h^{-1}$
Cumbria			
Rockcliffe Marsh	Salt marsh	4	0.076
Newton Arlosh	Salt marsh	4	0.11
Parton	Winkle bed	4	0.091
Whitehaven - outer harbour	Mud and sand	10	0.092
Whitehaven - outer harbour	Coal and sand	12	0.11
Whitehaven - outer harbour	Sand	1	0.085
Saltom Bay	Winkle bed	4	0.10
St Bees	Sand	4	0.070
Nethertown	Winkle bed	4	0.091
Sellafield	Sand	4	0.074
Drigg Barn Scar	Mussel bed	4	0.094
Ravenglass - Carleton Marsh	Salt marsh	4	0.22
Ravenglass - salmon garth	Mud and sand	3	0.12
Ravenglass - salmon garth	Mud, sand and stones	1	0.11
Ravenglass - salmon garth	Sand and stones	4	0.091
Ravenglass - salmon garth	Mussel bed	4	0.094
Ravenglass - ford	Mud and sand	4	0.11
Ravenglass - Raven Villa	Mud	8	0.12
Ravenglass - Raven Villa	Mud and sand	4	0.12
Ravenglass - Raven Villa	Salt marsh	12	0.18
Newbiggin	Mud	3	0.18
Newbiggin	Mud and sand	1	0.18
Newbiggin	Salt marsh	4	0.23
Tarn Bay	Sand	2	0.066
Tarn Bay	Winkle bed	2	0.088
Haverigg	Mud	3	0.095
Haverigg	Mud and sand	1	0.097
Haverigg	Sand	4	0.065
Millom	Mud and sand	4	0.10
Walney Channel - Vickerstown Church	Mud and sand	4	0.087
Sand Gate Marsh	Salt marsh	4	0.095
Flookburgh	Mud and sand	4	0.074
High Foulshaw	Salt marsh	4	0.090
Arnside	Salt marsh	4	0.10
Lancashire			
Calloway Marsh	Salt marsh	4	0.15
Aldcliffe Marsh	Salt marsh	4	0.11
Conder Green	Mud and sand	4	0.098
Conder Green	Salt marsh	4	0.11
Cockerham Marsh	Salt marsh	4	0.11
Heads - River Wyre	Salt marsh	2	0.11
Height o' th' hill - River Wyre	Salt marsh	4	0.12
Knott End	Mud and sand	2	0.082
Skippool Creek (boat 2)	Cabin[b]	1	0.099
Skippool Creek	Mud	1	0.093
Skippool Creek	Mud and sand	3	0.093
South-west Scotland			
Luce Bay	Sand	4	0.053
Garlieston	Mud	4	0.068
Innerwell	Mud and sand	8	0.077
Creetown	Salt marsh	4	0.089
Carsluith	Mud	4	0.081
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.074
Kirkcudbright	Salt marsh	4	0.077
Cutters Pool	Winkle bed	4	0.090
Rascarrel Bay	Winkle bed	4	0.12
Palnackie Harbour	Mud	4	0.076
Gardenburn	Salt marsh	4	0.084
Kippford - Slipway	Mud	4	0.10
Kippford - Merse	Salt marsh	4	0.10
Carsethorn	Mud and sand	4	0.064
Glencaple Harbour	Mud and sand	4	0.073

[a] *See section 3 for definition*
[b] *In the cabin of a boat or houseboat*

Table 4.6. Radioactivity in sediment from the Cumbrian coast and further afield, 1999

Location	Material	No. of sampling observ-ations[a]	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu
Cumbria											
Newton Arlosh	Turf	4	2.5	<2.4	<3.2	<8.2	<3.2	<0.80	630	<4.3	<2.8
St Bees	Sand	4	4.0	<0.88	<0.91	<3.3	<1.0	<0.34	85	<1.9	1.5
Sellafield	Sand	4	4.9	<0.97	<0.95	<3.7	<1.2	<0.39	84	<2.1	1.9
Ravenglass - Carleton Marsh	Mud	4	49	<2.6	<2.5	110	<6.5	<1.0	540	15	13
Ravenglass - Raven Villa	Mud and sand	4	43	<2.6	<2.7	73	<5.2	<1.0	270	9.7	7.0
Newbiggin	Mud	4	52	<2.8	<3.1	87	<6.1	<1.0	360	<12	8.9
Millom	Mud and sand	4	11	<1.8	<1.7	<21	<2.3	<0.72	250	<4.4	4.4
Flookburgh	Mud and sand	4	<1.5	<1.1	<1.2	<4.1	<1.3	<0.48	100	<2.5	<1.2
Sand Gate marsh	Turf	4	1.2	<1.4	<1.5	<5.3	<1.9	<0.58	240	<2.9	<1.7
Lancashire											
Conder Green	Turf	4	3.5	<1.7	<1.7	<7.8	<2.7	<0.79	310	<4.5	<1.9
South-west Scotland											
Garlieston	Mud[b]	4	1.0	<0.25	<0.20	<1.1	<0.41	<0.12	65	<0.78	<0.36
Innerwell	Mud[c]	6	<2.0	<0.69	<0.65	<3.4	<0.91	<0.31	120	<1.7	<1.0
Carsluith	Mud	4	2.9	<0.36	<0.29	8.9	<0.91	<0.18	200	<1.1	2.2
Kippford Merse	Salt marsh	4	5.3	<0.40	<0.29	<10	2.2	0.25	750	<1.0	5.8
Kippford Slipway	Mud	4	4.2	<0.36	<0.23	7.1	<1.3	<0.30	270	<1.3	2.2
Palnackie Harbour	Mud[d]	4	4.9	<0.34	<0.25	14	<1.0	<0.17	230	<0.97	2.3
Carsethorn	Mud and sand[e]	2	0.49	<0.77	<0.13	<0.91	<0.37	<0.12	110	<0.67	<0.35
Isle of Man											
Douglas	Mud	1	<0.21	<0.65	<0.64	<2.1	<0.61	<0.29	21	<1.4	<0.66
Northern Ireland											
Lough Foyle	Mud and sand	2	<0.22	<0.95	<1.3	<2.6	<0.74	<0.31	2.5	<2.1	<0.69
Portrush	Sand	2	<0.18	<0.93	<1.4	<2.1	<0.49	<0.24	1.2	<1.1	<0.58
Ballymacormick	Mud	2	<0.38	<1.6	<2.2	<3.9	<1.0	<0.48	37	<2.1	<1.1
Strangford Lough -Nickey's point	Mud	2	<0.19	<0.76	<1.0	<2.0	<0.57	<0.25	32	<1.4	<0.56
Dundrum Bay	Mud	2	<0.24	<0.89	<1.1	<2.5	<0.63	<0.32	9.3	<1.6	<0.79
Carlingford Lough	Mud	2	<0.49	<2.1	<3.0	<5.3	<1.6	<0.70	85	<3.1	<1.6
Oldmill Bay	Mud	2	<0.44	<2.0	<3.9	<4.3	<1.2	<0.53	68	<2.1	<1.3

Table 4.6. continued

Location	Material	No. of sampling observ-ations[a]	Mean radioactivity concentration (dry), Bq kg^{-1}						
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{243}Cm+ ^{244}Cm	Total beta
Cumbria									
Newton Arlosh	Turf	4	<2.5				240		
St Bees	Sand	4	<0.90				180		
Sellafield	Sand	4	<1.2				200		
Ravenglass - Carleton Marsh	Mud	4	6.6				1100		
Ravenglass - Raven Villa	Mud and sand	4	<3.2				550		
Newbiggin	Mud	4	<4.8	110	520	6100	810	1.8	1500
Millom	Mud and sand	4	<3.0				350		
Flookburgh	Mud and sand	4	<1.3				55		
Sand Gate marsh	Turf	4	<1.3				97		
Lancashire									
Conder Green	Turf	4	<2.3				160		
South-west Scotland									
Garlieston	Mud[b]	4	<0.49	6.1	34		47		
Innerwell	Mud[c]	6	<1.7				77		
Carsluith	Mud	4	<1.3	24	120		200		2100
Kippford Merse	Salt marsh	4	<2.5	60	310		450		
Kippford Slipway	Mud	4	<1.1	26	130		200		
Palnackie Harbour	Mud[d]	4	<1.7	30	160		310		
Carsethorn	Mud and sand[e]	2	<0.71				40		
Isle of Man									
Douglas	Mud	1	1.3				1.7		
Northern Ireland									
Lough Foyle	Mud and sand	2	<1.0	0.11	0.56		0.74	0.0031	
Portrush	Sand	2	<0.52				<0.61		
Ballymacormick	Mud	2	<0.96	3.0	17		20	0.031	
Strangford Lough -Nickey's point	Mud	2	<0.66	1.2	7.0		7.1	0.021	
Dundrum Bay	Mud	2	<0.79				<1.6		
Carlingford Lough	Mud	2	<2.4	2.2	13		8.3		
Oldmill Bay	Mud	2	<0.94	3.5	19		28	0.066	

* *Not detected by the method used*
[a] *See section 3 for definition*
[b] *The concentration of ^{56}Co was 0.13 Bq kg^{-1}*
[c] *The concentration of ^{54}Mn was <0.26 Bq kg^{-1}*
[d] *The concentration of ^{54}Mn was <0.15 Bq kg^{-1}*
[e] *The concentration of ^{3}H was 2.1 Bq kg^{-1}*

Table 4.7. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 1999

Vessel	Type of gear	No. of sampling observations[a]	Mean beta dose rate in tissue, $\mu Sv\ h^{-1}$
A	Nets	5	0.11
	Ropes	5	0.073
R	Nets	4	0.099
S	Gill nets	1	0.072
	Nets	1	0.13
	Pots	2	0.093
T	Gill nets	4	0.062
	Pots	2	0.11
X	Gill nets	4	0.074
	Pots	2	0.072

[a] *See section 3 for definition*

Table 4.8. Radioactivity in terrestrial food and the environment near Sellafield, 1999,[g,h]

Material		Selection[c]	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
				^{3}H (organic)	^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb
Milk	Near farms[i]		12	<3.8	<4.5	18	<0.83	<0.35	0.11	<0.0050	<2.3	<0.64
Milk	Near farms[i]	max		<6.8	10	28	2.0	<0.44	0.32		<2.8	<0.72
Milk	Far farms		4	<3.8	<3.8	14	<1.1	<0.35	0.057	<0.012	<2.4	<0.67
Milk	Far farms	max				16	<2.0	<0.39	0.065		<2.6	<0.71
Apples			2	<6.5	6.5	16	1.6	<0.40	0.051	<0.038	<2.4	<0.80
Apples		max		<7.0	7.0	18	1.7		0.065		<2.5	
Barley			2		<13	130	<2.3	<0.25	2.3		<1.2	<0.45
Barley		max			18		4.1	<0.30	3.0		<1.6	<0.50
Bovine kidney			1	<7.0	<7.0	34	<1.0	<0.20	0.18		<1.0	<0.70
Bovine liver			1	<7.0	<7.0	60	<1.1	<0.40	0.072	<0.031	<2.5	<0.50
Bovine muscle			1	<5.0	<5.0	48	2.2	<0.50	<0.036	<0.034	<2.3	<0.60
Cabbage			1	5.0	11	6.0	1.0	<0.60	0.69		<3.3	<1.0
Carrots			1	2.0	7.0	30	0.50	<0.40	0.56	<0.027	<2.8	<0.80
Cauliflower			1									
Chicken			1	<5.0	<5.0	34	2.2	<0.40	0.20		<2.9	<0.60
French beans			1	<5.0	<5.0	14	0.70	<0.50	0.56		<3.5	<0.90
Hares			1	<6.0	6.0	33	30	<0.20	0.055		<2.0	<0.70
Honey			1		<6.0	72	<0.60	<0.20	<0.0080		<3.3	<0.60
Mushrooms			1	<5.0	<5.0	<2.0	3.2	<0.40	0.14		<2.7	<0.70
Ovine offal			2	<5.5	<5.5	32	3.1	<0.45	0.44	<0.080	<3.1	<0.90
Ovine offal		max		<7.0	<7.0	36	4.5	<0.50	0.76	0.12	<3.2	<1.0
Ovine muscle			2	<5.0	<5.5	48	3.7	<0.20	0.078	<0.037	<1.4	<0.40
Ovine muscle		max		5.0	6.0	62	4.9		0.11	<0.045		
Pheasants			1	4.0	8.0	28	3.4	<0.20	<0.028	<0.030	<1.6	<0.40
Pigeons			1	7.0	13	27	4.1	<0.50	0.061		<3.9	<0.90
Potatoes			2	<3.5	5.5	25	0.55	<0.50	0.079		<3.4	<0.85
Potatoes		max		<6.0	6.0	27	0.80		0.12		<3.7	<1.0
Runner beans			1	<7.0	6.0	12	0.70	<0.50	0.28		<2.2	<0.80
Swede			1	1.0	16	12	<0.60	<0.30	0.93		<1.6	<0.20
Turnips			1									
Grass[d,e,f]			2							<0.036	<2.1	
Grass[d,e,f]		max									<2.2	

Table 4.8. continued

Material	Selection[c]	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{129}I	^{137}Cs	Total Cs	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk Near farms[i]		12	<0.012	<0.44	0.19		<0.00018	<0.00026	<0.069	<0.00015
Milk Near farms[i]	max		<0.018	<0.52	0.33		<0.00020	<0.00035	<0.081	<0.00018
Milk Far farms		4	<0.011	<0.35	0.12		<0.00018	<0.00023	<0.062	<0.00013
Milk Far farms	max			<0.37	0.15					
Apples		2	<0.061		0.13		<0.00030	0.00055	<0.061	0.00085
Apples	max		<0.079		0.16			0.00060	<0.064	0.0011
Barley		2	<0.12		0.79		0.0013	0.023	<0.18	0.016
Barley	max		0.12		0.97		0.0016	0.035	0.25	0.019
Bovine kidney		1			<0.047		<0.00020	0.0015	<0.084	0.00020
Bovine liver		1	<0.070		0.079		<0.00060	<0.00040	<0.067	<0.00040
Bovine muscle		1	<0.031		0.33		0.00020	0.0018	<0.12	<0.00010
Cabbage		1	<0.038		0.10		<0.00040	<0.00040	<0.082	<0.00020
Carrots		1	<0.053		0.084		<0.00040	0.0014	<0.075	0.00080
Cauliflower		1				<0.032				
Chicken		1	<0.035		0.13		0.00040	<0.00040	<0.069	<0.00020
French beans		1	<0.037		0.25		0.00030	0.00030	0.095	0.00090
Hares		1			3.7		<0.0010	<0.0011	0.30	<0.00050
Honey		1	0.018		0.31		0.00020	<0.00030	<0.060	0.00080
Mushrooms		1	<0.065		0.34		0.00040	0.0074	0.14	0.0040
Ovine offal		2			0.55		0.079	0.34	4.1	0.26
Ovine offal	max				0.61		0.14	0.59	7.6	0.42
Ovine muscle		2	<0.042		0.64		<0.00035	0.00065	<0.072	0.0015
Ovine muscle	max		<0.046		0.69		<0.00040	0.00090	<0.082	0.0022
Pheasants		1	<0.052		1.1		<0.00030	0.00080	0.24	0.00060
Pigeons		1	<0.057		4.5		<0.0010	<0.00070		0.0011
Potatoes		2	<0.047		0.19		<0.00025	0.0025	<0.10	0.0012
Potatoes	max		<0.049		0.30		<0.00030	0.0033	<0.11	0.0017
Runner beans		1	<0.040		0.24		<0.00050	<0.00050	<0.077	<0.00030
Swede		1	<0.066		0.25		0.00040	0.0081	0.12	0.0026
Turnips		1				0.048				
Grass[d,e,f]		2								
Grass[d,e,f]	max									

[a] *Except for milk where the units used are Bq l^{-1} and for soil where the dry concentrations apply*
[b] *See section 3 for definition*
[c] *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. See section 3 for definition*
[d] *The mean concentration of ^{45}Ca was 17 Bq kg^{-1}; the maximum was 18 Bq kg^{-1}*
[e] *The mean concentration of ^{55}Fe was 2.8 Bq kg^{-1}; the maximum was 4.6 Bq kg^{-1}*
[f] *The mean concentration of ^{63}Ni was <0.20 Bq kg^{-1}*
[g] *The concentrations of U, ^{234}U, ^{235}U and ^{238}U in soil were 49, 17, 0.72 and 16 Bq kg^{-1} respectively*
[h] *345 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.47, 1.8 and 1.3 Bq per cloth*
[i] *The mean concentration of ^{131}I was <0.030 Bq l^{-1}; the maximum was <0.032 Bq l^{-1}*
[j] *Three samples of grass were analysed for their Cs content following an unusual release in January 1999. The mean concentrations of ^{134}Cs and ^{137}Cs were <0.70 (max <0.90) and <1.4 (max 2.5) Bq kg^{-1} respectively*
k *A sample of barley was analysed as a follow up to the November 1997 enhanced discharge. The concentrations of ^{106}Ru, ^{134}Cs ad ^{137}Cs were <3.7, <0.50 and 3.7 Bq kg^{-1}*

Table 4.9. Individual radiation exposures due to consumption of terrestrial foodstuffs near Sellafield and Drigg, 1999

Exposed population[b]	Key foodstuffs	Exposure mSv[a]												
		Total	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{106}Ru	^{125}Sb	^{129}I	^{131}I	^{137}Cs	^{144}Ce	Others
Consumers near Sellafield aged 1 y	Milk Potatoes	0.044	0.006	0.004	0.005	0.011		0.010	0.002	0.002	0.002	0.002		<0.001
Consumers near Drigg aged 1 y	Milk Potatoes	0.020		0.001	0.004	0.004		0.006	0.001	0.001		0.001		<0.002
Consumers near Ravenglass aged 1 y	Milk Fruit	0.026		0.001	0.004	0.003	0.002	0.007		0.001		0.001	0.003	<0.002
Typical adult member of the public eating food grown near Sellafield	Milk Potatoes	0.013	0.001			0.002		0.003		0.001		0.002		<0.003

[a] *Excluding natural radionuclides. 'Others' comprises data for all radionuclides whose dose is not presented*
[b] *Representative of people most exposed unless stated otherwise*

Table 4.10. Radioactivity in terrestrial food and the environment near Drigg, 1999

Material and selection[c]		Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[d]		1	<3.8	15	<0.58	<0.38	0.096	<0.0070	<2.2	<0.63	<0.011
Cabbage		1	<4.0	11	<0.30	<0.30	0.33	<0.026	<3.5	<0.90	<0.037
Carrots		1	<4.0	16	0.20	<0.60	0.57		<3.4	<1.1	<0.037
Duck		1	<10	19	1.2	<0.50	0.049	0.051	<2.8	<0.80	
Ovine muscle		1	8.0	30	3.2	<0.20	0.058	<0.028	<1.2	<0.30	<0.042
Ovine offal		1	<7.0	26	4.5	<0.50	0.56	<0.039	<4.0	<0.80	
Potatoes		1	4.0	14	0.70	<0.40	0.19	<0.026	<2.6	<0.70	<0.046
Grass		2						<0.060			
Grass	max							<0.082			
Soil[e]		2									
Soil	max										

Material and selection[c]		Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Total Cs	^{147}Pm	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[d]		1	0.21	<0.33		<0.00018	<0.00038	<0.056	<0.00035
Cabbage		1	0.11	<0.20		<0.00030	<0.00020	<0.10	<0.00020
Carrots		1	0.28			<0.00030	0.0011	<0.085	0.0016
Duck		1	5.6						
Ovine muscle		1	0.66			<0.00030	<0.00020	<0.072	0.00090
Ovine offal		1	0.61			0.0010	0.0059	0.23	0.0029
Potatoes		1	0.49	<0.30		<0.00030	0.0019	<0.098	0.0011
Grass[e]		2		1.0	0.078				
Grass	max			1.4	0.083				
Soil[f]		2			35				
Soil	max				41				

* *Not detected by the method used*
[a] *Except for milk where units are Bq l^{-1} and for soil where dry concentrations apply*
[b] *See section 3 for definition*
[c] *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.*
[d] *The concentration of ^{137}Cs was <0.39 Bq l^{-1}*
[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U in soil were 0.039, <0.0016, and 0.040 Bq kg^{-1}*
[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 6.2, 0.21, and 5.9 Bq kg^{-1}*

Table 4.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 1999

Location	Ground type	No. of sampling observ-ations[a]	$\mu Sv\ h^{-1}$
Whitehaven outer harbour	Mud and sand	2	0.29
St Bees	Sand	2	0.18
Nethertown	Winkle bed	2	0.38
Sellafield pipeline	Sand	2	0.15
Drigg Barn Scar	Mussel bed	2	0.28
Ravenglass - Raven Villa	Salt marsh	2	0.65
Ravenglass - salmon garth	Mussel bed	2	0.40
Tarn Bay	Sand	2	0.13

[a] *See section 3 for definition*

Table 4.12. Radioactivity in terrestrial food and the environment near Ravenglass, 1999[e]

Material and selection[c]		Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{14}C	^{35}S	^{55}Fe	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[g, h]		3	<3.8	17	<0.53		<0.35	0.067	<0.70	<0.62	<0.0073	<2.4	<0.66	<0.011
Milk	max		<4.3		<0.60		<0.36	0.081	<0.72	<0.63	<0.0080	<2.5	<0.70	<0.012
Barley		1	<7.0	130	2.1		<0.40	0.56	<0.80	<0.70	<0.069	<2.9	<0.60	<0.025
Bovine kidney		1	<7.0	31	4.7		<0.30	<0.026	<0.60	<0.30	<0.027	<2.5	<0.90	
Bovine liver		1	<7.0	42	5.1		<0.50	0.25	<0.60	<0.40	<0.030	<2.3	<0.80	<0.035
Bovine muscle		1	<5.0	36	3.3		<0.50	1.1	<0.50	<0.60	<0.033	<3.2	<0.80	<0.031
Broad beans[j]		1									<0.032			
Cabbage		1	25	<5.0	0.30		<0.50	0.16	<0.80	<0.50	<0.026	<2.9	<0.90	<0.039
Carrots		1	20	9.0	1.1		<0.40	0.15	<0.70	<0.50	<0.030	<2.5	<0.80	<0.052
Honey		1	<7.0	80	<0.60		<0.50	<0.0080	<1.3	<1.6	<0.036	<3.9	<0.60	<0.024
Lettuce[i]		1									<0.028			
Ovine offal		2	<7.0	37	6.5		<0.35	0.43	<0.95	<0.60	<0.036	<3.4	<1.0	
Ovine offal	max		7.0	50	6.9		<0.40	0.69	<1.0	<0.70	<0.041	<3.9	<1.1	
Ovine muscle		2	<7.0	33	2.1		<0.15	0.037	<0.40	<0.20	<0.030	<1.3	<0.35	<0.060
Ovine muscle	max		9.0	35	2.6		<0.20	0.040				<1.4	<0.40	<0.066
Pears		1	<4.0	20	<1.4		<0.40	0.14	<0.50	<0.40	<0.038	<2.2	<0.80	<0.038
Potatoes		1	5.0	24	0.80		<0.40	0.049	<0.60	<0.40	<0.030	<2.4	<0.70	<0.055
Runner beans		1	<5.0	14	<0.20		<0.40	0.13	<0.80	<0.50	<0.030	<2.3	<0.80	<0.051
Grass[d, f]		2				1.6					<0.24			
Grass[d]	max					2.3					0.43			

Material and selection[c]		Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			Total Cs	^{144}Ce	^{155}Eu	^{147}Pm	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[g, h]		3	0.19	<1.3	<0.53	<0.33	<0.00020	<0.00030	<0.081	<0.00023
Milk	max		0.22	<1.4	<0.56		<0.00025	<0.00040	<0.099	<0.00025
Barley		1	0.62	<1.4	<0.50		<0.00060	0.0019	<0.078	0.0038
Bovine kidney		1	1.3	<2.0	<1.2		<0.00020	0.0013	<0.10	0.00030
Bovine liver		1	0.38	<1.4	<0.60		<0.00030	<0.00050	<0.072	0.00040
Bovine muscle		1	1.1	<2.1	<0.80		<0.00020	0.00060	<0.067	<0.00020
Broad beans[j]		1								
Cabbage		1	0.14	<1.4	<0.60	0.20	<0.00020	0.00080	<0.069	0.00080
Carrots		1	0.12	<2.0	<0.70		<0.00040	<0.00040	<0.077	0.00050
Honey		1	0.71	<1.9	<0.60		<0.00020	0.00030	0.12	0.00090
Lettuce[i]		1								
Ovine offal		2	0.51	<1.7	<0.65		<0.0023	<0.0034	0.90	0.0020
Ovine offal	max		0.53	<1.9	<0.70					
Ovine muscle		2	0.35	<0.70	<0.40		<0.00030	<0.00025	<0.081	<0.00020
Ovine muscle	max		0.38					<0.00030	<0.097	
Pears		1	0.17	<1.3	<0.50		<0.00030	<0.00040	<0.11	0.00050
Potatoes		1	0.098	<1.5	<0.50	<0.20	<0.00040	0.00050	<0.063	0.00060
Runner beans		1	0.15	<1.8	<0.70		<0.00020	0.00050	<0.086	0.0010
Grass[d, f]		2				2.8				
Grass[d]	max					3.2				

[a] *Except for milk where units are Bq l^{-1} and for soil where dry concentrations apply*
[b] *See section 3 for definition*
[c] *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. See section 3 for definition*
[d] *The concentration of ^{45}Ca was 5.6 Bq kg^{-1}, the maximum was 6.2 Bq kg^{-1}*
[e] *The concentrations of U, ^{234}U, ^{235}U and ^{238}U in soil were 47, 18, 0.60 and 17 Bq kg^{-1} respectively*
[f] *The mean concentration of ^{63}Ni was <0.20 Bq kg^{-1}*
[g] *The mean concentration of ^{134}Cs was <0.31 Bq l^{-1}, and the maximum was <0.32 Bq l^{-1}*
[h] *The concentration of ^{137}Cs was <0.37 Bq l^{-1}, and the maximum was <0.38 Bq l^{-1}*
[i] *The concentrations of U, ^{234}U, ^{235}U and ^{238}U were 0.066, 0.057, 0.0020 and 0.056 Bq kg^{-1} respectively*
[j] *The concentration of U was <0.034 Bq kg^{-1}*

Table 4.13. Radioactivity in aquatic plants from the Cumbrian coast and further afield, 1999

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{131}I
England												
St Bees	*Fucus vesiculosus*[c]	4	50	20	3.2	<0.17	<0.14	9800	<1.4	1.3	0.77	<0.85
St Bees	*Porphyra*	4	45	1.7	0.38	<0.16	<0.17	8.4	8.9	<0.13	0.82	<0.67
St Bees	*Rhodymenia spp.*	2		2.7		<0.16	<0.12		5.1	<0.28	0.26	<0.57
Braystones south	*Porphyra*	4		1.9		<0.13	<0.10		12	<0.13	<0.34	<0.52
Sellafield	*Fucus vesiculosus*	4		51	3.9	<0.30	<0.23	13000	<2.4	2.5	<1.1	<1.1
Seascale	*Porphyra*	52[d]		2.8		<0.53	<0.31		<13	<0.57	<1.5	<0.43
Rabbit Cat How, Ravenglass	Samphire	1		0.26		<0.13	<0.14	1.0	<0.43	<0.07	<0.10	*
Cockerham Marsh	Samphire	1		0.11		<0.09	<0.10		<0.25	<0.05	<0.07	*
Marshside Sands	Samphire	1		<0.03		<0.10	<0.14		<0.25	<0.05	<0.06	*
Isle of Man	*Fucus vesiculosus*	2		<0.10		<0.17	<0.15	980	<0.60	<0.13	<0.15	*
Wales												
Portmadoc	*Fucus vesiculosus*	1		<0.04		<0.08	<0.06	26	<0.34	<0.07	<0.08	<0.24
Fishguard	*Fucus vesiculosus*	1		<0.06		<0.12	<0.08	36	<0.48	<0.10	<0.12	<0.45
Lavernock Point	*Fucus serratus*	2		<0.05		<0.09	<0.06	1.6	<0.39	<0.08	<0.10	<1.6
South Wales,												
Manufacturer A	Laverbread	4		<0.07		<0.21	<0.28		<0.65	<0.11	<0.14	<0.39
Manufacturer C	Laverbread	5		<0.09		<0.27	<0.30		<0.93	<0.15	<0.20	<0.10
Manufacturer D	Laverbread	3		<0.07		<0.21	<0.27		<0.67	<0.11	<0.15	*
Scotland												
Port William	*Fucus vesiculosus*	8		<0.35		<0.19	<0.18	1600	<0.67	<0.11	<0.17	<0.34
Garlieston	*Fucus vesiculosus*	8		1.3		<0.16	<0.13	1800	<0.63	<0.12	<0.29	<0.66
Auchencairn	*Fucus vesiculosus*	8		1.8		<0.16	<0.13	2800	<0.76	<0.13	<0.40	<0.85
Knock Bay	*Porphyra*	8		<0.08		<0.14	<0.17		<0.46	<0.10	<0.12	<0.50
Cape Wrath	*Ascophyllum nodosum*	2		<0.05		<0.16	<0.20	910	<0.46	<0.10	<0.11	*
Wick	*Fucus vesiculosus*	1		<0.05		<0.10	<0.08		<0.40	<0.08	<0.10	<0.72
Northern Ireland												
Ardglass	*Fucus vesiculosus*	4		<0.10		<0.21	<0.21	500	<0.66	<0.14	<0.17	<0.49
Portrush	*Fucus serratus*	4		<0.06		<0.13	<0.11		<0.47	<0.10	<0.12	<0.29
Strangford Lough	*Rhodymenia spp.*	2		<0.12		<0.34	<0.36	66	<1.1	<0.20	<0.24	*
Carlingford Lough	*Fucus spp.*	2		0.12		<0.43	<0.61	700	<0.81	<0.16	<0.18	*
Isles of Scilly	*Fucus vesiculosus*	1		<0.08		<0.20	<0.19	1.4	<0.72	<0.15	<0.17	*

Table 4.13. continued

Location[a]	Material	No. of sampling observ-ations[b]	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													
St Bees	*Fucus vesiculosus*[c]	4	<0.08	7.5	<0.30	<0.16	2.1	10		6.1	*	0.012	
St Bees	*Porphyra*	4	<0.07	1.9	<0.32	<0.16	0.53	2.6	28	5.9	0.0039	0.011	190
St Bees	*Rhodymenia spp.*	2	<0.09	13	<0.34	<0.15	0.71	3.6		9.6	*	0.023	
Braystones south	*Porphyra*	4	<0.07	1.9	<0.27	<0.13	0.29	1.5	16	3.2	*	0.0057	
Sellafield	*Fucus vesiculosus*	4	<0.17	9.2	<0.53	<0.28	2.7	12		5.6	*	0.015	10000
Seascale	*Porphyra*	52[d]	<0.34	2.1	<1.5	<0.71				5.6			
Rabbit Cat How, Ravenglass	Samphire	1	<0.04	0.91	<0.22	<0.09				1.6			
Cockerham Marsh	Samphire	1	<0.03	2.1	<0.17	<0.08				1.1			63
Marshside Sands	Samphire	1	<0.03	0.56	<0.11	<0.05				<0.03			
Isle of Man	*Fucus vesiculosus*	2	<0.08	1.2	<0.31	<0.16				<0.19			1000
Wales													
Portmadoc	*Fucus vesiculosus*	1	<0.05	0.45	<0.18	0.14				<0.13			
Fishguard	*Fucus vesiculosus*	1	<0.06	0.14	<0.29	<0.17				<0.27			280
Lavernock Point	*Fucus serratus*	2	<0.05	0.26	<0.21	<0.11				<0.14			150
South Wales,													
Manufacturer A	Laverbread	4	<0.06	<0.19	<0.24	<0.09				<0.11			
Manufacturer C	Laverbread	5	<0.09	0.26	<0.40	<0.18				<0.22			
Manufacturer D	Laverbread	3	<0.06	0.24	<0.27	<0.11				<0.18			86
Scotland													
Port William	*Fucus vesiculosus*	8	<0.09	2.2	<0.36	<0.20				<0.35			
Garlieston	*Fucus vesiculosus*	8	<0.10	6.7	<0.33	<0.22				5.6			
Auchencairn	*Fucus vesiculosus*	8	<0.10	6.6	<0.38	<0.23				3.2			
Knock Bay	*Porphyra*	8	<0.08	0.39	<0.22	<0.11				<0.49			
Cape Wrath	*Ascophyllum nodosum*	2	<0.06	0.44	<0.27	<0.13				<0.17			610
Wick	*Fucus vesiculosus*	1	<0.05	0.24	<0.24	<0.13				<0.22			330
Northern Ireland													
Ardglass	*Fucus vesiculosus*	4	<0.08	1.0	<0.35	<0.17				<0.22			
Portrush	*Fucus serratus*	4	<0.06	0.16	<0.24	<0.13				<0.16			
Strangford Lough	*Rhodymenia spp.*	2	<0.11	0.99	<0.41	<0.17	0.050	0.27		0.41	*	0.00041	
Carlingford Lough	*Fucus spp.*	2	<0.11	1.7	<0.47	0.45				<0.27			
Isles of Scilly	*Fucus vesiculosus*	1	<0.08	0.17	<0.35	<0.16				<0.11			220

* *Not detected by the method used*
[a] *Sampling area*
[b] *See section 3 for definition*
[c] *The concentration of ^{129}I was 5.1 Bq kg^{-1}*
[d] *Counted wet*

Table 4.14. Radioactivity in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 1999

Location[b]	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am
Newton Arlosh	Grass	1				0.79						
Newton Arlosh	Washed grass	1				0.45						
Newton Arlosh	Soil	1				4.6						
Sellafield 1707[c]	Beetroot	1	<0.07	<0.18	<0.15	22	<0.76	<0.08	<0.07	<0.38	<0.17	<0.16
Sellafield 1707[c]	Courgettes	1	<0.03	<0.05	<0.04	10	<0.24	<0.03	<0.02	<0.09	<0.04	<0.02
Sellafield 1707[c]	Potatoes	1	<0.05	<0.09	<0.07	0.58	<0.37	<0.05	<0.04	<0.23	<0.13	<0.20
Sellafield 1707[c]	Soil	1	<0.18	<0.61	<0.70	52	<1.7	<0.25	31	<1.0	1.5	1.6
Sellafield 14[c]	Beetroot	1	<0.10	<0.23	<0.20	77	<0.93	<0.10	0.31	<0.35	<0.14	<0.08
Sellafield 14[c]	Onions	1	<0.08	<0.18	<0.16	1.5	<0.74	<0.08	0.19	<0.28	<0.12	<0.06
Sellafield 14[c]	Potatoes	1	<0.05	<0.13	<0.15	4.0	<0.41	<0.05	0.25	<0.26	<0.13	<0.21
Sellafield 1674[c]	Beetroot	1	<0.08	<0.18	<0.16	130	<0.72	<0.07	0.09	<0.26	<0.11	<0.06
Sellafield 1674[c]	Leaf Beet	1	<0.05	<0.08	<0.06	480	<0.35	<0.04	0.10	<0.13	<0.06	<0.04
Sellafield 1674[c]	Onions	1	<0.08	<0.18	<0.13	3.3	<0.83	<0.08	0.12	<0.42	<0.19	<0.17
Sellafield 1674[c]	Potatoes	1	<0.07	<0.12	<0.10	0.28	<0.53	<0.06	<0.06	<0.26	<0.12	<0.07
Sellafield 1674[c]	Soil	1	0.96	<0.68	<0.81	410	<1.9	0.50	71	<1.6	<0.77	1.6
Hutton Marsh	Grass	1				5.2						
Hutton Marsh	Washed grass	1				1.0						
Hutton Marsh	Soil	1				24						

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

Table 4.15(a). Radioactivity in food and the environment near Springfields, 1999[j]

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th
Aquatic samples									
Flounder	Ribble Estuary	1		<0.07		8.4			
Salmon	Ribble Estuary	1		<0.11		0.27			
Sea trout	Ribble Estuary	1		<0.09		15			
Bass	Ribble Estuary	1		<0.07		12			
Shrimps[e]	Ribble Estuary	2	47	<0.06	1.5	3.8	0.067	0.012	0.022
Cockles	Ribble Estuary	1		1.1		5.3			
Samphire	Marshside Sands	1		<0.03		0.56			
Grass (washed)	Hutton Marsh	1			1.0				
Grass (unwashed)	Hutton Marsh	1			5.2				
Soil	Hutton Marsh	1			24				
Mud & sand	Ribble Estuary	1		1.6		42	19	10	12

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{232}Th	^{234}Th	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$
Aquatic samples								
Flounder	Ribble Estuary	1		*			<0.08	
Salmon	Ribble Estuary	1		*			<0.55	
Sea trout	Ribble Estuary	1		*			<0.08	
Bass	Ribble Estuary	1		*			<0.06	
Shrimps[e]	Ribble Estuary	2	0.0052	*	0.0025	0.012	0.023	0.000048
Cockles	Ribble Estuary	1		47			7.8	
Samphire	Marshside Sands	1		*			<0.03	
Grass (washed)	Hutton Marsh	1						
Grass (unwashed)	Hutton Marsh	1						
Soil	Hutton Marsh	1						
Mud & sand	Ribble Estuary	1	7.2	450			35	

Table 4.15(a). continued

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	Total ^{60}Co	^{90}Sr	Cs	^{230}Th	^{232}Th
Terrestrial samples									
Milk	Near farms	5							
Apples [f]		1	4.0	13	<0.30	<0.0070	0.12	0.0093	0.0020
Cabbage		1	<4.0	11	<0.30	0.82	0.071	0.014	<0.0071
Cabbage/spinach[g]		1	<4.0	16	<0.50	0.31	0.080	<0.020	<0.011
Cauliflower/ spinach		1	<4.0	10	<0.40	0.28	<0.22	0.0064	<0.0018
Elderberries[h]		1	<4.0	25	<0.30	0.33	0.18	0.0045	<0.0037
Potatoes[i]		1	8.0	21	<0.40	0.14	<0.049	0.0087	0.0036
Runner beans		1	<4.0	15	<0.30	0.13	0.046	0.0020	0.0014
Bovine faeces		6							
Bovine faeces	max								
Ovine faeces		4							
Ovine faeces	max								
Grass		8							
Grass	max								
Silage		4							
Silage	max								
Soil		4							
Soil	max								

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{234}U	^{235}U+ ^{236}U	^{238}U	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples										
Milk	Near farms	5				<0.0073				
Apples [f]		1					<0.00020	<0.00050	<0.10	0.00020
Cabbage		1					<0.00050	0.00090	<0.12	<0.00030
Cabbage/spinach[g]		1					0.00040	<0.00050	<0.063	<0.00020
Cauliflower/ spinach		1					<0.00030	<0.00050	<0.080	<0.00030
Elderberries[h]		1					0.00030	<0.00050	<0.068	0.0019
Potatoes[i]		1					<0.00050	<0.00060	<0.11	<0.00030
Runner beans		1								
Bovine faeces		6				3.2				
Bovine faeces	max					7.1				
Ovine faeces		4				17				
Ovine faeces	max		23	1.4	22	43				
Grass		8				2.0				
Grass	max		1.1	0.049	1.0	7.5				
Silage		4				2.4				
Silage	max					7.2				
Soil		4				99				
Soil	max		180	15	200	230				

* *not detected by the method used*
[a] *Except for milk where units are Bq l^{-1} and for sediment and uranium in soil where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *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. See section 3 for definition*
[d] *See section 3 for definition*
[e] *The concentration of ^{237}Np was 0.0020 Bq kg^{-1}*
[f] *The concentration of ^{129}I was <0.037 Bq kg^{-1}*
[g] *The concentration of ^{129}I was <0.045 Bq kg^{-1}*
[h] *The concentration of ^{129}I was <0.033 Bq kg^{-1}*
[i] *The concentration of ^{129}I was 0.061 Bq kg^{-1}*
[j] *142 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.80, 2.2 and 0.64 Bq per cloth respectively*

Table 4.15(b). Monitoring of radiation dose rates near Springfields, 1999

Location	Material or ground type	No. of sampling observations[a]	$\mu Gy\ h^{-1}$
Gamma dose rates at 1 m over intertidal areas			
Warton Marsh	Mud	4	0.13
Warton Marsh	Mud[b]	4	0.14
Warton Marsh	Salt marsh	4	0.12
Banks Marsh	Mud	4	0.14
Banks Marsh	Mud[b]	4	0.14
Banks Marsh	Salt marsh	4	0.16
Beta dose rates			$\mu Sv\ h^{-1}$
Lytham - Granny's Bay	Mud and sand	1	0.26
Warton Marsh	Mud	4	4.6
Warton Marsh	Salt marsh	4	0.65
Banks Marsh	Mud	4	4.8
Banks Marsh	Salt marsh	4	1.1
Ribble estuary	Gill net	2	2.5
Ribble estuary	Shrimp net	2	0.55

[a] *See section 3 for definition*
[b] *15 cm above substrate*

Table 4.16. Radioactivity in food and the environment near Capenhurst, 1999[d]

Material	Location	No. of sampling observa-tions[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{60}Co	^{99}Tc	^{137}Cs	^{155}Eu	^{233}Pa	^{234}Th	^{234}U	^{235}U+^{236}U	^{238}U	^{237}Np	^{241}Am
Aquatic samples														
Dabs	Liverpool Bay	2	<25											
Dabs	Mersey Estuary	2	<25											
Shrimps	Hoylake	2	<130	<0.06	2.9	2.5	<0.15	*	*					<0.17
Mussels	Liverpool Bay	2	<25											
Mussels	Mersey Estuary	2	<25											
Cockles[e]	Dee Estuary	4		0.30	35	1.3	<0.20	*	<8.0					2.1
Elodea canadensis[f]	Rivacre Brook	2		<0.07	17	0.25	<0.32	0.97	180	28	1.2	2.4	0.099	<0.08
Mud	Rivacre Brook	2		<0.31	440	13	<1.5	98	420	290	14	240	2.5	<1.5
Freshwater	Rivacre Brook	2	4.2	<0.09	0.011	<0.09	<0.21	*	*	0.20	*	0.18	0.000045	<0.11

Material	Location or selection[c]	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{99}Tc	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples								
Milk	Near Farms	5		<0.0055				<0.0073
Milk	Far farms	6	<2.0					
Milk	max		<3.0					
Potatoes		1		<0.027				<0.033
Raspberries		1		<0.027				<0.019
Runner beans		1		<0.037				0.058
Bovine faeces		8		<0.067				1.8
Bovine faeces	max			<0.068	0.93	0.049	0.92	5.5
Grass		8						<0.18
Grass	max				0.069	0.0030	0.077	0.47
Silage		4		<0.029				0.13
Silage	max			<0.033				0.22
Soil		4						40
Soil	max				12	0.46	12	45
Rainwater		82	<1.9					
Rainwater	max		6.0					

* *not detected by the method used*

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

[b] *See section 3 for definition*

[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. See section 3*

[d] *118 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.19, 0.98 and 0.68 Bq kg^{-1} respectively*

[e] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.14, 0.79 and 0.0028 Bq kg^{-1} respectively*

[f] *The concentration of beta activity in this freshwater plant was 220 Bq kg^{-1}*

Table 4.17(a). Radioactivity in food and the environment near Chapelcross nuclear power station, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb
Aquatic samples										
Flounder[d]	Inner Solway	3	73	47	<0.11	<0.10	2.1	<0.65	<0.12	<0.21
Salmon	Inner Solway	1	9.4		<0.10			<0.44	<0.10	<0.14
Shrimps[e]	Inner Solway	4	10		<0.12	<0.10	5.5	<0.56	<0.10	<0.17
Winkles	Southerness	4	8.8		1.9		380	<0.99	0.64	<0.33
Fucus vesiculosus	Pipeline	4	11		0.78		2000	<0.71	<0.12	<0.22
Mud and sand	Pipeline	4	<4.1		4.1			<6.0	<0.17	<0.79
Seawater	Southerness	4	5.8							

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am
Aquatic samples									
Flounder[d]	Inner Solway	3	26	<0.42	<0.11	<0.19	0.0070	0.028	0.079
Salmon	Inner Solway	1	0.26	<0.34	<0.10	<0.18	0.0025	0.0030	<0.00052
Shrimps[e]	Inner Solway	4	7.0	<0.36	<0.10	<0.19	0.0036	0.013	0.036
Winkles	Southerness	4	1.9	<0.36	<0.10	<0.17	0.018	0.91	1.6
Fucus vesiculosus	Pipeline	4	19	<0.38	<0.12	<0.26	1.2	6.3	5.6
Mud and sand	Pipeline	4	370	<0.84	1.5	<1.1	24	120	170
Seawater	Southerness	4	0.24				0.00078	0.0023	0.0026

Material	Location[b] or selection[f]		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 alpha
Terrestrial samples									
Milk	Near farms		4	44	15	<5.0	<0.10	<0.050	
Milk	Near farms	max		57					
Milk	Far farms		4	58	14	<5.0	<0.10	<0.050	
Milk	Far farms	max		90					
Grass	Far farms		6	<82	23	<5.0	0.13	<0.11	<0.78
Grass	Far farms	max		160	39		0.24	<0.15	0.79

[a] *Except for sea water and milk where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*
[d] *The concentration of organic ^{3}H was 16 Bq kg^{-1}*
[e] *The concentration of ^{65}Zn was 0.14 Bq kg^{-1}*
[f] *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. See section 3 for definition.*

Table 4.17(b). Monitoring of radiation dose rates near Chapelcross, 1999

Location	Ground type	No. of sampling observa-tions[a]	μGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Seafield	Mud and sand	4	0.074
Seafield	Salt marsh	4	0.090
Battle Hill	Mud and sand	4	0.072
Browhouses	Mud, sand and stones	4	0.074
Dornoch Brow	Mud and sand	4	0.073
Dornoch Brow	Salt marsh	4	0.082
Powfoot	Salt marsh	4	0.073
Powfoot[b]	Salt marsh	4	0.080
Priestside Bank	Salt marsh	4	0.061
Beta dose rates			μSv h^{-1}
Seafield	Stake nets	4	*

[a] *See section 3 for definition*
[b] *15 cm above substrate*
* *not detected by the method used*

Table 4.17(c). Additional sampling at Chapelcross, 1999

Location	Sample Details	No. of sampling observa-tions[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	Organic ^{3}H	^{54}Mn	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	Total alpha	Total beta
Gullielands Burn -											
Upstream adjacent to											
sewage works	Sediment	2							0.80		
Upstream adjacent											
to sewage works	Water	2	120						<0.05	<0.08	0.17
Upstream of oil interceptor	Water	1	260						<0.05	<0.07	0.13
Oil interceptor	Water	1	260						0.63	<0.08	1.5
Downstream of oil interceptor	Water	1	260						<0.07	<0.07	<0.10
Annan - above tidal weir	Water	1	8.1	3.3						<0.04	0.05
Annan - above tidal weir	Sediment	1	3.8	0.40							
Annan - above tidal weir	Grass	1	21	4.4							
Gullielands Burn -											
500m below station	Water	1	430	*						<0.04	0.14
Sediment		1	94	0.80							
	Grass	1	81	29							
Purdomstone Reservoir	Water	1	12	*						<0.04	<0.05
	Sediment	1	4.4	1.1							
	Grass	1	19	7.0							

* *Not detected by the method used*

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

[b] *See section 3 for definition*

5. UNITED KINGDOM ATOMIC ENERGY AUTHORITY

The United Kingdom Atomic Energy Authority (UKAEA) operates 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. Disposals of radioactive waste are related to decommissioning and decontamination operations and the nuclear related research that is also undertaken. Some of this work is carried out by tenants such as AEA Technology. In addition, gaseous and liquid wastes are generated at Dounreay as a result of fuel reprocessing and small amounts of low level solid waste are disposed of by shallow land burial on the site. In previous years 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 disposals 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. Disposals from the Windscale site are negligible compared to Sellafield. Regular monitoring of the environment in relation to Dounreay, Harwell and Winfrith is undertaken and disposals from Windscale are monitored by the Sellafield programme. Disposals from Vulcan (NRTE) and AEA Technology (Dounreay) are monitored by the Dounreay programme.

5.1 Dounreay, Highland

Radioactive waste disposals from this establishment are made by UKAEA under an authorisation granted by SEPA. A new authorisation was issued by SEPA in August 1999 following an extensive public consultation process (SEPA, 1999). The quantities discharged from Dounreay in 1999 were generally similar to those in 1998. This reflects the shut down of processing activities within the fuel cycle area by formal direction issued in May 1998 by NII under the Nuclear Site Licence. Monitoring in 1999 continued to include sampling of ovine liver and thyroid, grass and soil. As there are no dairy herds in the Dounreay area 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, in combination with associated land based beta and gamma dose rate measurements. Seafood samples are collected under consent granted by The Scottish Office within the area covered by the FEPA Order that prohibits the harvesting of seafoods around the pipeline. The results of SEPA's monitoring are presented in Tables 5.1(a), (b) and (c).

During 1999 UKAEA instituted improved monitoring arrangements of local public beaches for fragments of irradiated nuclear fuel in compliance with the requirements of the new authorisation. In 1999 four fragments were recovered from Sandside Bay. The caesium-137 activity measured in these particles range between $6\ 10^4$ and $3\ 10^5$ Bq. SEPA and NRPB have conducted an extensive study into the likelihood of an encounter with these fragments, and the consequences that this might have on human health and the environment. The findings were published in 1998 (SEPA, 1998). As a result SEPA advised the then Scottish Office that the current two kilometre fishing restrictions should remain in force and that greater and speedier effort should be made by UKAEA to find and quantify the extent of contamination in the local marine environment, using the best available methodology and technology. In 1999 SEPA announced the formation of an expert advisory group to advise SEPA and UKAEA on Dounreay particles.

During 1999 remediation of a small beach in front of the Demonstration Fast Reactor was carried out by UKAEA resulting in the generation of 200 m^3 of radioactive waste. SEPA carried out independent monitoring before and after the remediation in order to ascertain the success of the remediation exercise. Also during 1999 UKAEA undertook remediation work on a contaminated landfill adjacent to the nuclear site boundary. The work successfully removed the majority of the exposed potentially contaminated sea face of the land fill from the erosion zone.

The Prohibition Notice served on AEA Technology relating to the treatment of radioactive waste sodium at a facility operated by AEA Technology remains in force. The Enforcement Notice served on UKAEA to control mobile radioactive particulate matter in the ventilation duct leading to the main fuel cycle discharge stack remains to allow time for the provision of new arrangements to modern standards. UKAEA are to fit a temporary HEPA filter at the base of the stack as soon as reasonably practicable in order to mitigate any release of the particulate matter in the duct. During the year enforcement notices were issued to UKAEA and AEAT regarding the keeping of records of solid low level waste disposals. Both operators have complied with the enforcement notices and records have been checked and corrected where necessary.

A habits survey was undertaken in 1999 to review potential exposure pathways in the Dounreay area. The results for the terrestrial pathways are being analysed in relation to the surveillance programme sponsored by SEPA. Until the analysis is complete, the assessment method is based on the concentrations in vegetables derived from the modelling approach outlined in Appendix 2 and the generic consumption rates in Appendix 4.

The marine habits survey established the existence of four potential exposure pathways at Dounreay. Details are given in Appendix 4.

The first potential pathway relates to the internal exposure of consumers of locally collected fish and shellfish. Crabs, lobsters and winkles from the outfall area were sampled to enable this pathway to be reviewed. Additionally, sea water and seaweed were sampled as indicator materials. Concentrations of radionuclides in 1999 were generally similar to those for 1998. Technetium-99 in lobsters and seaweed due to disposals from Sellafield, remained at levels typical of recent years. Despite this, doses from consumption of fish and shellfish were low and on the basis of the new habits survey data, the dose to high-rate consumers was less than 0.005 mSv which was less than 0.5% of the principal annual dose limit for members of the public of 1 mSv. Consumers of locally collected fish and shellfish represent the critical group for internal exposure by marine pathways in 1999.

The second 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 particles. The critical group is represented by a small number of people who operate a fishery close to Dounreay. Measurements on their fishing gear in 1999 indicated that this pathway was of no radiological significance.

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. In 1999, monitoring of sludge at Oigin's Geo indicated similar concentrations of radionuclides compared with 1998. However, there is significant variability in the concentrations with differing sea and weather conditions. The more important measurements of gamma dose rates above areas of the foreshore remained similar to those for 1998. Public radiation dose via this pathway was 0.005 mSv which was 0.5% of the principal annual dose limit for members of the public of 1 mSv.

The fourth potential pathway is due to external exposure over local beaches. Gamma dose rates were measured over intertidal areas and were similar in 1999 to those measured in previous years. The radiation dose due to occupancy in such areas was less than 0.005 mSv which was less than 0.5% of the principal annual dose limit for members of the public of 1 mSv.

The results for terrestrial samples are given in Table 5.1(a) and generally show low levels of radioactivity. Very low levels of plutonium isotopes were detected in ovine liver and soil. The isotope ratios indicate that the plutonium originates from the nuclear industry. The dose to the most exposed group of local terrestrial consumers, including a contribution due to weapon test fallout, was estimated to be 0.016 mSv which was less than 2% of the principal dose limit for members of the public of 1 mSv.

Additional sampling was undertaken in 1999 to investigate radium-226 concentrations in process water and uranium levels in grass following a fire in the Fuel Cycle Area that involved a package containing uranium waste. The results are given in Table 5.1(c).

5.2 Harwell, Oxfordshire

Disposals of radioactive wastes from Harwell continued in 1999 with liquid disposals made under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site, while gaseous disposals were made to the atmosphere. The monitoring programme sampled milk, other terrestrial foodstuffs, freshwater fish and indicator materials together with measurements of gamma dose rates around the liquid discharge point. Monitoring of the aquatic environment at Newbridge is undertaken to indicate background levels remote from nuclear establishments.

The results of measurements of radioactivity concentrations and dose rates are shown in Tables 5.2(a) and (b). Tritium was detected in honey collected near the site but at very low levels. No other radionuclides were found above the limit of detection. The dose to the most exposed group of terrestrial food consumers was estimated to be less than 0.005 mSv which was less than 0.5% of the principal 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, 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. However there are other potential sources of tritium in this area. Its radiological effect was trivial since tritium has a very low toxicity. The concentration of caesium-137 in pike decreased in 1999 to 7.4 Bq kg^{-1} (1998: 26 Bq kg^{-1}) but this is unlikely to be indicative of a more general effect in the environment since concentrations in freshwater fish are known to vary significantly from sample to sample.

Habits surveys have identified anglers as the most exposed group affected by direct disposals into the river. Their occupancy of the river bank has been assessed to estimate their external exposures. Consumption of freshwater fish was not found, 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 1999 was 0.012 mSv, which was about 1% of the principal dose limit for members of the public of 1 mSv.

5.3 Winfrith, Dorset

Disposals of radioactive wastes from this site continued in 1999 at the low rates typical of recent years following the shutdown of the Steam Generating Heavy Water Reactor (SGHWR) in September 1990. Liquid wastes are disposed of under authorisation to deep water in Weymouth Bay. At this site the monitoring programme consisted of samples of milk, crops, fruit, seafood and indicator materials.

Data are presented in Table 5.3. Results for terrestrial samples gave little indication of an effect due to gaseous disposals. The most exposed group for gaseous disposals was the 1-year-old age group who were estimated to receive an dose of less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv. Concentrations of radionuclides in the marine environment continued at the low levels attained since closure of the SGHWR. No indication of the effect of disposals from the Cap de la Hague facility in France was detected. The radiation dose to the most exposed group of fish and shellfish consumers remained low in 1999 at less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public.

5. United Kingdom Atomic Energy Authority (UKAEA)

Table 5.1(a). Radioactivity in food and the environment near Dounreay, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb
Aquatic samples										
Crabs	Pipeline	6		<0.13	<0.60	<1.0	3.5	<1.1	<0.30	<0.29
Lobsters	Pipeline	1		<0.32	<1.2	<2.8	130	<2.6	1.7	<0.74
Winkles	Brims Ness	4		<0.29	<0.31	<0.27		<1.2	0.91	<0.33
Winkles	Sandside Bay	4		<0.38	<0.34	<0.29		<1.2	0.97	<0.32
Sludge[e]	Oigins Geo	4		<4.9	<2.5	<11		<8.9	<0.92	<2.3
Sand	Sandside Bay	4		<0.12	<0.25	<0.27		<0.93	<0.11	<0.21
Fucus vesiculosus	Sandside Bay	4		0.52	<0.14	<0.13	310	<0.42	<0.10	<0.13
Fucus vesiculosus	Brims Ness	4		<0.25	<0.14	<0.24		<0.41	<0.10	<0.13
Seawater	Sandside Bay	4	<1.4							

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Aquatic samples									
Crabs	Pipeline	6	<0.40	<0.70	<0.16	<0.31	0.0060	0.020	0.032
Lobsters	Pipeline	1	0.32	<1.7	<0.37	<0.71	0.016	0.013	0.074
Winkles	Brims Ness	4	<0.23	<0.66	<0.16	<0.33	0.027	0.099	0.10
Winkles	Sandside Bay	4	0.32	<0.61	<0.16	<0.31	0.027	0.11	0.11
Sludge[e]	Oigins Geo	4	22	<4.2	<1.4	<2.5	4.8	18	21
Sand	Sandside Bay	4	3.5	<0.50	1.1	<0.71	3.4	14	14
Fucus vesiculosus	Sandside Bay	4	0.54	<0.25	<0.12	<0.19			1.5
Fucus vesiculosus	Brims Ness	4	0.51	<0.26	<0.11	<0.15			<0.39
Seawater	Sandside Bay	4	<0.05						

Material	Location[b] or selection[d]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{90}Sr	^{129}I	^{131}I	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial samples										
Ovine liver		3				<0.52	<0.22	<0.0026	<0.0032	<0.021
Ovine liver	max					<0.56	<0.32	0.0037	0.0073	0.057
Ovine thyroid		3			<0.067	<0.071				
Ovine thyroid	max				<0.15	<0.081				
Grass		6	<25	<0.46	<0.11	<0.19	<0.83	<0.050	<0.050	<0.050
Grass	max			1.1	<0.14	<0.23	2.5			
Soil		6	<25	2.8	<0.35	<0.37	24	<0.062	0.43	0.16
Soil	max			4.7	<0.50	<0.46	33	0.087	0.66	0.29

[a] *Except for sea water where units are Bq l^{-1}, and for soil and sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*
[d] *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. See section 3*
[e] *The concentrations of activity in individual samples varied significantly as they depend on a varying proportion of more active spume and less active sediments. Individual results are available from SEPA*

Table 5.1(b). Monitoring of radiation dose rates near Dounreay, 1999

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over substrate			
Oigins Geo	Stones	1	0.15
Oigins Geo	Intertidal sediment	4	0.14
Sandside Bay	Sand	1	0.056
Sandside Bay	Winkle bed	4	0.11
Sandside Bay	Gill nets	1	0.081
Castletown Harbour	Mud	1	0.070
Beta dose rates			µSv h^{-1}
Pipeline	Lobster pots	1	*

[a] *See section 3 for definition*
* *Not detected by the method used*

Table 5.1(c). Additional sampling at Dounreay, 1999

Location	Sample Details	No. of sampling observations[b]	Mean radioactivity concentration, (wet)[a], Bq kg^{-1}			
			^{226}Ra	^{234}U	^{235}U	^{238}U
On-site	Process water	1	<1.3			
PRF Training	Grass	1		0.50	*	0.30
Whatling Tower	Grass	1		0.13	0.0049	0.097
Under Met. Tower	Grass	1		0.29	0.0099	0.21
Near fuel pumps	Grass	1		0.17	0.0085	0.13

* *not detected by the method used*
[a] *Except for water where units are Bq l^{-1}*
[b] *See section 3 for definition*

Table 5.2(a). Radioactivity in food and the environment near Harwell, 1999

Material	Location	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{60}Co	^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am
Aquatic samples								
Pike	Outfall (Sutton Courtenay)	1	200	<0.05	<0.06	7.4	<0.16	<0.25
Pike[g]	Newbridge	1	<25	<0.04	<0.04	0.08	<0.13	0.0016
Pike	Shepperton	1	<25	<0.06	<0.06	0.27	<0.18	<0.29
Pike	Teddington	1	<25	<0.05	<0.05	0.19	<0.13	<0.17
Flounder	Becton	1	<25	<0.05	<0.05	0.21	<0.10	<0.13
Nuphar lutea	Outfall (Sutton Courtenay)	1	<25	<0.05	<0.04	0.23	<0.07	<0.03
Nuphar lutea	Newbridge	1	<25	<0.09	<0.08	<0.07	<0.13	<0.06
Nuphar lutea	Staines	1	<25	<0.06	<0.06	0.12	<0.14	<0.12
Mud	Position 'E' [e]	2		7.8	<1.1	1100	<2.5	3.1

Material	Location or selection[c]		No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
				^{3}H	^{60}Co	^{134}Cs	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples										
Milk[d]	Near farms		4	<3.8	<0.39	<0.33	<0.34			
Milk[d]	Near farms	max			<0.43	<0.35	<0.38			
Apples[f]			1	<4.0	<0.40	<0.30	<0.30			
Blackberries[f]			1	<4.0	<0.50	<0.50	<0.50			
Cabbage[f]			1	<4.0	<0.50	<0.30	<0.40			
Honey			1	7.0	<0.20	<0.30	<0.30			
Potatoes[f]			1	<4.0	<0.50	<0.40	<0.50			
Runner beans[f]			1	<4.0	<0.40	<0.30	<0.40			
Dry cloths			96					0.18	1.1	0.67

[a] *Except for milk and dry cloths where units are Bq l^{-1} and Bq per cloth respectively, and for sediment where dry concentrations apply*
[b] *See section 3 for definition*
[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition.*
[d] *The concentration of ^{3}H (organic) was <3.8 Bq l^{-1}*
[e] *Near the outfall*
[f] *The concentration of ^{3}H (organic) was <4.0 Bq kg^{-1}*
[g] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were 0.00020 and 0.00094 Bq kg^{-1} respectively*

Table 5.2(b). Monitoring of radiation dose rates near Harwell, 1999

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over river bank			
Position 'E'[b]	Soil	2	0.082

[a] *See section 3 for definition*
[b] *Near the outfall*

Table 5.3. Radioactivity in food and the environment near Winfrith, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{60}Co	^{65}Zn	^{131}I	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Aquatic samples											
Cod	Weymouth Bay	2	<0.06	<0.14	<0.07	0.18			<0.14		
Plaice	Weymouth Bay	2	<0.05	<0.13	*	0.10			<0.09		
Crabs	Chapman's Pool	1	0.56	<0.15	<0.28	<0.06	0.0024	0.0098	0.016	0.000084	0.00012
Crabs	Lulworth Banks	1	0.33	<0.23	*	<0.08	0.00021	0.00094	0.0019	*	0.000053
Pacific Oysters	Poole	1	<0.14	<0.35	*	0.19			<0.28		
Cockles	Poole	1	1.2	<0.07	<0.57	0.03			<0.04		
Whelks	Weymouth Bay	1	0.38	<0.12	<0.43	<0.05			<0.15		
Whelks	Poole	1	0.35	<0.10	*	<0.04	0.00054	0.0027	0.0032	*	0.000071
Fucus serratus[e]	Kimmeridge	2	0.76	<0.19	<0.30	<0.07			<0.07		
Fucus serratus[f]	Bognor Rock	2	0.56	<0.10	<0.48	0.09			<0.18		

Material	Location or selection[d]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples									
Milk	Near farms	4	<3.8	<3.8	<0.31	<0.33			
Milk	Near farms max		<4.3	<4.3	<0.35	<0.35			
Apples		1	<4.0	<4.0	<0.40	<0.30			
Cabbage		1	<4.0	<4.0	<0.50	<0.50			
Carrots		1	<5.0	4.0	<0.40	<0.30			
Honey		1		<7.0	<0.40	<0.50			
Potatoes		1	<4.0	<4.0	<0.30	<0.40			
Raspberries		1	<3.0	<3.0	<0.50	<0.40			
Dry cloths		55					0.13	0.77	0.38

* *not detected by the method used*

[a] *Except for milk where units are Bq l^{-1} and for dry cloths where units are Bq per cloth*

[b] *Landing point or sampling area*

[c] *See section 3 for definition*

[d] *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. See section 3*

[e] *The concentration of ^{99}Tc was 0.23 Bq kg^{-1}, the concentration of beta activity was 110 Bq kg^{-1}*

[f] *The concentration of ^{99}Tc was 0.88 Bq kg^{-1}*

6. NUCLEAR POWER STATIONS OPERATED BY ELECTRICITY GENERATING COMPANIES

This Section considers the effects of disposals from 12 locations where nuclear power stations were operating or undergoing decommissioning during 1999. 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. and Magnox Electric (a wholly owned subsidiary of BNFL plc.) The correspondence between power station and company is given in Appendix 1. Other BNFL sites are considered in Section 4.

6.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire

Berkeley Power Station ceased electricity generation in March 1989, but radioactive wastes still need to be disposed of as part of decommissioning operations. In addition there is a component of the discharge from the adjoining Berkeley Centre. 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.

Habits surveys have established that the two potentially critical pathways for public radiation exposure in the aquatic environment are internal radiation following consumption of locally-caught fish and shellfish, and external exposure from occupancy of muddy intertidal areas. Therefore, samples of fish and shellfish are analysed and gamma dose rates are monitored. Measurements of tritium in seafood were introduced in 1998 in surveillance of the local effects of discharges from Cardiff (see Section 8). In addition, measurements of external exposure are supported by analyses of intertidal mud, and *Fucus vesiculosus* is collected as an indicator material. The focus for terrestrial sampling is on the tritium, carbon-14 and sulphur-35 content of milk, crops and fruit, supported by analysis of dry cloths.

Data for 1999 are presented in Tables 6.1(a) and (b). Where comparisons can be drawn, gamma dose rates and concentrations in the aquatic environment were similar to those in recent years. Unfortunately shrimp samples, which tend to contain good indicators of local sources, were not available in 1999 since fishing in the estuary was poor. Most of the artificial radioactivity detected was due to radiocaesium and sulphur-35. Concentrations of radiocaesium represent the combined effect of disposals from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance. The total dose to the most exposed group of fish and shellfish consumers including external radiation was estimated to be low, at less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv. This dose includes an estimate of the concentrations of radionuclides that would have been present in samples of shrimps.

Sulphur-35 was detected at very low levels in some of the terrestrial food samples monitored; the most significant indications of the effects of the sites were in cereals. Carbon-14 was detected in local foodstuffs, at levels slightly above background values. The most exposed group dose continued to be low and was estimated to be 0.005 mSv which was 0.5% of the principal dose limit.

6.2 Bradwell, Essex

This power station, powered by Magnox reactors, is authorised to discharge gaseous wastes to the local environment and liquid wastes to the estuary of the River Blackwater. Magnox Electric are planning to close the station on 31 March 2002 after 40 years of operation. Terrestrial sampling is similar to that for other power stations including analyses of milk and crop samples for tritium, carbon-14 and sulphur-35. Aquatic sampling was directed at consumption of locally caught fish and shellfish and external exposure of people who live on houseboats in muddy areas of the estuary. It included the commercial oyster fishery of importance in the northern part of the estuary. Gamma dose rate measurements were supported by analyses of intertidal sediment, and *Fucus vesiculosus* was analysed as an indicator material.

Measurements for 1999 are summarised in Tables 6.2(a) and (b). Dose rates at West Mersea and Maldon could not be distinguished from the natural background. Low concentrations of artificial radioactivity were detected in aquatic materials due to the combined effects 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 1998. The technetium-99 detected in *Fucus vesiculosus* at Waterside was due to the long distance transport of Sellafield derived activity. A calculation based on concentrations of radionuclides in sediments has been used to estimate the external exposure of the houseboat dwellers who were consuming local seafood in 1999. Their dose, including the effects of consumption pathways, was small, amounting to 0.014 mSv which was about 1% of the principal dose limit for members of the public of 1 mSv. The dose assessment is based on new habits survey information collected in 1999.

Concentrations of activity were also low in terrestrial samples. There was nevertheless an indication that carbon-14 levels had been enhanced by the operation of the power station. Low concentrations of sulphur-35 were also detected in some samples. The most exposed group dose was estimated to be less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv, confirming that the radiological impact of authorised disposals from Bradwell was very low.

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). Disposals are made via separate but adjacent outfalls and stacks, for the purposes of environmental monitoring these are considered together.

Analyses for tritium, carbon-14 and sulphur-35 in terrestrial samples were supplemented by a small number of analyses for strontium-90 and caesium-137 taken primarily for comparison with Sellafield samples. Marine monitoring included gamma and beta dose rate measurements in Rye Harbour and analysis of seafood and indicator materials.

The results for 1999 are given in Tables 6.3(a) and (b). Concentrations of radiocaesium in marine materials are attributable to disposals from the stations and to weapon test fallout with a contribution due to disposals 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 most exposed group was reassessed in 1999 on the basis of a local habits survey but it continued to be represented by local bait diggers who also eat fish and shellfish. Their radiation dose, at revised consumption and occupancy rates, was low at 0.010 mSv which was 1% of the principal 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 sources, however some enhancements were observed particularly in peas. Low concentrations of sulphur-35 and caesium-137 were detected in some samples; the former is due to station disposals, but the latter is likely to have contributions from other sources, e.g. weapon test and Chernobyl fallout. The maximum dose due to gaseous disposals was received by adults. Their dose in 1999 was estimated to be 0.005 mSv which was 0.5% of the principal dose limit for members of the public.

6.4 Hartlepool, Cleveland

This station is powered by twin AGRs. A recent habits survey examined the potential pathways for radiation exposure due to liquid effluent disposals. This established that exposures could be represented by consumption of local fish and shellfish and external radiation whilst digging for bait. The aquatic sampling and measurement programmes reflect those pathways. However 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 to cover surveillance of gaseous disposals.

Results of the monitoring programme carried out in 1999 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 most exposed group dose in 1999 was 0.006 mSv which was 0.6% of the principal dose limit for members of the public of 1 mSv.

In common with discharges from other AGRs, disposals of tritium in liquid effluents from the power station are discontinuous and levels in the environment vary accordingly. Camplin *et al.* (1990) has observed concentrations in seawater in excess of 100,000 Bq l^{-1} immediately after a discharge. Even at this level the radiological significance of the disposals is minor because of the very low radiotoxicity of the nuclide. High levels of tritium in seawater were not observed in 1999. A decrease in the level of technetium-99 in *Fucus vesiculosus* was noted this year (58 Bq kg^{-1}: 1999; 110 Bq kg^{-1}: 1998). While disposals of technetium-99 from Sellafield increased in 1999, the decrease of this radionuclide in *Fucus vesiculosus* at this time is believed to be due to the transit time from the Irish Sea. 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 may be due to waste slag from a local steel works which can be found containing enhanced levels of gamma-ray-emitting natural radionuclides. The radiation dose to the most exposed group of local fish and shellfish consumers was low, at 0.005 mSv which was 0.5% of the principal 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 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 and indicator materials and measurements of gamma dose rates, but for completeness the data considered in this sub-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. Samphire is also collected and analysed because of its use as a foodstuff.

The results for 1999 are given in Tables 6.5(a) and (b). In general, similar levels to those for 1998 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. The radiation dose in 1999 to the most exposed group of fishermen including a component due to external radiation was 0.071 mSv that is well within the principal dose limit for members of the public of 1 mSv. There was little change from the estimate for 1998 of 0.074 mSv (MAFF and SEPA, 1999). Most of this exposure was due to the effects of disposals from Sellafield. Concentrations of radioactivity in samphire were of negligible radiological significance.

The effects of gaseous disposals were also difficult to detect in 1999. Small enhancements of concentrations of carbon-14 were apparent in some samples. The most exposed group dose was estimated to be less than 0.005 mSv which was less than 0.5% of the principal 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 is powered by Magnox reactors and the 'B' station by AGRs. Magnox Electric plan to close the 'A' station in 2000. 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 muddy intertidal areas were also carried out. Measurements of tritium and carbon-14 are primarily made to establish the local effects of discharges from the Nycomed Amersham plant at Cardiff.

In January 2000, Magnox Electric reported that their estimates of discharges of gaseous wastes had been found to be unreliable. Discharge data for this site contained in earlier versions of this report since 1996 should therefore be disregarded. Initial estimates suggest discharges were under reported by up to 55%. Surveillance data contained in this and earlier reports are valid and are not affected by the uncertainty in discharges.

The environmental results for 1999, presented in Tables 6.6 (a) and (b) 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 in fruit were higher than the default values used to represent background levels (Appendix 6). The estimated most exposed group dose due to radioactivity in the terrestrial environment was less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

The concentrations observed in the Bristol Channel were generally similar to those in 1998, though a small reduction in the tritium concentration in shrimps was observed (1999: 1400 Bq kg^{-1}; 1998: 1900 Bq kg^{-1}). The concentration of tritium in seawater increased in 1999 but, as discussed for Hartlepool, the results of such measurements are highly variable in view of the discontinuous discharge of this radionuclide. 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 effects of releases from the stations, from other establishments which discharge into the Bristol Channel, from Sellafield, and from weapon test and Chernobyl fallout. Apportionment is generally difficult at the low levels detected. However the tritium and carbon-14 content in seafood was likely to have been due to disposals from Nycomed Amersham, Cardiff. The concentrations of transuranic nuclides were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment, measured using portable instruments, were difficult to distinguish from the natural background. The most exposed group from liquid disposals from the site in 1999 was represented by local fishermen who were estimated to receive a dose of 0.011 mSv which was around 1% of the principal dose limit for members of the public of 1 mSv. This estimate includes the effects of discharges of tritium and carbon-14 from Cardiff but excludes the effects of direct radiation from the site.

6.7 Hunterston, North Ayrshire

At this establishment there are two separate nuclear power stations - Hunterston A and Hunterston B.. 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. SEPA is currently determining applications under RSA93 for authorisations for Hunterston A that relate to decommissioning work and will incorporate the change of ownership to BNFL.

SEPA served a warning letter on Hunterston B relating to the maintenance of liquid radioactive waste discharge systems after on site spillage of cooling water from the discharge system which is used intermittently for liquid waste disposal. Liquid disposals are made to the Firth of Clyde from Hunterston A and Hunterston B at a common point under the current authorisations granted by SEPA. Gaseous disposals are made separately 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 *Fucus* seaweed are analysed as indicator materials. The terrestrial monitoring programme includes the analysis of grass and quarterly bulked samples of milk.

The results of monitoring in 1999 are shown in Tables 6.7(a) and (b). The concentrations of artificial radioactivity in the marine environment are predominantly due to Sellafield disposals, the general values being consistent with those to be expected at this distance from Sellafield. Small concentrations of tritium and activation products such as manganese-54 that are likely to have originated from the site were detected. However, these were of negligible radiological significance. In 1999, the dose to the critical group from external radiation and consumption of fish and shellfish was 0.015 mSv which was less than 2% of the principal dose limit for members of the public of 1 mSv.

The concentrations of radionuclides in milk and grass were low and similar to concentrations in previous years. The radiation dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout, was 0.019 mSv which was less than 2% of the principal dose limit for members of the public of 1 mSv.

6.8 Sizewell, Suffolk

At this establishment there are two stations. The 'A' station is powered by Magnox reactors whilst the 'B' station is powered by a Pressurised Water Reactor (PWR). The 'B' station began operation in 1995. Authorised disposals of radioactive liquid effluent from both power stations are discharged 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 1999 are shown in Tables 6.8 (a) and (b).

In the aquatic programme, analysis of seafood and indicator materials and measurements of gamma and beta dose rates in intertidal areas were undertaken. Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield disposals and to weapons testing. Tritium levels in seafood were low. Trace levels of activation products were likely to have been due to disposals from the power stations. In 1999, 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 principal dose limit for members of the public of 1 mSv. Measured gamma and beta dose rates were indistinguishable from the natural background. The above assessment includes a contribution for external exposure based on a calculation using radionuclide concentrations in sediment.

Gamma spectrometry and analysis of tritium, carbon-14, sulphur-35, strontium-90 and actinides in milk, crops and fruit showed very low levels of artificial radioactivity near the power stations in 1999. Trace quantities of sulphur-35 were detected in some samples. The estimated dose to the most exposed group of consumers eating such foods was less than 0.005 mSv which was less than 0.5% of the principal 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. The monitoring programme at this site includes sampling of milk and seafood, and samples of seawater, seaweed and grass are monitored as indicator materials. Measurements are 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 1999 are shown in Tables 6.9(a) and (b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield disposals and to weapon testing and Chernobyl fallout, although trace levels of activation products such as cobalt-60 and manganese-54 are likely to have originated from the station. The dose to fish and shellfish consumers (the most exposed group) was less than 0.005 mSv, which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

Beta radiation from fishermen's nets and pots was below the limit of detection. The dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout was 0.015 mSv, which was less than 2% of the principal dose limit for members of the public of 1 mSv.

6.10 Trawsfynydd, Gwynedd

This station is being decommissioned. Low level disposals continued during 1999 under authorisations granted by the Environment Agency. Disposals of liquid radioactive waste were made to a freshwater lake making the power station unique in United Kingdom terms. Monitoring is carried out on behalf of the National Assembly for Wales 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 those of radiocaesium and, to a lesser extent, strontium-90. 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 those of 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. 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. No evidence was therefore found that resuspension of activity in sediment from the lake shore contributed to exposure from transuranic radionuclides in 1999.

The most exposed group for terrestrial foods at Trawsfynydd in 1999 received doses of less than 0.005 mSv which was less than 0.5% of the principal 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 disposals from the power station. However, gamma dose rates found on the shoreline where occupancy by anglers is relevant were only slightly enhanced above background and were similar to those in 1998.

The concentrations of caesium-137 in lake water remained above those expected in catchment water coming into the lake. However, there were also small decreases in concentrations of radiocaesium in fish in 1999 reflecting the lower discharges typical of recent years. The sediment activities and the residual activity in the fish from earlier discharges are now likely to the major sources of activity in these fish. Taking the levels of radionuclides in these fish and the results of measurements of gamma dose rates into account, the dose to the most exposed group of anglers was 0.021 mSv in 1999, which was about 2% of the principal dose limit for members of the public of 1 mSv.

6.11 Wylfa, Isle of Anglesey

This station is powered by Magnox reactors. Gaseous and liquid wastes from this station were discharged in 1999 under authorisations granted by the Environment Agency. Environmental monitoring of the effects of disposals on the Irish Sea and the local environment is carried out on behalf of the National Assembly for Wales and the Food Standards Agency. Such disposals and effects are very low.

The results of the programme in 1999 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 disposals though trace levels of activation products were likely to have been due to disposals from the station. The concentrations were generally similar to those for 1998, and continued to show the effects of technetium-

99 from Sellafield. The dose to the most exposed group of high-rate fish and shellfish consumers was low, at 0.007 mSv which was less than 1% of the principal dose limit for members of the public of 1 mSv. Gamma dose rates, measured using portable instruments, continued to be difficult to distinguish from the natural background.

The results for terrestrial foods indicate a small effect due to the total gaseous disposals from the power station. This is seen in the data for sulphur-35, particularly in blackberries and barley. Also sulphur-35 was detected in grass. However, the dose received by high-rate food consumers remained low at less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public.

Table 6.1(a). Radioactivity in food and the environment near Berkeley and Oldbury nuclear power stations, 1999

Material	Location	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am
Aquatic samples								
Salmon	Beachley	1	<25	26	<0.09	0.23	<0.16	<0.09
Elvers	Littleton Warth	1	<25		<0.12	0.24	<0.28	<0.26
Fucus vesiculosus[f]	Pipeline[d]	2			<0.08	0.49	<0.12	<0.10
Mud	Hill Flats	2			1.1	31	2.0	0.94
Mud	1 km south of Oldbury	2			1.1	31	2.4	0.78

Material	Location or selection[c]		No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
				^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples											
Milk	Near farms		7	<3.8	18	<0.55	<0.28	<0.32			
Milk	Near farms	max		<4.0	22	<0.73	<0.30	<0.35			
Milk	Far farms		1	<4.0	18	<0.50	<0.28	<0.38			
Apples			1	<4.0	23	<0.30	<0.30	<0.40			
Blackberries			1	<4.0	28	<0.80	<0.30	<0.30			
Cabbage[e]			1	4.0	<2.0	<0.50	<0.40	<0.40			
Carrots			1	<4.0	12	<0.60	<0.40	<0.40			
Goats milk			1	<4.0	9.0	<1.0	<0.20	<0.20			
Potatoes			1	<4.0	19	<0.40	<0.40	<0.50			
Runner beans			1	6.0	31	<1.2	<0.30	<0.30			
Wheat			1	7.0	170	6.7	<0.30	<0.30			
Dry cloths			160						0.16	1.0	0.49

[a] *Except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *See section 3 for definition*
[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. See section 3*
[d] *Berkeley*
[e] *The concentration of ^{55}Fe was 0.50 Bq kg^{-1}*
[f] *The concentration of total beta activity was 130 Bq kg^{-1}*

Table 6.1(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 1999

Location	Ground type	No. of sampling observa-tions[a]	μGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
1 km south of Oldbury	Mud	2	0.071
2 km south west of Berkeley	Mud	2	0.066
Sharpness	Mud	2	0.069
Hills Flats	Mud	2	0.070

[a] *See section 3 for definition*

Table 6.2(a). Radioactivity in food and the environment near Bradwell nuclear power station, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{14}C	^{60}Co	^{65}Zn	^{99}Tc	^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am
Aquatic samples										
Sole	Bradwell	2		<0.04	<0.13		0.09	0.53	<0.11	<0.14
Bass	Pipeline	1		<0.04	<0.10		0.32	2.2	<0.12	<0.13
Mullet	Pipeline	1		<0.06	<0.16		0.19	0.86	<0.18	<0.29
Native oysters[e]	Tollesbury N. Channel	2	16	<0.05	0.41		<0.11	0.42	<0.08	0.0029
Pacific oysters	Goldhanger Creek	1		<0.11	0.95		<0.13	0.54	<0.28	<0.40
Winkles	Pipeline	2		0.37	<0.52		<0.10	<0.16	<0.15	<0.07
Fucus vesiculosus[f]	Waterside	2		0.24	<0.14	29	<0.43	1.9	<0.13	<0.15
Mud	West Mersea	2		1.1	<0.93		2.4	20	1.5	<0.54
Mud	Maldon	2		1.6	<1.3		7.2	62	<1.4	<1.4

Material	Location or selection[d]		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	Total gamma
Terrestrial Samples												
Milk	Near farms		4	<3.8	18	<0.47	<0.31	<0.29	<0.30			
Milk	Near farms	max		<4.0	23	<0.55	<0.33	<0.33	<0.33			
Milk	Far farms		2	<4.0	19	<0.45	<0.30	<0.28	<0.30			
Milk	Far farms	max			21	<0.48						
Apples			1	<4.0	18	0.20	<0.30	<0.30	<0.40			
Cabbage[g]			1	<4.0	10	1.2	<0.50	<0.40	<0.40			
Carrots			1	<5.0	13	<0.20	<0.50	<0.40	<0.40			
Potatoes			1	<5.0	27		<0.40	<0.40	<0.40			
Raspberries			1	<4.0	21	<0.30	<0.40	<0.30	<0.40			
Wheat			1	9.0	97	15	<0.40	<0.30	<0.30			
Lucerne			1	<3.0	22	1.5	<0.50	<0.40	<0.40			
Dry Cloths			111							0.21	1.2	0.74

[a] *Except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*
[d] *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. See section 3*
[e] *The concentrations of ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were 0.00026, 0.0014, 0.000037 and 0.00017 Bq kg^{-1} respectively*
[f] *The concentration of total beta activity was 180 Bq kg^{-1}*
[g] *The concentration of ^{55}Fe was <0.60 Bq kg^{-1}*

Table 6.2(b). Monitoring of radiation dose rates near Bradwell nuclear power station, 1999

Location	Ground type	No. of sampling observa-tions[a]	μGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
West Mersea	Mud	2	0.064
3 km N.W. Tollesbury (houseboat 1)	Salt marsh	1	0.063
3 km N.W. Tollesbury (houseboat 2)	Mud	1	0.068
1 km W. Tollesbury	Mud	1	0.072
Goldhanger Creek	Mud, sand and stones	1	0.049
Maldon (houseboat 3)	Mud	1	0.059
Maldon (houseboat 4)	Mud	1	0.058
Maldon	Mud	2	0.056
2 km W. Maldon	Mud	1	0.063

[a] *See section 3 for definition*

Table 6.3(a). Radioactivity in food and the environment near Dungeness nuclear power stations, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{60}Co	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+^{244}Cm
Aquatic samples											
Plaice	Pipeline	3	<25	<0.05	<0.05	0.12			<0.08		
Cod	Pipeline	2	<25	<0.06	<0.06	0.30			<0.10		
Bass	Pipeline	1	<25	<0.22	<.0.23	0.83			<0.46		
Spiny Spider Crabs	Hastings	1		0.89	<0.06	<0.05			<0.26		
Shrimps[f]	Pipeline	2		<0.05	<0.07	0.24			<0.10		
Whelks[g]	Pipeline	2		<0.23	<0.13	<0.12	0.00032	0.0022	0.0026	0.00029	0.00022
Fucus vesiculosus[e,h]	Copt Point	2		0.26	<0.06	<0.10			<0.11		
Mud	Seabed										
	- offshore	1		2.0	<0.32	2.1			<0.52		
Mud & sand	Rye Harbour	2		1.3	<0.28	1.6	*0.16*	*0.29*	*0.25*	*0.0034*	*0.014*
Sea water	Pipeline	2	<2.1								

Material	Location or selection[d]	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	Total gamma
Terrestrial Samples											
Milk[i]	Far Farms	2	<3.1	16	<0.35	<0.35	<0.29	<0.29			
Milk[i]	Far farms	max	<3.3		<0.38	<0.38	<0.30	<0.30			
Beans		1	<7.0	47	<2.2	<0.60	<0.40	<0.40			
Blackberries		1	<4.0	35	0.40	<0.50	<0.30	<0.40			
Honey		1	<6.0	96	<0.20	<0.10	<0.20	<0.20			
Peas		1	<6.0	140	2.3	<0.50	<0.40	<0.40			
Potatoes		1	<5.0	21	<0.20	<0.40	<0.30	<0.30			
Sea kale[j]		1	<4.0	15	2.9	<0.50	<0.40	0.70			
Dry cloths		96							0.25	1.4	0.95

[a] *Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*
[d] *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. See section 3*
[e] *The concentration of ^{99}Tc was 2.1 Bq kg^{-1}*
[f] *The concentration of ^{14}C was 25 Bq kg^{-1}*
[g] *The concentration of ^{90}Sr was <0.029 Bq kg^{-1}*
[h] *The concentration of total beta activity was 130 Bq kg^{-1}*
[i] *There are no 'near' farms producing milk near this site*
[j] *The concentration of ^{55}Fe was <0.60 Bq kg^{-1}*

Table 6.3(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 1999

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose at 1m over intertidal areas			
Rye Harbour	Mud and sand	2	0.065
Beta dose rates			µSv h^{-1}
Rye Harbour	Mud and sand	3	0.22

[a] *See section 3 for definition*

Table 6.4(a). Radioactivity in food and the environment near Hartlepool nuclear power station, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{14}C	^{60}Co	^{99}Tc	^{131}I	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm	Total beta
Aquatic samples														
Plaice	Pipeline	2		24	<0.12		<1.2	0.44	<0.16			<0.09		
Cod	Pipeline	2			<0.04		<0.23	0.60	<0.09			<0.07		
Crabs	Pipeline	2		44	<0.07		*	<0.14	<0.22	0.00042	0.0023	0.0022	*	
Winkles	Paddy's Hole	2			<0.06		<0.19	0.48	<0.16	0.0073	0.049	0.020	0.000031	
Fucus vesiculosus	Pilot Station	2			<0.04	58	<2.8	0.22	<0.08			<0.05		230
Mud	Paddy's Hole	2			<0.35		*	14	2.1			<0.89		
Sea water	Pipeline	2	4.5											

Material	Location or selection[d]	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	Total gamma
Terrestrial samples										
Milk	Far Farms[f]	6	<4.0	18	<0.34	<0.35	<0.32			
Milk	Far Farms[f] max			25	<0.38	<0.40	<0.37			
Apples		1	4.0	33	<0.50	<0.50	<0.40			
Cabbage[e]		1	5.0	9.0	2.6	<0.30	<0.30			
Cauliflower		1	3.0	<3.0	<0.50	<0.30	<0.40			
Elderberries		1	<4.0	33	<0.40	<0.30	<0.30			
Honey		1	<6.0	86	<0.60	<0.20	<0.20			
Potatoes		1	<4.0		3.6	<0.30	<0.50			
Runner Beans		1	<4.0	9.0	<0.40	<0.20	<0.30			
Swede		1	<4.0	21	<0.60	<0.50	<0.40			
Wheat		1	<7.0	75	<1.5	<0.60	<0.40			
Dry Cloths		99						0.28	1.3	0.91

* *not detected by the method used*

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

[b] *Landing point or sampling area*

[c] *See section 3 for definition*

[d] *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. See section 3*

[e] *The concentration of ^{55}Fe was 0.60 Bq kg^{-1}*

[f] *There are no 'near farms' producing milk near this site*

Table 6.4(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 1999

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Paddy's Hole	Mud	2	0.081
Paddy's Hole	Winkle bed	2	0.20

[a] *See section 3 for definition*

Table 6.5(a). Radioactivity in food and the environment near Heysham nuclear power stations, 1999[e]

Material	Location[b] or selection[c]	No. of sampling observ- ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{14}C	^{35}S	^{54}Mn	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{137}Cs
Aquatic samples													
Flounder	Flookburgh	4		77		<0.08	<0.09			<0.85	<0.16	<0.24	17
Plaice	Morecambe	4	37			<0.07	<0.08	0.042	16	<0.75	<0.13	<0.20	7.1
Bass	Morecambe	2				<0.11	<0.12			<1.2	<0.21	<0.30	15
Whitebait	Sunderland Point	1				<0.05	0.30	0.15		<0.44	<0.09	<0.12	6.4
Shrimps	Flookburgh	4		75		<0.07	<0.11		3.8	<0.74	<0.13	<0.20	6.2
Cockles	Middleton Sands	2				<0.05	2.5			<0.95	<0.11	<0.15	4.6
Cockles	Flookburgh	4		63		<0.05	2.2	0.49	37	<0.96	<0.09	<0.18	5.2
Winkles	Red Nab Point	4				<0.13	1.4			<1.3	<0.37	0.34	6.6
Mussels	Morecambe	4	87	72		<0.09	0.81		190	<1.0	<0.15	<0.33	4.8
Fucus vesiculosus[f]	Half Moon Bay	4				<0.07	1.1		2800	<0.56	<0.11	<0.32	6.2
Samphire[g]	Cockerham Marsh	1				<0.03	0.11			<0.25	<0.05	<0.07	2.1
Mud and sand	Flookburgh	4				<0.38	<1.5			<4.1	<0.67	<1.3	100
Mud and sand	Half Moon Bay	4				<0.47	7.5			<10	<0.78	<1.7	200
Mud and sand	Morecambe Central Pier	4				<0.39	2.5			<4.4	<0.64	<1.3	110
Turf	Conder Green	4				<0.65	3.5			<7.8	<1.1	<2.7	310
Turf	Sand Gate Marsh	4				<0.47	1.2			<5.3	<0.82	<1.9	240
Sea water	Pipeline	2	18										
Sea water	Half Moon Bay	1											0.21
Terrestrial samples													
Milk	Near farms	6	<3.9	18	<0.43		<0.34			<2.4	<0.35		<0.34
Milk	Near farms	max	<4.5	20	<0.58		<0.40			<2.8	<0.40		<0.35
Apples		1	5.0	20	<0.30		<0.50			<3.2	<0.40		<0.40
Barley		1	<6.0	90	<1.5		<0.40			<3.8	<0.40		<0.50
Beetroot/ Turnips		1	<4.0	24	<0.20		<0.30			<2.3	<0.20		<0.30
Blackberries		1	<4.0	40	<0.50		<0.50			<3.8	<0.40		<0.40
Cabbage[h]		1	<5.0	7.0	1.5		<0.40			<2.3	<0.40		<0.40
Honey		1	<7.0	120	<1.0		<0.30			<2.2	<0.30		<0.30
Potatoes		1	<5.0	23	0.20		<0.50			<3.6	<0.30		<0.40
Sprouts		1	<4.0	12	<0.60		<0.30			<1.6	<0.20		<0.20

Table 6.5(a). continued

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Aquatic samples											
Flounder	Flookburgh	4	<0.37	<0.28	<0.18	0.0012	0.0063		0.012	*	0.000021
Plaice	Morecambe	4	<0.38	<0.23	<0.18	0.00023	0.0012		0.0022	*	*
Bass	Morecambe	2	<0.49	<0.36	<0.21				<0.15		
Whitebait	Sunderland Point	1	<0.23	<0.14	<0.10	0.066	0.35	3.6	0.59	*	0.00083
Shrimps	Flookburgh	4	<0.42	<0.21	<0.19	0.0046	0.027	0.70	0.046	*	0.00013
Cockles	Middleton Sands	2	<0.25	<0.17	<0.13	0.39	2.2		5.1	*	0.0073
Cockles	Flookburgh	4	<0.25	<0.13	<0.11	0.48	2.5	27	6.9	0.013	0.0017
Winkles	Red Nab Point	4	<0.35	<0.24	<0.20	0.42	2.3		4.1	*	0.013
Mussels	Morecambe	4	<0.40	<0.24	<0.19	0.36	2.0		3.6	*	0.0038
Fucus vesiculosus[f]	Half Moon Bay	4	<0.29	<0.21	<0.15				0.82		
Samphire[g]	Cockerham Marsh	1	<0.17	<0.08	<0.08				1.1		
Mud and sand	Flookburgh	4	<2.5	<1.2	<1.3				55		
Mud and sand	Half Moon Bay	4	<3.6	<2.4	<2.4	23	120		210	0.21	0.25
Mud and sand	Morecambe Central Pier	4	<2.5	<1.1	<2.1				68		
Turf	Conder Green	4	<4.5	<1.9	<2.3				160		
Turf	Sand Gate Marsh	4	<2.9	<1.7	<1.3				97		
Sea water	Pipeline	2									
Sea water	Half Moon Bay	1									

* *Not detected by the method used*
[a] *Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*
[d] *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. See section 3*
[e] *78 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.12, 0.64 and 0.32 Bq per cloth respectively*
[f] *The concentration of total beta activity was 2100 Bq kg^{-1}*
[g] *The concentration of total beta activity was 63 Bq kg^{-1}*
[h] *The concentration of ^{55}Fe was <0.50 Bq kg^{-1}*

Table 6.5(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 1999

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Sand Gate Marsh	Salt marsh	4	0.095
High Foulshaw	Salt marsh	4	0.090
Arnside	Salt marsh	4	0.10
Morecambe Central Pier	Mussel bed	4	0.077
Morecambe Central Pier	Mud and sand	4	0.078
Half Moon Bay	Mud	1	0.077
Half Moon Bay	Mud and sand	3	0.078
Colloway Marsh	Salt marsh	4	0.15
Aldcliffe Marsh	Salt marsh	4	0.11
Conder Green	Mud and sand	4	0.098
Conder Green	Salt marsh	4	0.11
Cockerham Marsh	Salt marsh	4	0.11

[a] *See section 3 for definition*

Table 6.6(a). Radioactivity in food and the environment near Hinkley Point nuclear power stations, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{134}Cs	^{137}Cs
Aquatic samples									
Flounder	Stolford	3		95	<0.05	<0.06	<0.13	<0.12	0.80
Shrimps	Stolford	2	1400	88	<0.06	<0.07	<0.16	0.17	0.74
Fucus vesiculosus[e]	Pipeline	2			<0.77	2.7	<0.27	5.8	21
Mud	1.6 km east of pipeline	2			<0.56	<1.4	<1.2	7.9	48
Mud and sand	River Parrett	2			<0.55	<0.61	<1.3	2.8	34
Sea water	Pipeline	2	120						

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Aquatic samples								
Flounder	Stolford	3	<0.22	<0.11			<0.10	
Shrimps	Stolford	2	<0.34	<0.16	0.00017	0.00073	0.00060	0.000080
Fucus vesiculosus[e]	Pipeline	2	<0.70	<0.14			<0.32	
Mud	1.6 km east of pipeline	2	<2.7	<2.2			<2.0	
Mud and sand	River Parrett	2	<2.2	<1.9			<1.1	
Sea water	Pipeline	2						

Material	Location or selection[d]	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	Total gamma
Terrestrial samples											
Milk	Near farms	5	<3.8	16	<0.62	<0.38	<0.31	<0.32			
Milk	Near farms	max	<4.0	20	<0.87	<0.43	<0.33	<0.37			
Milk	Far Farms	1	<4.0	23	<0.43	<0.35	<0.30	<0.33			
Apples		1	<4.0	29	<0.20	<0.30	<0.30	<0.30			
Blackberries		1	<4.0	25	<0.20	<0.40	<0.30	<0.40			
Cabbage[f]		1	<4.0	23	5.4	<0.50	<0.40	<0.40			
Honey		1	<7.0	66	0.60	<0.20	<0.20	<0.20			
Potatoes		1	<5.0	31	1.1	<0.50	<0.40	<0.50			
Rabbit[g]		1	9.0	26	6.0		<0.50	<0.60			
Runner beans		1	<5.0	13	2.8	<0.50	<0.40	<0.40			
Wheat		1	<7.0	77	<0.80	<0.20	<0.20	<0.20			
Fodder beet		1	<5.0	19	<0.80	<0.50	<0.40	<0.50			
Dry cloths		104							0.17	1.1	0.95

[a] *Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *Landing point or sampling area.*
[c] *See section 3 for definition*
[d] *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. See section 3*
[e] *The concentration of total beta activity was 220 Bq kg^{-1}*
[f] *The concentration of ^{55}Fe was <0.60 Bq kg^{-1}*
[g] *The concentration of organic ^{3}H was 4.0 Bq kg^{-1}*

Table 6.6(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 1999

Location	Ground type	No. of sampling observa-tions[a]	μGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
River Parrett	Mud and sand	2	0.072

[a] *See section 3 for definition*

Table 6.7(a). Radioactivity in food and the environment near Hunterston nuclear power station, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{54}Mn	^{60}Co	^{95}Nb	^{110m}Ag	^{137}Cs	^{144}Ce	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Aquatic samples												
Cod	Millport	2		<0.10	<0.10	<0.14	<0.10	2.7	<0.33			<0.18
Hake	Millport	2		<0.10	<0.11	<0.13	<0.10	3.3	<0.47			<0.25
Crabs	Millport	2		<0.11	<0.11	<0.13	<0.10	0.66	<0.48	0.27	0.53	0.085
Nephrops	Millport	2		<0.16	<0.16	<0.66	<0.15	1.6	<0.66			<0.36
Lobsters	Largs	1		<0.11	<0.11	<0.24	<0.10	1.8	<0.63			0.46
Squat lobsters[e]	Largs	4		<0.11	<0.11	<0.21	<0.11	0.56	<0.35	0.0058	0.029	0.019
Oysters	Fairlie	1		0.12	<0.10	<0.10	0.33	0.38	<0.15			<0.10
Winkles	Pipeline	2		2.5	0.97	<0.22	1.4	1.0	<0.54	0.034	0.13	0.39
Scallops	Largs	4		<0.10	<0.10	<0.13	<0.10	0.63	<0.26	0.0087	0.030	0.064
Fucus vesiculosus	Pipeline	2		2.6	0.62	<0.10	<0.10	1.8	<0.24			<0.17
Sand	Pipeline	2		0.80	0.49	<0.19	<0.10	19	<0.65			<0.48
Seawater	Pipeline	12	<180					<0.060				

Material	Location[b] or selection[d]	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 alpha
Terrestrial samples								
Milk		4	<25	14	<5.0	<0.10	<0.30	
Milk	max			17			0.79	
Grass		4	<25	27	<5.0	<0.48	0.59	<0.59
Grass	max			46		1.3	1.4	<0.68

[a] *Except for milk and sea water where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*
[d] *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. See section 3 for definition*
[e] *The concentration of ^{99}Tc was 8.8 Bq kg^{-1}*

Table 6.7(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 1999

Location	Ground type	No. of sampling observa-tions[a]	μGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
0.5 km north of pipeline	Sand	2	0.053
0.5 km south of pipeline	Sand and stones	2	0.055

[a] *See section 3 for definition*

Table 6.8(a). Radioactivity in food and the environment near Sizewell nuclear power stations, 1999[f]

Material	Location[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am	^{243}Cm+^{244}Cm	Total beta
Aquatic samples												
Cod	Sizewell	1	130		<0.05	0.42	<0.13			<0.21		
Sole	Sizewell	1	<25		<0.18	0.29	<0.31			<0.36		
Crabs	Sizewell	2		37	<0.06	0.16	<0.09	0.00013	0.00070	0.0012	0.000052	
Shrimps	Sizewell	1			<0.25	0.43	<0.45	0.00059	0.0035	0.0050	*	
Pacific Oyster	Blyth estuary	1			<0.02	0.07	<0.04			<0.03		
Whelks	Dunwich	1			<0.18	0.25	<0.24			<0.12		
Mud	Southwold	2			1.1	11	<1.3			<1.1		750
Sand	Aldeburgh	2			<0.11	0.29	<0.30			<0.19		
Sea water	Aldeburgh	2	2.5									

Material	Location[b] or selection[c]		No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
				^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{137}Cs	Total Cs	^{238}Pu	$^{239+240}$Pu	^{241}Am
Terrestrial samples													
Milk	Near farms		3	<3.8	16	<0.58	<0.37		<0.33				
Milk	Near farms	max		<4.0	17	<0.68	<0.43		<0.35				
Milk	Far farms		3	<4.0	15	<0.53	<0.35		<0.33				
Milk	Far farms	max			17	<0.60	<0.40		<0.38				
Apples			1	<4.0	17	0.40	<0.40		<0.40				
Carrots			1	<4.0	7.0	0.20	<0.60		<0.50				
Cauliflower[e]			1	<4.0	17	1.6	<0.60		<0.30				
Courgettes			1	<4.0	3.0	0.30	<0.60		<0.50				
Honey			1	<7.0	140	<0.60	<0.50		<0.60				
Ovine muscle			1	<5.0	41	<0.60	<0.40	0.031		0.081	<0.00020	<0.00030	0.00060
Ovine offal			1	<7.0	68	4.5	<0.30	0.68		0.077	0.00020	<0.00030	<0.00040
Porcine muscle			1	<5.0	30	1.2	<0.40	0.27		0.25	<0.00020	<0.00020	<0.00030
Porcine kidney			1	<7.0	12	0.90	<0.30	0.051		0.23	<0.00030	<0.00050	0.00030
Porcine liver			1	<8.0	87	1.7	<0.50	0.022		0.57	0.00020	<0.00040	<0.00020
Potatoes			1	<5.0	36	1.9	<0.50		<0.40				
Raspberries			1	<4.0	11	<0.50	<0.30		<0.30				
Runner beans			1	<4.0	6.0	0.50	<0.40		<0.30				
Wheat			1	<7.0	120	3.8	<0.50		<0.40				

* *Not detected by the method used.*
[a] *Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *Landing point or sampling area.*
[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. See section 3.*
[d] *See section 3 for definition*
[e] *The concentration of ^{55}Fe was <0.70 Bq kg^{-1}*
[f] *116 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.31, 1.6 and 0.72 Bq per cloth respectively*

Table 6.8(b). Monitoring of radiation dose rates near Sizewell nuclear power stations, 1999

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Aldeburgh	Sand and gravel	2	0.042
Southwold Harbour	Mud	2	0.062
Beta dose rates			µSv h^{-1}
Southwold Harbour	Mud	2	0.19

[a] *See section 3 for definition*

Table 6.9(a). Radioactivity in food and the environment near Torness nuclear power station, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{54}Mn	^{60}Co	^{99}Tc	^{106}Ru	^{110m}Ag
Aquatic samples								
Cod	Pipeline	2		<0.10	<0.10		<0.43	<0.10
Crabs	Cove	2		<0.10	<0.10		<0.62	<0.10
Lobsters	Cove	1		<0.10	<0.10	54	<0.73	<0.10
Nephrops	Dunbar	4		<0.12	<0.12		<1.0	<0.12
Winkles[e]	Pipeline	2		<0.20	<0.34		<0.75	0.37
Fucus vesiculosus	Pipeline	2		0.80	0.95		<0.45	<0.10
Mud	Eyemouth Harbour	1		<0.10	<0.10		<0.56	<0.10
Mud and sand	Dunbar inner harbour	2		<0.12	<0.10		<0.76	<0.10
Mud and sand	Barns Ness	1		<0.10	<0.10		<0.50	<0.10
Sand	Thornton Loch Beach	2		<0.10	<0.10		<0.73	<0.10
Seawater	Pipeline	12	<6.9					

Material	Location	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{137}Cs	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Aquatic samples							
Cod	Pipeline	2	0.86	<0.15			<0.10
Crabs	Cove	2	<0.13	<0.23			<0.14
Lobsters	Cove	1	0.48	<0.23			<0.11
Nephrops	Dunbar	4	<0.38	<0.31	0.0025	0.0081	0.0065
Winkles[e]	Pipeline	2	0.18	<0.24			<0.16
Fucus vesiculosus	Pipeline	2	0.33	<0.15			<0.17
Mud	Eyemouth Harbour	1	4.1	0.57			0.67
Mud and sand	Dunbar inner harbour	2	4.0	<0.69			<0.56
Mud and sand	Barns Ness	1	5.1	0.27			<0.44
Sand	Thornton Loch Beach	2	1.6	<0.25			<0.23
Seawater	Pipeline	12	<0.05				

Material	Location[b] or selection[d]	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 Alpha
Terrestrial Samples								
Milk		4	<25	13	<5.0	<0.10	<0.05	
Milk	max			19				
Grass		6	<25	28	<5.0	0.24	<0.10	<0.84
Grass	max			64		0.68	<0.13	1.4

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*
[d] *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. See section 3 for definition*
[e] *The concentration of total beta activity was <18 Bq kg^{-1}*

Table 6.9(b). Monitoring of radiation dose rates near Torness nuclear power station, 1999

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Barns Ness	Mud and sand	2	0.049
Skateraw Harbour	Sand	2	0.043
Thornton Loch Beach	Sand	2	0.056
Eyemouth Harbour	Mud	1	0.058
Dunbar Inner Harbour	Mud and sand	2	0.078
St Abbs	Sand	2	0.092
Beta dose rates on fishing gear			µSv h^{-1}
Cove	Pots	1	*
Dunbar Harbour	Nets	1	*

[a] *See section 3 for definition*
* *Not detected by the method used*

Table 6.10(a). Radioactivity in food and the environment near Trawsfynydd nuclear power station, 1999

Material	Location or selection[c]	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{125}Sb	^{134}Cs	^{137}Cs	Total Cs
Freshwater samples											
Brown trout	Lake	6		33		<0.11	11	<0.48	1.0	78	
Rainbow trout	Lake	6				<0.09		<0.23	<0.11	5.5	
Perch	Lake	4				<0.14	5.7	<0.70	2.0	150	
Rudd	Lake	1				<0.22		<0.97	2.1	150	
Mud	Pipeline	1				24		31	17	1700	
Water	Bailey Bridge	1	*								
Water	Cold Lagoon	2							*	0.04	
Terrestrial Samples											
Milk	Near farms	1	<3.8	15		<0.30	0.069	<0.68			0.13
Milk	Far farms	1	<3.8	18		<0.35	0.064	<0.63			0.13
Blackberries		1	<4.0	24	1.1	<0.30		<0.70	<0.30	0.40	
Carrots		1	<4.0	10	0.50	<0.50		<1.1	<0.40	<0.40	
Chicken		1	<5.0	16	3.3	<0.30		<0.80	<0.30	<0.40	
Hazlenuts		1	6.0	65	<1.0	<0.40		<0.80	<0.40	2.0	
Ovine muscle		2	<5.0	61		<0.45	0.037	<0.80			1.1
Ovine muscle	max		5.0	69		<0.50	0.051				1.4
Ovine offal		2	<7.0	20		<0.20	0.093	<0.40			0.46
Ovine offal	max			24			0.11				0.73
Potatoes		1	<5.0	27	1.1	<0.40		<0.80	<0.30	<0.40	
Sprouts[d]		1	<4.0	12	1.1	<0.40		<1.0	<0.40	<0.60	

Material	Location or selection[c]	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Freshwater samples								
Brown trout	Lake	6	<0.34	<0.32	0.00014	0.00068	0.00081	0.000018
Rainbow trout	Lake	6	<0.30	<0.20			<0.19	
Perch	Lake	4	<0.38	<0.52	0.00025	0.00088	0.0013	0.000041
Rudd	Lake	1	<0.62	<0.72			<0.67	
Mud	Pipeline	1	8.5	6.7			37	
Water	Bailey Bridge	1						
Water	Cold Lagoon	2						
Terrestrial Samples								
Milk	Near farms	1	<0.38	<0.53				
Milk	Far farms	1	<0.38	<0.48				
Blackberries		1	<0.40	<0.50	<0.00020	<0.00040	0.00010	
Carrots		1	<0.60	<0.60	<0.00020	0.00050	<0.00040	
Chicken		1	<0.30	<0.50	<0.00030	0.00040	<0.00030	
Hazlenuts		1	<0.40	<0.60	<0.0012	0.0024	<0.0013	
Ovine muscle		2	<0.45	<0.65	<0.00020	<0.00020	<0.00030	
Ovine muscle	max		<0.50	<0.70				
Ovine offal		2	<0.20	<0.30	<0.00020	0.00015	<0.00030	
Ovine offal	max					0.00020		
Potatoes		1	<0.40	<0.60	<0.00020	0.00050	<0.00030	
Sprouts[d]		1	<0.50	<0.80				

* *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] *See section 3 for definition*

[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. See section 3 for definition*

[d] *The concentration of ^{55}Fe was <0.60 Bq kg^{-1}*

[e] *114 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.15, 1.1 and 0.34 Bq per cloth respectively*

Table 6.10(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 1999

Location	Ground type	No. of sampling observations[a]	$\mu Gy\ h^{-1}$
Gamma dose rates at 1 m over areas near lake shoreline			
Footbridge	Rock	2	0.092
Nant Islyn Bay	Stones	2	0.099
West of footbridge	Stones	2	0.10

Table 6.11(a). Radioactivity in food and the environment near Wylfa nuclear power station, 1999

Material	Location[c]	No. of sampling observ-ations[b]	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	$^{243}Cm+^{244}Cm$	Total beta
Aquatic samples												
Plaice	Pipeline	1	23	<0.07		0.52			<0.15			
Winkles[e]	Cemaes Bay	2		<0.18		1.0	0.053	0.30	0.43	0.00078	0.0011	
Fucus vesiculosus	Cemaes Bay	2		<0.07	560	1.2			<0.26			550

Material	Location or selection[d]	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples										
Milk	Near farms	5	<3.5	15	<0.85	<0.34	<0.31			
Milk	Near farms	max	<3.8	19	1.0	<0.38	<0.35			
Apples		1	<4.0	27	1.7	<0.40	<0.40			
Barley		1	<6.0	170	2.8	<0.30	<0.40			
Blackberries		1	<4.0	16	3.1	<0.50	<0.40			
Broad beans		1	<3.0	43	1.5	<0.40	<0.40			
Cabbage[f]		1	<4.0	10	0.90	<0.20	<0.40			
Carrots		1	<4.0	13	<0.20	<0.60	<0.50			
Honey		1	<6.0	97	<0.60	<0.30	0.20			
Potatoes		1	<4.0	28	0.40	<0.60	<0.40			
Grass		2	<5.5	22	4.8	<0.60	<0.50			
Grass		max	6.0	33	5.0	<0.70	<0.60			
Dry cloths		90						0.23	1.3	0.51

[a] *Except for milk and sea water where units are Bq l^{-1} and for dry cloths where units are Bq per cloth*
[b] *See section 3 for definition*
[c] *Landing point or sampling area*
[d] *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. See section 3*
[e] *The concentration of ^{241}Pu was 2.6 Bq kg^{-1}*
[f] *The concentration of ^{55}Fe was 1.0 Bq kg^{-1}*

Table 6.11(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 1999

Location type	Ground sampling	No. of observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Cemaes Bay	Sand	4	0.059

[a] *See section 3 for definition*

7. DEFENCE ESTABLISHMENTS

Surveillance by the Food Standards Agency and SEPA is undertaken near 8 defence-related establishments in the United Kingdom. Low-level discharges also occur from Burghfield in Berkshire. Environmental monitoring at this site is carried out by the operator. Monitoring at nuclear submarine berths is carried out by the Ministry of Defence (DRPS, 1999).

7.1 Aldermaston, Berkshire

The Atomic Weapons Establishment (AWE) at Aldermaston is authorised to discharge low levels of radioactive waste to the environment. Revised authorisations were granted by the Environment Agency to AWE on 9 March 2000 and came into effect on 1 April 2000. Liquid disposals are made to the River Thames at Pangbourne and to the sewage works at Silchester. Samples of milk, other terrestrial foodstuffs, freshwater fish and indicator materials were collected. Monitoring of the aquatic environment at Newbridge is undertaken to indicate background levels remote from nuclear establishments.

The results of measurements of radioactivity concentrations are shown in Table 7.1. The concentrations of artificial radioactivity detected in the Thames catchment were very low. Levels of tritium were all below the limit of detection. Habit surveys have established that the most exposed group affected by disposals into the river are anglers whose occupancy of the river bank has been assessed to estimate their external exposures. No consumption of freshwater fish has been established, however the assessment has conservatively included consumption of fish at a low rate of 1 kg year $^{-1}$. The overall radiological significance of liquid disposals was very low: the radiation dose to anglers was much less than 0.005 mSv, which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

The concentrations of radioactivity in milk, vegetables, fruit and terrestrial indicator materials were also very low. Results for tritium, uranium and transuranic radionuclides were similar to those for 1998. The most likely source of the radionuclides detected was natural background or weapon test fallout. The dose in 1999, including contributions from the natural and fallout sources, was less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

7.2 Barrow, Cumbria

Whilst the site operated by Marconi Marine (VSEL) Ltd. at Barrow is not strictly a defence establishment, the small amounts of liquid radioactive wastes which are authorised for disposal to the Irish Sea are related to submarine activities and are therefore included in this section for completeness. Measurements of gamma dose rates and analyses of grass and of sediments collected near the outfall were made. The results, given in Tables 7.2(a) and (b), show no enhancement due to site activities above the background to be expected in the Irish Sea at this distance from Sellafield. The external dose to the most exposed group at the site was estimated to be 0.025 mSv, representing less than 3% of the principal dose limit for members of the public of 1 mSv. Most of this exposure was due to historic disposals from Sellafield.

7.3. Devonport, Devon

Disposals of liquid radioactive waste are made by Devonport Royal Dockyard Ltd. under authorisation and the Ministry of Defence under administrative agreement into the Tamar Estuary. The monitoring programme in 1999 consisted of a measurement of gamma dose rate and analysis of indicator materials. No seafood was available in 1999. The results given in Tables 7.2(a) and (b) were similar to those in 1998. A small amount of tritium activity was detected in grass. Trace quantities of fission and activation products and actinides were detected in the marine environment. The detection of iodine-131 is most likely to be related to its medical uses. The dose to the most exposed group taking account of consumption of marine foods and occupancy times was estimated to be 0.009 mSv which was less than 1% of the principal 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.

7.4 Faslane and Coulport, Argyll and Bute

Disposals of liquid radioactive waste into Gare Loch from Faslane (HMNB Clyde) and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from RNAD Coulport are made under letters of agreement between SEPA and the Ministry of Defence. The monitoring programme in 1999 was undertaken primarily to investigate external radiation pathways in Gare Loch. Caesium-137 concentrations were consistent with the distant effects of disposals from Sellafield and weapons testing and Chernobyl fallout. Gamma dose rates were difficult to distinguish from natural background (Table 7.2(b)). In 1999 the dose to the most exposed group from external radiation and the consumption of fish and shellfish was less than 0.005 mSv in 1999 which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

7.5 Greenwich, London

In order to monitor the potential effects of the small disposals of gaseous activity from the Royal Naval College (RNC) at Greenwich, grass is sampled and analysed by gamma spectrometry. In 1999, the results were all below the limits of detection and were within those expected due to the effects of weapon tests and Chernobyl fallout in the area. Therefore there was no detected impact in the environment due to the operation of the site in 1999.

Decommissioning of the JASON reactor in the King William building at RNC was completed in September 1999 and all relevant Approvals and Notifications relating to the site were revoked by the Environment Agency in November 1999. No further terrestrial sampling will be undertaken by the Food Standards Agency at this site.

7.6 Holy Loch, Argyll and Bute

A small programme of monitoring at Holy Loch continued in order to determine the effects of past disposals from the US submarine support facilities which closed in March 1992. Low levels of cobalt-60 detected in sediments from the Loch are due to these earlier operations. Measurements of gamma dose rates in intertidal areas were difficult to distinguish from natural background (Tables 7.2(a) and (b)). The external radiation dose to the most exposed group was 0.005 mSv in 1999 which was 0.5% of the principal dose limit for members of the public of 1 mSv.

7.7 Rosyth, Fife

Activities at Rosyth Royal Dockyard continued to give rise to disposals of liquid radioactive waste into the Firth of Forth. No discharges of gaseous radioactive waste were reported in 1999. All disposals were well within the authorised limits.

A habits survey was carried out during July 1999 by CEFAS . In addition to the aquatic pathway considered in the previous habits survey, pathways associated with gaseous discharges and direct radiation exposure were included. The assessments of the doses in 1999 uses the habits survey for aquatic pathways. Two potential critical pathways were identified, seafood consumption by local fishermen and external exposure over sediment to a member of the public using and maintaining boats.

There were no consignments of solid radioactive waste from the Rosyth Royal Dockyard since January 1999 following a general embargo placed by BNFL on MoD(N) waste. This was because carbon-14 was detected in solid radioactive waste from Devonport Dockyard at much higher levels than previously assumed from 'fingerprint' analyses conducted by MoD in the 1980's. Subsequent analysis of waste at Rosyth and elsewhere generally confirmed the Devonport findings. Consignment of waste to Drigg will not resume until BNFL are satisfied that past consignments of waste have been adequately re-assessed for carbon-14 and that assessment techniques for future consignments will fully account for all significant radioactivity.

The 1999 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 effects of Sellafield, weapons testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background. The dose to the most exposed group of local fishermen in 1999 was estimated to be less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

7.8 Vulcan NRTE, Highland

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

Table 7.1. Radioactivity in food and the environment near Aldermaston, 1999

Material	Location	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$
Aquatic samples								
Pike	Newbridge	1	<25	0.08	0.00020	0.00094	0.0016	*
Pike	Outfall (Pangbourne)	1	<25	0.50	0.00030	0.0025	0.0031	0.0000080
Pike	Shepperton	1	<25	0.27			<0.29	
Pike	Teddington	1	<25	0.19			<0.17	
Flounder	Becton	1	<25	0.21			<0.13	
Nuphar lutea	Newbridge	1	<25	<0.07			<0.06	
Nuphar lutea	Staines	1	<25	0.12			<0.12	
Clay[c]	Outfall (Pangbourne)	1		<0.18			<0.72	

Material	Location or selection[d]	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{137}Cs	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total alpha	Total beta	Total gamma
Terrestrial samples											
Milk	Near farms	4	<3.4	<0.34	<0.0073	<0.00011	<0.00019	<0.00019			
Milk	Near farms max		<3.8	<0.35		<0.00013	<0.00030	<0.00023			
Apples		1	<4.0	<0.40	<0.012	<0.00010	<0.00020	<0.00030			
Carrots		1	<6.0	<0.40	0.061	<0.00020	<0.00040	0.00010			
Figs/ Pears		1	<4.0	<0.50	<0.019	<0.00020	0.00020	<0.00030			
Honey		1	<7.0	<0.50	<0.0056	<0.00010	<0.00010	<0.00050			
Lettuce[e]		1	<4.0	<0.40	0.10	<0.00030	0.00040	<0.00080			
Marrow		1	<4.0	<0.40	<0.019	0.00040	0.00020	<0.00020			
Potatoes		1	<5.0	<0.40	0.030	<0.00020	<0.00030	0.00050			
Wheat		1	7.0	<0.40	<0.034	<0.00020	<0.00020	<0.00060			
Soil[f]		4			42						
Soil[f]	max				49						
Dry cloths		84							0.11	0.63	0.32

* *Not detected by the method used*

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

[b] *See section 3 for definition*

[c] *The concentration of total beta activity was 390 Bq kg^{-1}*

[d] *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.*

[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.041, <0.0015 and 0.046 Bq kg^{-1} respectively*

[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 11, 0.40 and 11 Bq kg^{-1} respectively*

Table 7.2(a). Radioactivity in food and the environment near naval establishments, 1999

Material	Location[b] or selection[c]		No. of sampling observ- ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
				^{3}H	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{106}Ru	^{124}Sb	^{125}Sb
Barrow											
Mud and sand	Walney Channel (Vickerstown Church)		4		<0.42	<0.57	14	<0.95	17	<0.92	<1.9
Grass	Barrow		2	<4.5							
Grass		max		<5.0							
Devonport											
Fucus vesiculosus[e]	Kinterbury		2		<0.37	<0.04	<0.04	<0.10	<0.33	<0.07	<0.09
Mud[h]	Kinterbury		2		<0.45	<0.50	<0.44	<1.0	<3.8	<1.1	<0.99
Grass	Devonport		4	<5.5			<0.43		<3.8		
Grass		max		7.0			<0.50		<3.9		
Faslane											
Mud and sand	Carnban boatyard		2		<0.18		<0.13		<0.73		<0.23
Seawater	Carnban boatyard		1	2.0							
Holy Loch											
Sand	Mid-Loch		1		<0.10		0.21		<0.56		<0.20
Sediment[f]	Sandbank		4		<0.13		0.69		<0.87		<0.25
Rosyth											
Crabs	East of dockyard		2		<0.10		<0.11		<0.76		<0.22
Fucus vesiculosus[g]	East of dockyard		2		<0.10		<0.10		<0.33		<0.12
Mud	Port Edgar		2		<0.15		<0.15		<1.2		<0.37
Mud and sand	West of dockyard		2		<0.11		<0.10	0.26	<0.78		<0.23
Mud and sand	Blackness Castle		2		<0.10		<0.10		<0.45		<0.14
Sand	Burntisland Bay		2		<0.10		<0.10		<0.51		<0.16
Sand	East of dockyard		2		<0.20		<0.10		<0.64		<0.21

Material	Location[b] or selection[c]		No. of sampling observ- ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
				^{131}I	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{241}Am
Barrow										
Mud and sand	Walney Channel (Vickerstown Church)		4	<3.0	<0.53	150	<4.0	<2.6	<2.2	220
Grass	Barrow		2							
Grass		max								
Devonport										
Fucus vesiculosus[e]	Kinterbury		2	0.43	<0.04	0.09	<0.20	<0.14	<0.11	<0.13
Mud[h]	Kinterbury		2	<1.9	<0.56	4.2	<1.9	<1.4	<1.6	0.16
Grass	Devonport		4		<0.40	<0.40	<1.9			
Grass		max					<2.1			
Faslane										
Mud and sand	Carnban boatyard		2		<0.10	8.3	<0.56	<0.14	<0.50	<0.62
Seawater	Carnban boatyard		1							
Holy Loch										
Sand	Mid-Loch		1		0.06	14	<0.53	<0.14	0.64	<0.26
Sediment[f]	Sandbank		4		<0.11	9.3	<0.78	<0.16	<1.0	<0.77
Rosyth										
Crabs	East of dockyard		2		<0.10	<0.15	<0.46	<0.12	<0.23	<0.18
Fucus vesiculosus[g]	East of dockyard		2	0.97	<0.10	0.36	<0.19	<0.10	<0.15	<0.16
Mud	Port Edgar		2		<0.13	32	<0.81	<0.21	<1.2	<0.96
Mud and sand	West of dockyard		2		<0.10	3.7	<0.52	<0.14	<0.49	<0.42
Mud and sand	Blackness Castle		2		<0.10	4.5	<0.35	<0.10	<0.24	<0.23
Sand	Burntisland Bay		2		<0.10	1.0	<0.42	<0.11	<0.25	<0.38
Sand	East of dockyard		2		<0.10	5.2	<0.52	<0.14	<0.48	<0.44

[a] *Except for sediment where dry concentrations apply, and for seawater where units are Bq l^{-1}*
[b] *Landing point or sampling area*
[c] *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. See section 3*
[d] *See section 3 for definition*
[e] *The concentration of ^{99}Tc was 0.35 Bq kg^{-1}*
[f] *The concentration of ^{139}Ce was <0.14 Bq kg^{-1}*
[g] *The concentration of ^{109}Cd was 0.26 Bq kg^{-1}*
[h] *The concentrations of ^{238}Pu, $^{239+240}Pu$ and $^{243+244}Cm$ were 0.019, 0.40 and 0.0049 Bq kg^{-1} respectively*

Table 7.2(b). Monitoring of radiation dose rates near naval establishments, 1999

Establishment	Location	Ground type	No. of sampling observations[a]	$\mu Gy\ h^{-1}$
Gamma dose rates at 1 m over intertidal areas				
Barrow	Walney Channel (Vickerstown church)	Mud and sand	4	0.087
Devonport	Kinterbury	Mud	1	0.073
Faslane	Gareloch Head	Mud, sand and stones	2	0.051
Faslane	Gulley Bridge Pier	Sand and stones	2	0.054
Faslane	Rhu	Gravel	2	0.050
Faslane	Rosneath	Sand and gravel	2	0.047
Faslane	Carnban boatyard	Mud and sand	2	0.056
Holy Loch	North Sandbank	Mud and sand	1	0.063
Holy Loch	Kilmun Pier	Sand and stones	1	0.068
Holy Loch	Mid-Loch	Sand	1	0.050
Rosyth	Blackness Castle	Mud and sand	2	0.053
Rosyth	Burntisland Bay	Sand	2	0.046
Rosyth	East of Dockyard	Sand	2	0.052
Rosyth	Port Edgar	Mud	2	0.056
Rosyth	West of Dockyard	Mud and sand	2	0.052

[a] *See section 3 for definition*

8. NYCOMED AMERSHAM PLC

This company manufactures radioactive 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 Harwell facility is being shut down and any environmental effects from it are covered by surveillance of the UKAEA operations on the same site.

8.1 Amersham, Buckinghamshire

Disposals 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. Disposals of gaseous wastes are also authorised. The monitoring programme consists of analysis of fish, milk, crops and indicator materials. Monitoring at Newbridge on the Thames acts as an indication of background levels in the catchment. Additional monitoring of non-food pathways is carried out by the Environment Agency.

The results are presented in Table 8.1. The concentration of carbon-14 in fish was typical of the background level and its radiological significance was low. Concentrations of a few radionuclides, e.g. cobalt-57 and zinc-65, were enhanced close to the outfall but their levels were very low. Tritium concentrations in biota in the Thames and the Grand Union Canal were close to or below the limit of detection.

The activity concentrations in milk and crops were generally lower than the limits of detection. However, low levels of tritium, sulphur-35 and iodine-125 were detected in a few samples.

Habits surveys have identified anglers as the most exposed group affected by disposals into the canal/river system. Their occupancy of the river bank has been assessed to estimate their external exposures. Consumption of freshwater fish was also considered but none was found. Nevertheless, 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 assumed. The anglers' dose in 1999 was much less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

The dose to the most exposed group of terrestrial food consumers was assessed as being 0.008 mSv which was 0.8% of the principal dose limit for members of the public.

8.2 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 Severn estuary via the sewer system. Disposals from the site are also made by Johnson and Johnson Clinical Diagnostics Ltd.

Monitoring, carried out on behalf of the National Assembly for Wales and the Food Standards Agency, includes consideration of consumption of food and external exposure over muddy, intertidal areas. Measurements of external exposure are supported by analyses of intertidal sediment. Indicator materials including seawater, *Fucus* seaweed, rape and dry cloths provide additional information.

The results of routine monitoring in 1999 are presented in Tables 8.2(a) and (b). The main effect of liquid disposals is seen in tritium and carbon-14 activities above those expected due to background. The relatively high levels of organically bound tritium (OBT) in local fish and shellfish continued to be found in 1999, but there were reductions in levels corresponding with reductions in discharges, although these reductions in discharges are mainly in the tritiated water component not the OBT. Further information on tritium levels in seawater and at other nuclear sites in the Bristol Channel can be found in Sections 6 and 11. Research and further sampling sponsored by the Food Standards Agency, the Environment Agency and Nycomed Amersham are underway to examine the mechanisms by which tritium becomes incorporated into biota in the marine environment. In 1999 additional sampling of tide washed pasture and ducks that feed in intertidal areas was undertaken. The results of the additional sampling are given in Table 8.2(c). Most of the samples showed elevated levels of tritium. The highest values found were in shelduck at about 61000 Bq kg^{-1} total tritium.

Concentrations of other radionuclides in aquatic samples were low and can be explained by other sources such as Chernobyl and weapon test fallout and disposals from other establishments. Gamma and beta dose rates over sediment, as measured using portable instruments, were difficult to distinguish from those expected from the natural background. The dose to the most exposed group of fish and shellfish consumers including external radiation was 0.053 mSv which was about 5% of the principal dose limit for members of the public of 1 mSv.

Exposures of hypothetical high-rate consumers of (i) duck and (ii) beef and milk from cows eating tide washed pasture, were conservatively estimated using the highest concentrations given in Table 8.2(c). The duck and tide washed pasture pathways gave doses of 0.032 and 0.009 mSv y^{-1} respectively. Given that maximum values for concentration have been used, and that consumption of these duck species is only hyperthetical, actual exposures through these pathways are likely to be less than 1% of the principal dose limit for members of the public.

The main effects of gaseous disposals were seen in results for tritium and carbon-14. Concentrations of tritium, organically bound tritium and carbon-14 were found to be higher in milk sampled from farms close to the site than from farms far from the site. When compared with data for other sites, relatively high concentrations of these nuclides were also detected in other terrestrial samples. Sulphur-35 and calcium-45 were also detected. The sources of these radionuclides are unclear and are being considered. All these measurements were of low radiological significance.

The maximum estimated dose from terrestrial food consumption was to the 1-year-old age group. The most exposed group received 0.015 mSv which was less than 2% of the principal dose limit for members of the public of 1 mSv. The largest contribution was from carbon-14 in milk.

Table 8.1. Radioactivity in food and the environment near Amersham, 1999

Material	Location	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{57}Co	^{58}Co	^{65}Zn	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Aquatic samples												
Pike	Newbridge	1	<25		<0.04	<0.06	<0.11	<0.04	0.08	0.00020	0.00094	0.0016
Pike	Outfall (Grand Union Canal)	1	34	19	<0.03	<0.06	0.28	0.05	0.24			<0.18
Pike	Shepperton	1	<25		<0.05	<0.08	<0.16	<0.06	0.27			<0.29
Pike	Teddington	1	<25		<0.03	<0.07	<0.14	<0.05	0.19			<0.17
Flounder	Becton	1	<25		<0.03	<0.05	<0.12	<0.05	0.21			<0.13
Nuphar lutea	Newbridge	1	<25		<0.04	<0.15	<0.21	<0.08	<0.07			<0.06
Nuphar lutea	Outfall (Grand Union Canal)	1	<25		0.16	0.27	0.55	<0.07	0.10			<0.05
Nuphar lutea	Staines	1	<25		<0.04	<0.09	<0.15	<0.06	0.12			<0.12
Mud[d]	Outfall (Grand Union Canal)	1			1.2	<0.46	4.6	<0.29	6.7			<0.27

Material	Location or selection[c]		No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
				^{3}H	^{35}S	^{75}Se	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples													
Milk	Near farms		2	<3.2	<0.64	<0.41	<0.033	<0.030	<0.30	<0.33			
Milk	Near farms	max		<3.3	0.77	<0.50	<0.043	<0.038	<0.40	<0.40			
Beetroot			1	<4.0	<0.60	<0.40	<0.12		<0.40	<0.40			
Cabbage			1	<4.0	<0.20	<0.40	<0.057		<0.40	<0.40			
Carrots			1	<4.0	0.30	<0.60	<0.097		<0.50	<0.50			
Courgettes			1	<4.0	1.0	<0.30	<0.089		<0.30	<0.30			
Runner beans			1	<4.0	<0.30	<0.40	0.15		<0.30	<0.40			
Strawberries			1	<4.0	0.40	<0.70	<0.22		<0.50	<0.40			
Wheat			1	11	7.4	<0.40	<0.50		<0.30	<0.40			
Dry cloths			66								0.15	0.85	0.36

[a] *Except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *See section 3 for definition*
[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. See section 3 for definition*
[d] *The concentration of total beta activity was 290 Bq kg^{-1}*

Table 8.2(a). Radioactivity in food and the environment near Cardiff, 1999[d]

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H (organic)	^{3}H[e]	^{14}C	^{131}I	^{134}Cs	^{137}Cs	^{155}Eu
Aquatic samples									
Flounder	East of new pipeline	3	16000	23000	450	<0.22	<0.06	0.34	<0.11
Sole	East of new pipeline	1		17000	500	*	<0.06	0.26	<0.17
Cod	East of new pipeline	1		33000	700	*	<0.06	0.40	<0.15
Winkles	Orchard Ledges	1	3900	4000	260				
Mussels	Orchard Ledges	3	20000	26000	580	*	<0.16	0.47	<0.37
Fucus vesiculosus	Orchard Ledges	2			21	3.0	<0.05	0.33	<0.12
Mud	Orchard Ledges East	1			23	<4.1	0.59	20	<1.0
Mud and sand	Orchard Ledges East	1			12	*	<0.43	12	2.5
Lugworm	Orchard Ledges East	1	22000	16000	230				
Sea water	Orchard Ledges	2		10					
Sea water	Orchard Ledges East	2		9.2					

Material	Location[b] or selection[c]		No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
				^{3}H (organic)	^{3}H[e]	^{14}C	^{32}P	^{35}S	^{45}Ca	^{125}I	^{134}Cs	^{137}Cs
Terrestrial samples												
Milk	Near farms		5	<24	<45	24	<0.34	<0.62	<0.33	<0.031	<0.29	<0.32
Milk	Near farms	max		51	88	29	<0.36	<0.88	<0.35	<0.035	<0.30	<0.33
Milk	Far farms		1	<4.6	<6.6	17		<0.66	<0.34	<0.033	<0.28	<0.33
Milk	Far farms	max		<5.2	<7.0			<0.73	<0.35			<0.35
Apples			1	<14	9.0			0.10				
Barley			1		29	67		7.6	1.5	<0.40	<0.30	<0.40
Blackberries			1	7.0	33	21		<0.80	0.60	<0.32	<0.40	<0.40
Broad beans			1	<4.0	<4.0			0.80				
Honey			1		47	89		<0.40	0.30	<0.050	<0.20	<0.20
Kale			2	<4.5	<8.0	19		<1.8	5.9	0.18	<0.20	<0.20
Kale		max		5.0	12			2.7				
Potatoes			1	<10	6.0	19		<0.40	<0.20	<0.11	<0.20	<0.20
Rape			1	<12	5.0			4.7				
Rape oil			1		38	200		6.1	3.4	<0.26	<0.50	<0.50
Raspberries			1	2.0	4.0			0.50				
Strawberries			1	<4.0	<4.0	9.0		0.20	<0.20	0.16	<0.30	<0.40
Swede			1	2.0	88	16		0.40	0.90	<0.31	<0.40	<0.40
Turnips			1	3.0	14			2.0				

* *Not detected by the method used*
[a] *Except for milk and sea water where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *Landing point or sampling area.*
[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. See section 3 for definition.*
[d] *96 dry cloths were analysed. The concentration of alpha, beta and gamma activity was 0.16, 0.57 and 0.34 Bq per cloth respectively*
[e] *Total ^{3}H*

Table 8.2(b). Monitoring of radiation dose rates near Cardiff, 1999

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Orchard Ledges East	Mud	2	0.077
Beta dose rates			µSv h^{-1}
Orchard Ledges East	Mud	2	0.079

[a] *See section 3 for definition*

Table 8.2(c). Additional sampling near Cardiff, 1999

Sample		No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			Organic ^{3}H	^{3}H[d]
Curlew		1	16000	20000
Duck		4	2300	2400
	max		7100	7500
Duck		4	9400	9500
	max		15000	15000
Pintail		1	4900	11000
Shelduck		6	24000	33000
	max		42000	61000
Teal		3	1500	1700
	max		2400	2700
Grass		1		25
Grass		1		1400
Grass		1		40
Grass		1		280
Grass		1		550
Grass		1		2000
Grass		1		540
Grass		1	140	250
Grass		1	130	260
Grass		1	120	180
Grass		1	130	290
Grass		1	200	230
Grass		1	210	320
Grass		1	150	200
Grass		1	170	280
Grass		1	73	170
Grass		1	170	280
Grass[c]		1	<3.0	<3.0
Grass[c]		1	<4.0	4.0
Grass[c]		1	<3.0	<3.0
Grass[c]		1	4.0	9.0
Grass[c]		1	5.0	8.0
Grass[c]		1	2.0	5.0
Grass[c]		1	3.0	5.0
Grass[c]		1	7.0	9.0
Grass[c]		1	<3.0	<3.0
Grass[c]		1	8.0	10
Soil		1		19
Soil		1		60
Soil		1		18
Soil		1		33
Soil		1		40
Soil		1		60
Soil		1		21
Sediment		1		290
Sediment		1		95
Sediment		1		2500

[a] *Except for sediment and soil where dry concentrations apply.*
[b] *See section 3 for definition.*
[c] *Sampled from the English side of the Bristol Channel. Other samples collected in Wales near Cardiff.*
[d] *Total* ^{3}H.

9. MINOR SITES

Four minor sites with very low levels of discharge are monitored using a small programme of sampling indicator materials. The results, given in the following sub-sections, show that there was no detected impact on the environment in 1999 due to operation of these sites.

9.1 Imperial College Reactor Centre, Ascot, Berkshire

Two grass samples were analysed by gamma spectrometry. All results in 1999 were less than the limits of detection.

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. All results in 1999 were less than the limits of detection.

9.3 Rolls Royce Marine Power Operations Ltd., Derby, Derbyshire

Results of monitoring at Derby are presented in Table 9.1. The operator became Rolls Royce Marine Power Operations Ltd. with effect from 15 January 1999. Uranium activity detected in grass and soil samples was similar to levels in 1998. Isotopic analysis of the soil samples confirmed that the activity was not enriched in uranium-235. The activities detected are therefore due to natural sources.

9.4 Scottish Universities' Research Reactor Centre, South Lanarkshire

The small research reactor at this site has now ceased operation. The reactor has been defuelled and the fuel removed from the site for storage. Decommissioning plans are advancing, and applications have been made to SEPA under RSA 93 for authorisations relating to decommissioning waste. Disposals of small amounts of liquid radioactive wastes to sewerage systems still occurprimarily from research laboratories. The only monitoring carried out is that performed by the operator.

Table 9.1. Radioactivity in the environment near Derby, 1999

Material	No. of samples	Mean radioactivity concentration, Bq kg^{-1}			
		Total U	^{234}U	^{235}U	^{238}U
Grass[a]	4	0.13			
Grass[a]	max	0.30	0.094	0.0040	0.087
Soil[b]	4	66			
Soil[b]	max	82	34	1.3	31

[a] *Fresh weight*
[b] *Dry weight*

10. INDUSTRIAL AND LANDFILL SITES

10.1 Rhodia Consumer Specialties Ltd., Whitehaven, Cumbria

In view of the radiological importance of natural radionuclides to fish and shellfish consumers (Pentreath *et al.,* 1989; Rollo *et al*., 1992; Camplin *et al*., 1996), a small programme of monitoring for these radionuclides in the United Kingdom marine environment has continued. Previous surveys (Rollo *et al.,* 1992) have established that an important man-made source was the Rhodia Consumer Specialties Ltd. (formerly Albright and Wilson) chemical plant at Whitehaven in Cumbria which has manufactured phosphoric acid from imported phosphate ore. Phosphogypsum, a waste product of this process, has been discharged as a liquid slurry by pipeline to Saltom Bay. The radioactive waste disposals are authorised by the Environment Agency and contain low levels of natural radioactivity consisting mainly of thorium, uranium and their daughter products. Discharge rates during 1999 continued at the low rates attained since the introduction of changes in waste treatment techniques and the cessation of use of phosphate ore in 1992.

The results of monitoring for natural radioactivity near the site in 1999 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 1989, 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 slightly less than those in 1998 (MAFF and SEPA, 1999). Concentrations of all natural radionuclides were difficult to distinguish from natural levels.

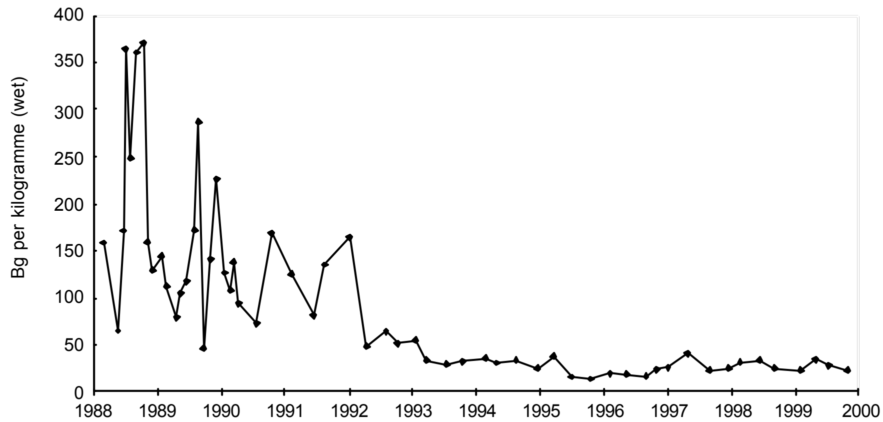

Figure 10.1 Polonium-210 in Parton winkles

The critical radiation exposure pathway is internal irradiation, due to the ingestion of natural radioactivity in local fish and shellfish. In this assessment, the contribution due to background levels of natural radionuclides has been subtracted. The most exposed group consists of people who consume seafood collected from Saltom Bay and Parton. This group is distinct from the group associated with commercial fisheries at Whitehaven discussed in section 4. Consumption rates were reviewed in 1999 but no changes to fish and shellfish data were made. The dose to the most exposed group in 1999 was 0.30 mSv on the basis of the current generic ICRP advice for a gut transfer factor of 0.5 for polonium. This value is to be applied in the absence of specific information.

10. Industrial and landfill sites

As discussed in Section 3.6.4, 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 also been calculated using the conservative assumption that the value of 0.8 applies to the total intake of polonium. These data indicate that the most exposed group dose has slightly decreased from 0.49 mSv in 1998 (MAFF and SEPA, 1999) to 0.47 mSv in 1999. It is worth noting that this level is an upper estimate for two reasons. Firstly it is based on the application of a relatively high gut transfer factor of 0.8 to all species, whereas the experimental evidence is limited to crabs. Secondly, there is limited information on the normal background levels of natural radionuclides in seafood. In view of the uncertainty we have chosen low values in order to ensure that the assessment of local enhancements of these nuclides is not underestimated. It is entirely plausible that the actual dose received is an order of magnitude less than the estimate above.

The fish and shellfish consumed by the most exposed group also contains artificial radionuclides due to Sellafield disposals. The additional exposure due to artificial radionuclides has been calculated using data from Section 4. In 1999 these exposures added a further 0.064 mSv to the doses above resulting in a total dose to this group of up to 0.54 mSv. The estimated doses in 1999 are therefore well within the principal 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 1999 six sites were chosen for study:

- Avonmouth, Avon (clinical waste incinerator)
- Basildon, Essex (hospital)
- Billingham, Cleveland (manufacture of radiochemicals)
- Plymouth, Devon (clinical waste incinerator)
- Redcar, Cleveland (steel works)
- Welwyn Garden City, Hertfordshire (manufacture of radiochemicals)

The results of the sampling of grass, soil and animals in 1999 are given in Table 10.2.

There is considerable variability in the normal concentrations of natural radionuclides in the terrestrial environment. It is therefore difficult to draw firm conclusions about the effects of man-made sources of radionuclides that can enhance normal concentrations. With this proviso and with one exception, we conclude that in 1999 the concentrations of such radionuclides in grass and soil at most sites were within the ranges expected for natural sources.

The exception was Billingham in Cleveland. Both the tritium and carbon-14 concentrations in grass were well above those expected due to background sources. The sampling at Billingham was directed towards a manufacturer of radiochemicals, Blychem Ltd. However, it should be emphasised that there are several other industrial sites in the area that are authorised to dispose of gaseous radioactive wastes including tritium and carbon-14. These include: Air Products where the radioactivity comes from traces in chemical production; two ICI plants, one being a chemicals & polymers plant and the other an acrylic plant; Synetix an analytical services centre which now has stopped working with radioactivity; Terra Nitrogen Ltd. another plant where the radioactivity comes from traces in chemical production; and Thomas Swan and sons manufacture of radiochemicals.

Bleychem Ltd. are authorised to discharge 2.4 and 0.26 TBq y^{-1} of gaseous tritium and carbon-14 respectively. Modelling suggests that it is highly unlikely that the discharges from Blychem alone could account for these elevated levels of radionuclides. Further sampling is being undertaken in the area in 2000.

The grass samples were taken within 500 m of the Blychem discharge point. No known food production is carried out within 2 km of the discharge point. By extrapolation, and assuming Blychem is the source of the contamination (a highly unlikely event), a reduction of more than an order of magnitude would be expected at 2 km in any enhancement of tritium or carbon-14 above background levels due to other sources. On this basis, and assuming conservatively that the concentrations of tritium and carbon-14 in food produced 2 km from the site would have the same specific activity as grass, we estimate that high-rate consumers would have received a dose of 0.094 mSv in 1999 which was less than 10% of the principal dose limit for members of the public of 1 mSv. 98% of this is due to the carbon-14 content of the food. The four sites sampled near the Blychem site in Billingham have been re-sampled during 2000. Preliminary results for these samples average less than half the levels found in 1999.

The concentrations of other radionuclides in all other samples were all low and of negligible radiological significance. Estimated doses from consumption of rabbit sampled near the industrial 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 very low levels of radioactivity to approved landfill sites. In addition waste with very limited radioactivity can be disposed of in general refuse. Radioactivity in wastes can migrate into leachate, and in some cases can enter the groundwater. Monitoring of leachates in England and Wales is carried out by the Environment Agency (Environment Agency, 1999). In Scotland, monitoring is undertaken by SEPA and the results are presented in Table 10.3. The results show very low levels of carbon-14 and caesium-137 in leachate, in common with data for sites in England and Wales. In 1999 a more detailed survey of Ness Tip in Aberdeen was carried out due to its impending closure. Inadvertent ingestion of leachate (2.5 l y^{-1}) at the highest concentration of tritium observed, would result in a dose of 0.001 mSv which was 0.1% of the principal annual dose limit for members of the public of 1 mSv.

Table 10.1. Natural radioactivity in fish, shellfish, seaweed and sediment, 1999

Material	Location[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			^{210}Po	^{210}Pb	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Rhodia Consumer Specialties Ltd, Whitehaven											
Winkles	Saltom Bay	4	21	2.5							
Winkles	Parton	4	26	3.7	0.050	1.1	1.8	0.72	1.8	0.080	1.7
Winkles	North Harrington	1	31								
Winkles	Fleswick Bay	3	17								
Winkles	Nethertown	4	17	2.6							
Winkles	Drigg	4				0.47	0.66	0.32			
Winkles	Tarn Bay	1	12								
Mussels	Parton	2	53	3.2							
Mussels	Nethertown	4	47	3.1							
Whelks	Sellafield offshore Area	1	4.2								
Crabs	Parton	4	26	0.17		0.073	0.013	0.0074	0.073	0.0029	0.070
Crabs	St Bees	2	17	0.30							
Crabs	Sellafield coastal area	4	13	0.12							
Lobsters	Parton	4	14	0.21		0.066	0.033	0.011	0.045	0.0019	0.039
Lobsters	St Bees	2	14	0.050							
Lobsters	Sellafield coastal area	2	26								
Cod	Parton	3	0.77	0.018		0.025	0.0049	0.0030	0.010	0.00030	0.0090
Dab	Whitehaven	1	1.9								
Other samples											
Shrimps	Ribble Estuary	2			0.067	0.012	0.022	0.0052			
Mussels	Portishead	1	19	1.4							
Cockles	Southern North Sea	2				0.38	0.20	0.25			
Limpets	Kirkcudbright	1	10								
Porphyra	Portishead	1	0.95	0.55							
Mud and sand	Ribble Estuary	1			19	10	12	7.2			

[a] *Landing point or sampling area*
[b] *Except for sediment where dry concentrations apply*
[c] *See section 3 for definition*

Table 10.2 Radioactivity in food and the environment near industrial sites, 1999

Site	Material	No. of samples	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{7}Be	^{14}C	^{40}K	^{134}Cs	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	^{238}Pu	^{239}Pu+ ^{240}Pu
Avonmouth, Avon	Grass[b]	4			60		<0.27	<0.37	7.6	4.3	0.22	0.035	<0.00013	<0.00038
	Soil	4		<4.1		470	<0.73	13	55	62	34	15	0.018	0.30
	Rabbit	2		<1.7		100	<0.19	<0.18	0.018	0.028	0.015	<0.0017	<0.00029	<0.00017
Basildon, Essex	Grass[c]	4		52		120	<0.12	<0.21	4.3	1.7	0.36	0.26	<0.00029	<0.00022
	Soil	4		<3.7		600	<0.47	8.0	33	28	20	18	<0.0090	0.18
Billingham, Cleveland	Grass	4	400	53		190	<0.21	<0.20	3.8	1.5	0.18	0.032	<0.00016	<0.00035
	Soil	4		<3.8		410	<0.60	9.9	33	32	26	14	<0.014	0.19
	Rabbit	1		<1.7		100	<0.19	<0.19	0.040	0.051	0.020	0.0037	<0.000091	<0.00017
Plymouth, Devon	Grass[d]	4			44	200	<0.19	<0.17	5.4	2.7	0.33	0.12	<0.00027	<0.00087
	Soil	4		<4.2		830	<0.64	10	36		33	17	0.020	0.29
	Rabbit	1		<1.5		90	<0.16	0.26	0.010	0.025	0.011	<0.0011	<0.00024	<0.00014
Redcar, Redcar & Cleveland	Grass	3		83			<0.20	<0.18	9.0	7.0	0.22	0.060	<0.00038	0.00057
	Soil	3		<3.4		310	<0.45	6.1		28	23	16	<0.0077	<0.092
Welwyn, Hertfordshire	Grass[e]	4		59	41	180	<0.23	<0.62	3.2	3.2	0.60	0.66	<0.00052	<0.0053
	Soil	4		<4.4		370	<0.52	8.9	26	24	19	17	<0.011	0.20

[a] *except for soil where dry concentrations apply*
[b] *Concentrations of <9.4, <0.053 and <1.1 Bq kg^{-1} (wet) of ^{123}I, ^{125}I and ^{131}I were also detected in this sample*
[c] *Concentrations of <3.9 and <3.2 Bq kg^{-1} (wet) ^{99m}Tc and ^{131}I were also detected in this sample*
[d] *The concentration of ^{131}I was <0.85 Bq kg^{-1}*
[e] *Concentrations of 3.1 and <0.043 Bq kg^{-1} (wet) ^{35}S and ^{125}I were also detected in this sample*

Table 10.3. Radioactivity in surface water leachate from landfill sites in Scotland, 1999

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{40}K	^{137}Cs
Aberdeen City	Ness Tip	1	140	<15	2.7	<0.050
Aberdeen City	Ness Tip (Pond)	1	<25	<0.3	<0.6	<0.050
Aberdeen City	Ness Tip (SP1)	1	94	<0.3	1.5	<0.050
Aberdeen City	Ness Tip (Outfall SP 2)	1	570	<0.3	5.9	<0.050
Aberdeen City	Ness Tip (SP3)	1	3800	<0.3	<0.5	<0.050
Aberdeen City	Ness Tip (Pond)	1	120	0.50	0.64	<0.050
Aberdeen City	Ness Tip (WM2)	1	2400	0.31	15	<0.050
Aberdeen City	Ness Tip (WM1)	1	1200	0.35	7.6	<0.050
Aberdeen City	Ness Tip (WM6)	1	<25	0.34	5.0	<0.050
Aberdeen City	Ness Tip (WM8)	1	12000	0.58	11	<0.050
Aberdeen City	Ness Tip (Outfall SP2)	1	1400	0.41	10	<0.050
City of Edinburgh	Braehead	1	<25	<15	0.90	<0.050
City of Glasgow	Summerston Tip	1	280	<15	5.6	<0.050
Clackmannanshire	Black Devon	1	<25	<15	<0.64	<0.050
Dundee City	Riverside	1	<25	<15	5.4	0.077
East Dunbartonshire	Birdston Tip	1	<25	<15	<0.42	<0.050
Fife	Balbarton	1	79	<15	3.1	<0.050
Fife	Melville Wood	1	77	<15	18	<0.050
Highland	Longman Tip	1	<25	<15	<0.60	<0.050
North Lanarkshire	Dalmacoulter	1	71	<15	5.5	<0.050
North Lanarkshire	Kilgarth	1	<25	<15	<0.60	0.070
Stirling	Lower Polmaise	1	110	<15	12	0.21

11. CHERNOBYL AND REGIONAL MONITORING

11.1 Chernobyl

The programme of monitoring in relation to the effects of fallout from this accident has continued in 1999 with surveillance of sheep and indigenous freshwater fish. Radiocaesium is detected in sheep grazing certain upland areas in the United Kingdom which were subjected to heavy rainfall after the Chernobyl accident in 1986. Restrictions are in place on the movement, sale and slaughter of sheep from these areas in order to prevent animals from entering the food chain above the action level of 1000 Bq kg^{-1} of caesium; a level that was recommended by an EU expert committee in 1986.

In the summer of 1999, intensive monitoring surveys of parts of the post-Chernobyl restricted areas of Cumbria and Scotland were carried out. The results of the surveys enabled controls to be lifted on 2 farms in Cumbria. This leaves 388 farms or parts of farms and approximately 230,000 sheep within the restricted areas of England, Scotland and Wales. These areas are identified in Figures 11.1 to 11.3. This represents a reduction of 96% since 1986 when approximately 8900 farms were under restriction.

In addition, the radiocaesium monitoring of sheep carcasses at slaughter houses has continued in England and north Wales to ensure that continuing restrictions are adequate. The mean result of samples analysed in 1999 was 37 Bq kg^{-1} and the highest result was 320 Bq kg^{-1}. Further information and results have been published by MAFF (MAFF and DoH, 2000) and the Scottish Executive (Scottish Executive, 2000).

In Northern Ireland, the remaining restricted farms in the Glenshane and Belrough areas of County Londonderry were monitored during summer 1999 (Figure 11.4). Since the results were well below the action level, restrictions were removed from the 45 affected farms on 24 March 2000 (Department of Agriculture and Rural Development, 2000).

Sampling locations for freshwater fish were mostly in areas of relatively high deposition of fallout from Chernobyl, namely Cumbria and Scotland. 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. Artificial radionuclides, other than those of radiocaesium were, in 1999, no longer detectable from the Chernobyl accident. Concentrations of radiocaesium in freshwater fish varied between locations, reflecting the areas of deposition of radioactivity from Chernobyl and the small sampling programme. Concentrations in all species were less than 1000 Bq kg^{-1}, the level attained shortly after the accident. Where there are data for the same species and locations to compare with results for 1998 there are likely to be large statistical fluctuations because of the small sampling programme, but concentrations of radiocaesium were generally similar in 1999 to those in 1998.

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously (MAFF and SEPA, 1999). A consumption rate of brown trout 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 of much lower radiocaesium concentration may contribute to the diet. In 1999, estimated doses were less than 0.15 mSv.

11.2 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 monitoring of aquatic foodstuffs are presented in Section 4 and Tables 4.1-4.3.

Radioactivity monitoring of terrestrial foods 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

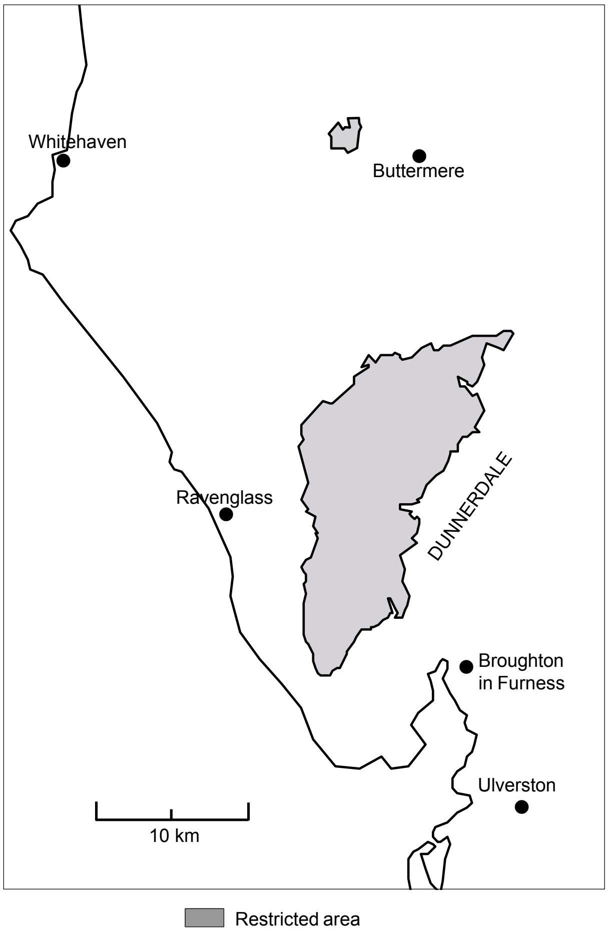

Figure 11.1. ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - England***

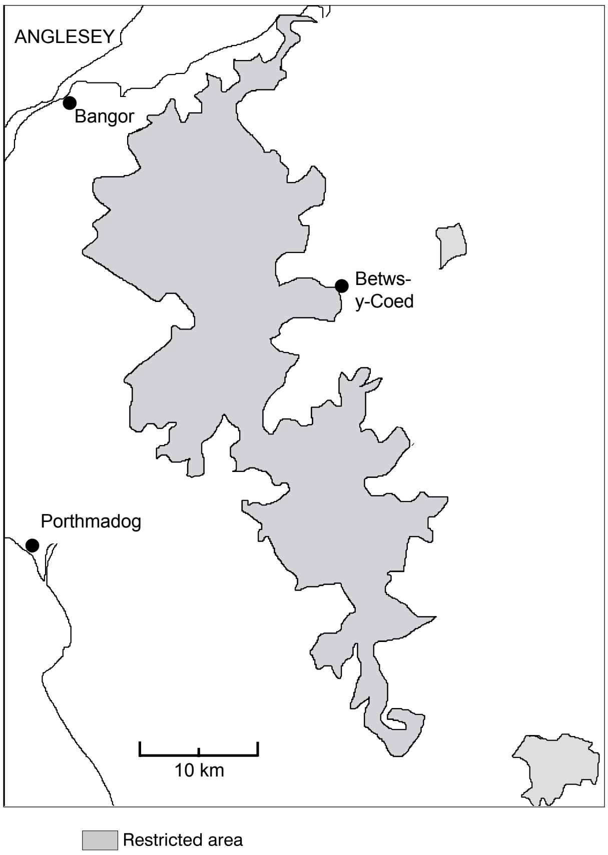

Figure 11.2. ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Wales***

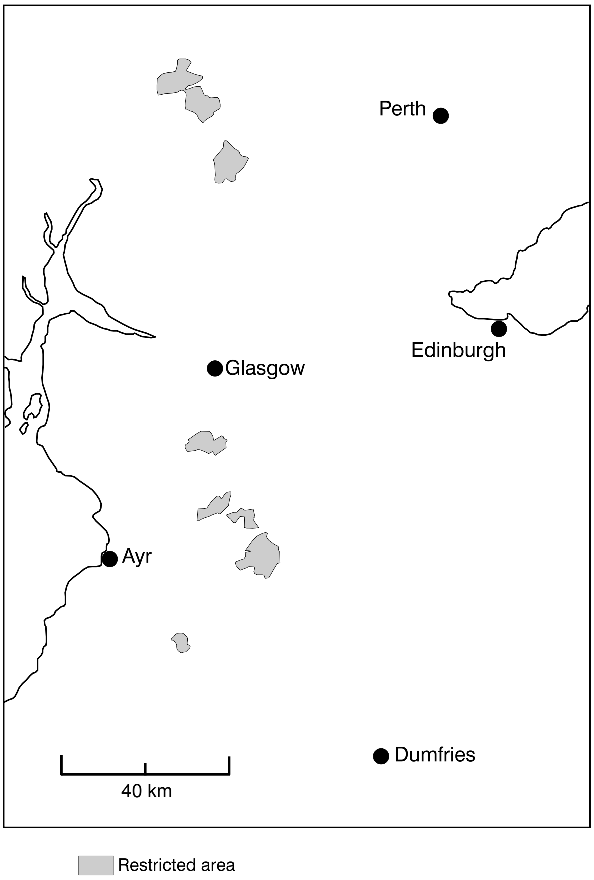

Figure 11.3. ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Scotland***

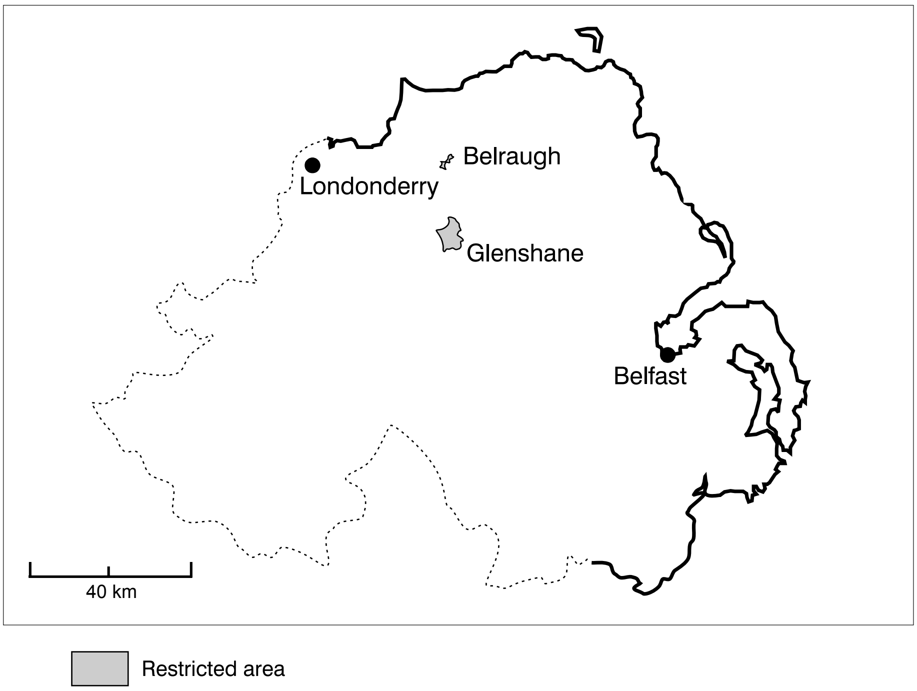

Figure 11.4. ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Northern Ireland (All restrictions were lifted in Northern Ireland from 24 March 2000)***

exposure from the United Kingdom nuclear industry are: (i) liquid disposals into the Irish sea and sea-to-land transfer; and (ii) gaseous disposals of tritium, carbon-14 and sulphur-35 and atmospheric transport.

The results of monitoring for 1999 are presented in Table 11.2. 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 similar 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 United Kingdom 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 agriculture from operation of mainland nuclear installations in 1999.

These data are similar to results obtained in previous years. The dose to the most exposed group from consumption of Manx foodstuffs monitored in 1999 was 0.021 mSv which was around 2% of the principal dose limit for members of the public of 1 mSv.

11.3 Channel Islands

Marine environmental samples provided by the Channel Island States have continued to be analysed. The programme monitors the effects of radioactive disposals from the French reprocessing plant at Cap de la Hague and the power station at Flamville; it also serves to monitor any effects of historical disposals of solid 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 1999 are given in Table 11.3. 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. However, no evidence for release of activity from the Hurd Deep site was found.

An assessment of the most exposed group of high-rate fish and shellfish consumers gives a dose of 0.006 mSv in 1999 which was 0.6% of the principal 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 therefore continued to be of negligible radiological significance.

11.4 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 United Kingdom. In England and Wales the samples are derived from the Food Standards Agency's Total Diet Study (TDS). The TDS uses mixed diets that are representative samples of all types of food, for which the consumption rates are well defined by national statistics. Each diet is prepared as for consumption, and combined in amounts that reflect their relative importance in the average United Kingdom diet. These samples are analysed for a range of food components including radioactivity. The results for the measurements of radioactivity are presented here. 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 1999. The results are provided in Tables 11.4 and 11.5.

All of the results for man-made radionuclides were low and of little radiological significance. Caesium-137 and actinide concentrations were below or close to the limit of detection and were similar to levels in previous years. Tritium concentrations were also low, indeed lower than those for 1998 which were enhanced due to suspected contamination during analysis (NRPB, 1999b). Concentrations of sulphur-35 were generally higher than in 1998, and strontium-90 correspondingly lower. We have no explanation for these changes. However they are of low radiological significance.

Exposures as a result of consuming diet at average rates at the concentrations given in Tables 11.4 and 11.5 have been assessed for adults, infants and 15 and 10-year-old children. In all cases the exposures of infants were higher than other age groups. The data are summarised in Table 11.6. 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 0.004 mSv. Similar doses were estimated for 1998 (MAFF and SEPA, 1999).

The mean dose due to consumption of natural radionuclides was 0.19 mSv, which is significantly less than the mean dose in 1998 of 0.31 mSv. As for 1998, the most important radionuclides were lead-210 and polonium-210. However, in 1999 the average activity of lead-210 was 0.13 Bq kg^{-1} which was less than half of the level found in 1998 of 0.29 Bq kg^{-1}. In 1995 - 1997 the range of average levels of lead-210 in TDS was 0.018 - 0.049 Bq kg^{-1}. Significant contributions would also have been made by other members of the uranium-238 and thorium-232 decay series that were not determined in this year's analytical schedule. Further data for these nuclides is provided by MAFF (1995). Nevertheless it remains true that the results demonstrate that natural radionuclides are by far the most important source of exposure in the average diet of consumers.

11.5 Milk

The programme of milk sampling in the United Kingdom continued in 1999. Samples were collected monthly and analysed for natural and man-made radionuclides. The programme, together with that for crops presented in the following sub-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. The data from this programme is supplied to the European Commission as part of the requirements under the EURATOM treaty (e.g. JRC, 1996).

Where measurements are comparable, detected activity concentrations of all radionuclides in 1999 were similar to those for previous years. These results are summarised in Table 11.7. Sulphur-35, iodine-129, uranium and plutonium results were either very close to or below their respective limits of detection. Results for tritium were generally close to or below the limit of detection and similar to the value detected in rain of 4.8 Bq l^{-1} (Playford *et al*., 1995). Raised values of 23 and 10 Bq l^{-1} were found at Tyneside and Shropshire respectively. Mean and maximum values for carbon-14 from all dairies were similar and at expected background levels. The concentration of strontium-90 was less than 0.04 Bq l^{-1}, which is in good agreement with results from other surveillance studies (Welham *et al.*, 1996; Hammond *et al*., 2000).

The levels of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout. The results were in reasonable agreement with those from the NRPB surveillance programmes for 1993-4 which showed mean levels in England and Wales of 0.03 and 0.02 Bq l^{-1} respectively, Scotland 0.07 Bq l^{-1} and those in Northern Ireland to be 0.09 Bq l^{-1} (Welham *et al.,* 1996). Similarly for 1995-6 the mean levels were 0.04 and 0.05 Bq l^{-1} for England and Wales, respectively, 0.08 Bq l^{-1} for Scotland and 0.13 Bq l^{-1} for Northern Ireland. In 1996 the NRPB discontinued the collection of milk from creameries (Hammond *et al*., 2000)

The assessed doses from consumption of dairy milk at average rates were highest to the one-year-old infant age group. For the full range of radionuclides analysed, the average dose was 0.041 mSv that was dominated by the presence of the natural radionuclides lead-210 and polonium-210. Man-made radionuclides contributed less than 5% to these exposures.

11.6 Crops, bread and meat

The programme of monitoring natural and man-made radionuclides in crops continued in 1999 (Table 11.8). Tritium activity was close to or below the limit of detection in all samples. The activities of carbon-14 detected in crop samples were those expected from consideration of background sources. The concentrations of other radionuclides in crops were similar to those observed in 1998.

Sampling of bread and meat continued in Scotland in 1999. The results, presented in Tables 11.9 and 11.10, 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 1998 (MAFF and SEPA, 1999).

11.7 Fresh water and air particulates

Sampling and analysis of fresh water throughout Scotland continued in 1999. Analyses of tritium, strontium-90, caesium-137 and total alpha and beta activity were undertaken. The results, in Table 11.11, are similar to those found in England and Wales (DETR, 1998). The observed concentrations were observed to be at the low levels of recent years (MAFF and SEPA, 1999). An assessment of the dose to high-rate consumers on the basis of the highest concentrations observed gave an estimated dose of less than 0.001 mSv in 1999.

Air particulates continued to be sampled at Glasgow. The results for beta activity were <2.0 mBq m^{-3} and are largely dominated by fallout from weapons testing and natural radioactivity in the air.

11.8 Seawater surveys

Seawater surveys support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 1993b) 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 large factor in determining the variation in individual exposures at coastal sites, as this is a major contribution to the food chain. Therefore a programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling. Detailed historical data on radiocaesium in seawater have been published in a series of reports to aid model development (Camplin and Steele, 1991; Baxter *et al.,* 1992; Baxter and Camplin 1993(a-c)) and have been used to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). Data have also been used to examine the long distance transport of activity to the Arctic (Leonard *et al,* 1998; Kershaw *et al*, 1999b). The research vessel programme on radionuclide distribution currently comprises cruises in the Irish Sea, Scottish waters and the North Sea every two or three years. The results of the 1999 cruises are presented in Figures 11.5 - 11.7. Data from shoreline sampling in the Irish Sea and Scottish waters in 1999 are given in Table 11.12.

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 50-500 mBq kg^{-1} and 2-20 mBq kg^{-1} respectively. The 1999 data for the Irish Sea show similar levels to those observed from sampling in recent years, the general distribution being one of falling concentrations as the distance from Sellafield increases. This distribution is governed by recent disposals from the Sellafield site and the effects of activity previously discharged which had become associated with seabed sediments but is now being remobilised into the water column. The concentrations now observed are only a small percentage of those prevailing in the late 1970s, typically up to 30,000 mBq kg^{-1} (Baxter *et al.,* 1992), when disposals were substantially higher.

The concentrations of tritium observed in the Irish Sea (Figure 11.7) were higher than those observed in the North Sea (MAFF and SEPA, 1999) due to the influence of discharges from Sellafield. In the Bristol Channel, the extent of the combined effects of discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is evident (Figure 11.6).

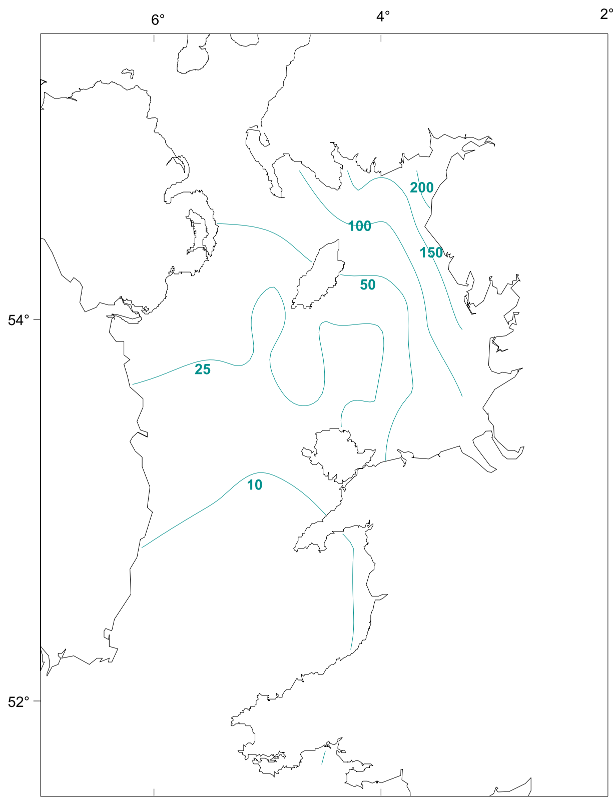

Figure 11.5 ***Concentrations (mBq kg^{-1}) of caesium-137 in filtered surface seawater from the Irish Sea, September 1999***

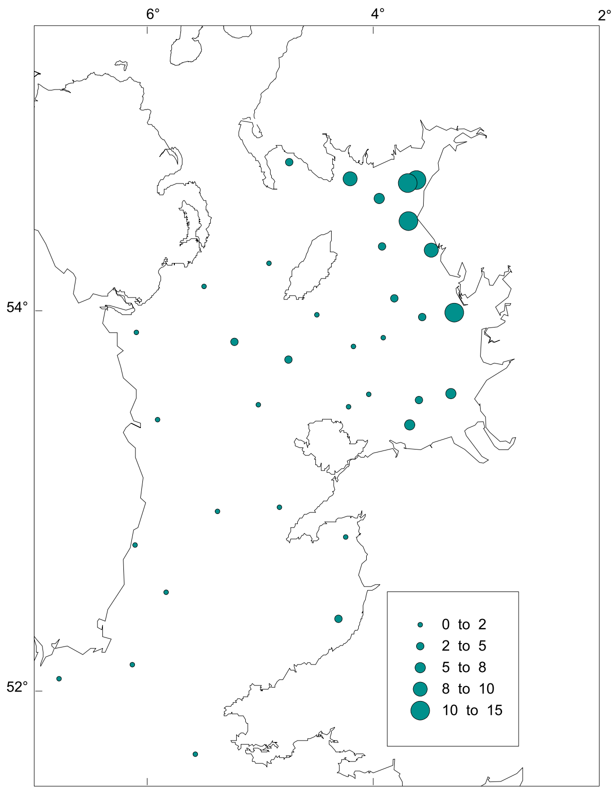

Figure 11.7 ***Concentrations (Bq kg^{-1}) of tritium in surface seawater from the Irish Sea, September 1999***

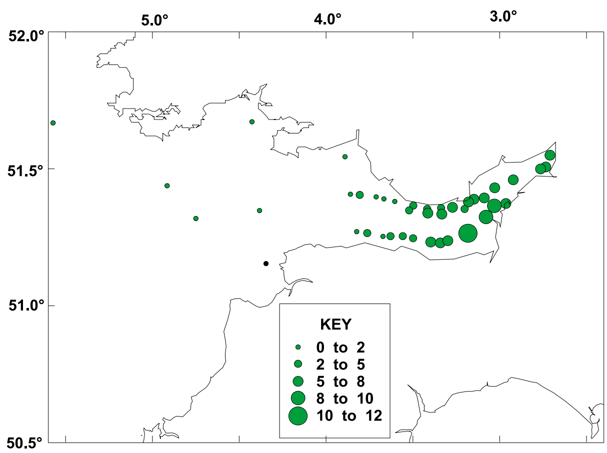

Figure 11.6 ***Concentrations (Bq kg^{-1}) of tritium in surface seawater from the Bristol Channel, September 1999***

Technetium-99 concentrations in seawater have increased in recent years due to increases in disposals of this nuclide from Sellafield. The results of research cruises to study this radionuclide have been published by Leonard *et al.* (1997a and b). Trends in plutonium and americium concentrations in seawater of the Irish Sea have been considered by Leonard *et al*. (1999).

Measurements of beta and potassium-40 activity in water from the Clyde in 1999 gave results of <1600 and <3900 mBq kg^{-1} respectively. These concentrations are similar to those for 1998.

Table 11.1. Caesium radioactivity in the freshwater environment, 1999

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Branthwaite	Rainbow trout	1	<0.06	0.29
Narborough[b]	Rainbow trout	1	<0.06	0.30
Ennerdale Water	Water	1	*	0.001
Devoke Water	Perch	1	1.5	220
Devoke Water	Brown trout	1	0.52	68
Devoke Water	Water	1	*	0.01
Gilcrux	Rainbow trout	1	<0.06	0.39
Scotland				
Loch Dee	Brown trout	1	1.9	310
Loch Dee	Water	3	*	0.02

* *not detected by the method used*
[a] *except for water where units are Bq l^{-1}*
[b] *Concentrations of 26, 0.000027, 0.000094, 0.00013 Bq kg^{-1} (wet) of carbon-14, plutonium-238, plutonium-239+240 and americium-241 were also detected in this sample*

Table 11.2. Radioactivity in terrestrial food from the Isle of Man, 1999

Material or selection[c]		No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Milk		2	<3.8	18	<0.71	<0.29	0.069	<1.2	<1.8	<0.0060	<2.3	<0.59
Milk	max			22	0.88	<0.33	0.087		<1.9			<0.60
Cabbage		1	<4.0	3.0	1.5	<0.30	<0.020	<0.80	<0.70	<0.029	<2.3	<0.70
Potatoes		1	<4.0	15	<0.20	<0.50	0.070	<0.60	<0.60	<0.029	<3.4	<0.90
Strawberries		1	<4.0	11	0.60	<0.40	0.17	<0.50	<0.60		<2.3	<0.70

Material or selection[c]		No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{129}I	Total Cs	^{144}Ce	^{147}Pm	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Milk		2	<0.010	0.17	<1.3	<0.50	<0.00010	<0.00020	0.043	<0.00010
Milk	max			0.20	<1.4					
Cabbage		1	<0.025	0.22	<1.2	<0.20	<0.00030	<0.00050	<0.13	0.00030
Potatoes		1	0.058	0.053	<1.5	<0.20	<0.00030	<0.00050	<0.084	<0.00020
Strawberries		1		<0.031	<1.3					

[a] *Except for milk where units are Bq l^{-1}*
[b] *See section 3 for definition.*
[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. See section 3 for definition.*

Table 11.3. Radioactivity in seafood and the environment near the Channel Islands, 1999

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	^{154}Eu
Rays	Guernsey	1			<0.20			<1.9		0.37	<0.59
Mackerel	Guernsey	1			<0.09			<0.86		<0.10	<0.31
Plaice	Jersey	1			<0.04			<0.41		0.11	<0.13
Pollack	Jersey	1			<0.14			<1.4		0.32	<0.42
Edible crabs	Guernsey	1			0.13			<0.43		<0.04	<0.15
Edible crabs	Jersey	1			0.12			<0.36		0.09	<0.11
Edible crabs	Alderney	2		37	<0.23		0.11	<1.4		<0.24	<0.43
Spiny spider crab	Jersey	1			0.38			<1.4		<0.13	<0.43
Spiny spider crab	Alderney	2			1.4			<1.6		<0.13	<0.44
Lobsters	Guernsey	1			<0.08			<0.59		<0.06	<0.21
Lobsters	Jersey	1			<0.17			<1.7		<0.16	<0.49
Lobsters	Alderney	1			<0.14			<1.2		<0.11	<0.39
Oysters	Jersey	1			0.12			<0.28		0.02	<0.09
Limpets	Guernsey	1			0.12			<0.57		<0.05	<0.14
Limpets	Jersey La Rozel	1			0.16			<0.46		<0.05	<0.15
Toothed winkle	Alderney	1		26	0.35	<0.13		1.1		0.08	<0.14
Scallops	Guernsey	1			<0.06			<0.51		<0.05	<0.16
Scallops	Jersey	1			<0.05			<0.37		0.06	<0.13
Ormers	Guernsey	1			<0.14			<1.3		<0.11	<0.38
Porphya	Guernsey Fermain Bay	4			<0.07			<0.66		<0.07	<0.19
Porphya	Jersey Plemont Bay	4			<0.20			<1.1		<0.23	<0.41
Porphya	Alderney Quenard Point	2			<0.03			<0.40		<0.03	<0.09
Fucus vesiculosus	Jersey La Rozel	4			0.50	<0.052	7.3	<0.52		0.10	<0.21
Fucus vesiculosus	Alderney Quenard Point	2							1.3		
Fucus serratus	Guernsey Fermain Bay	4			<0.22	0.023	2.2	<0.45		0.07	<0.17
Fucus serratus	Alderney Quenard Point	4			0.42	0.027	4.3	<0.40		<0.06	<0.15
Laminaria digitata	Jersey Verclut	4			<0.06			<0.43		<0.09	<0.18
Mud	Guernsey St. Sampson's Harbour	1			3.9			<1.8		3.7	<0.56
Mud	Jersey St Helier	1			8.8			<1.6		3.2	0.60
Sand	Alderney Lt. Crabbe Harbour	1			0.26			<1.9		1.7	<0.55
Seawater	Guernsey	4								0.003	
Seawater	Jersey	1								0.003	
Seawater	Alderney	4	5.0							0.003	

Table 11.3. continued

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total Beta
Rays	Guernsey	1	<0.50	0.000053	0.00045	0.00052	*	*	93
Mackerel	Guernsey	1	<0.22	0.000062	0.00022	0.00025	*	0.000035	82
Plaice	Jersey	1	<0.08	0.000034	0.000072	0.00012	*	0.000011	110
Pollack	Jersey	1	<0.33			<0.31			130
Edible crabs	Guernsey	1	<0.09	0.00037	0.0010	0.0025	*	0.00046	100
Edible crabs	Jersey	1	<0.11	0.00056	0.0020	0.0054	0.000042	0.00045	85
Edible crabs	Alderney	2	<0.22	0.0012	0.0017	0.0041	*	0.00088	56
Spiny spider crab	Jersey	1	<0.22			<0.11			84
Spiny spider crab	Alderney	2	<0.31	0.0023	0.0045	0.0067	0.000098	0.0015	55
Lobsters	Guernsey	1	<0.12			<0.07			69
Lobsters	Jersey	1	<0.44	0.00034	0.0026	0.0031	0.000049	0.00048	63
Lobsters	Alderney	1	<0.19	0.00055	0.0016	0.0061	*	0.0014	55
Oysters	Jersey	1	<0.09	0.0034	0.0082	0.0094	0.000088	0.0018	59
Limpets	Guernsey	1	<0.17			<0.16			50
Limpets	Jersey La Rozel	1	<0.16	0.0044	0.011	0.017	0.000095	0.0026	88
Toothed winkle	Alderney	1	<0.17	0.0096	0.024	0.032	*	0.0068	69
Scallops	Guernsey	1	<0.15	0.0013	0.0038	0.0026	0.000064	0.00042	110
Scallops	Jersey	1	<0.12	0.0035	0.0089	0.0067	*	0.00079	100
Ormers	Guernsey	1	<0.20			<0.10			60
Porphya	Guernsey Fermain Bay	4	<0.11	0.0029	0.0087	0.010	<0.000059	0.0016	100
Porphya	Jersey Plemont Bay	4	<0.25			<0.24			350
Porphya	Alderney Quenard Point	2	<0.05			<0.03			92
Fucus vesiculosus	Jersey La Rozel	4	<0.15	0.014	0.031	0.013	*	0.0018	230
Fucus vesiculosus	Alderney Quenard Point	2							
Fucus serratus	Guernsey Fermain Bay	4	<0.10	0.0060	0.019	0.0075	0.00017	0.0012	170
Fucus serratus	Alderney Quenard Point	4	<0.10	0.0090	0.022	0.0094	0.00018	0.0014	170
Laminaria digitata	Jersey Verclut	4	<0.10			<0.09			320
Mud	Guernsey St. Sampson's Harbour	1	0.91	0.36	1.0	1.4	*	0.21	570
Mud	Jersey St Helier	1	1.4	0.75	1.8	3.1	*	0.41	500
Sand	Alderney Lt. Crabbe Harbour	1	<0.39			0.38			310
Seawater	Guernsey	4							
Seawater	Jersey	1							
Seawater	Alderney	4							

* *Not detected by the method used*
[a] *Except for seawater where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*

Table 11.4. Radioactivity in regional diet in England, Northern Ireland and Wales, 1999

Region	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
		^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po
Wales	1	<3.2	42	<0.90	84	0.080	<0.08	0.20	0.060
East Midlands	1	<3.4	52	0.30	74	0.077	0.05	0.40	0.038
Wessex	1	<3.5	47	4.0	79	0.096	0.04	0.12	0.069
North East	1	3.4	53	0.40	64	0.089	<0.06	0.020	0.039
South East	1	<3.7	44	9.0	70	0.11	0.05	0.030	0.040
North Mercia	1	<3.2	47	<0.80	74	0.090	0.08	0.050	0.061
Anglia	1	<3.2	25	<0.70	84	0.064	0.03	0.080	0.045
South Mercia	1	<3.2	43	<0.70	61	0.069	0.03	0.19	0.037
Northern	1	<3.2	51	0.50	43	0.097	0.04	<0.060	0.060
Northern Ireland	1	<3.3	18	<1.3	68	0.12	0.04	0.030	0.079

Region	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
		^{226}Ra	^{232}Th	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Wales	1	0.035	0.0047	0.020	<0.00010	0.00021	<0.00052
East Midlands	1	0.041	0.0028	<0.018	0.00020	0.00018	<0.00030
Wessex	1	0.043	<0.0012	0.018	<0.000065	0.00019	<0.00046
North East	1	0.028	<0.0016	<0.018	<0.00020	0.00019	<0.00014
South East	1	0.045	<0.0051	0.019	<0.00020	0.00019	<0.00080
North Mercia	1	0.063	0.0025	0.023	<0.000059	0.00011	<0.00070
Anglia	1	0.037	0.0026	0.022	<0.000060	0.00015	<0.00054
South Mercia	1	0.038	<0.00085	<0.019	<0.00012	0.00015	<0.00040
Northern	1	0.041	<0.0012	<0.019	<0.00020	0.00020	<0.00028
Northern Ireland	1	0.049	<0.0010	<0.016	<0.00010	0.00014	<0.00018

[a] *Results are available for other artificial nuclides detectable by gamma spectrometry*
All such results are less than the limit of detection
[b] *See section 3 for definition*

Table 11.5. Radioactivity in regional diet in Scotland, 1999

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}			
		^{3}H	^{40}K	^{90}Sr	^{137}Cs
Dumfries and Galloway (Dumfries)	12	<25	95	<0.10	<0.077
East Lothian (North Berwick)	12	<25	88	<0.10	<0.068
Highland (Dingwall)	12	<25	99	<0.10	<0.10
Renfrewshire (Paisley)	12	<25	87	<0.10	<0.091

Table 11.6. Estimates of radiation exposure from radionuclides in regional diet, 1999

Nuclide[a]	Exposure, mSv[b]
Man-made radionuclides	
Tritium	0.0002
Sulphur-35	0.002
Strontium-90	0.002
Caesium-137	0.0001
Plutonium-238	0.00001
Plutonium-239+240	0.00001
Americium-241	0.00003
Sub-total	0.004
Natural radionuclides	
Carbon-14	0.01
Lead-210	0.08
Polonium-210	0.09
Radium-226	0.008
Uranium	0.0005
Thorium-232	0.0002
Sub-total	0.19
Total	0.19

[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*

Table 11.7. Radioactivity in milk remote from nuclear sites, 1999

Location	Selection[a]	No. of sampling observ-ations[b]	Mean radioactivity concentration, Bq l^{-1}											
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{129}I	Total Cs	^{210}Pb	^{210}Po	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$	Total alpha
Co. Antrim		6	<3.3	17		0.030		0.28	<0.030	<0.0050	<0.0073	<0.00020	<0.00010	
	max		<4.0	20		0.038		0.36						
Co. Armagh		6	<3.3	15		0.034		0.11	<0.033	0.0070	<0.0073	<0.00010	<0.00010	
	max		<4.0	22		0.046		0.20						
Cambridgeshire[c]		12	<2.1			<0.019		0.038	<0.037	0.0080	<0.0073	<0.00010	<0.00020	
	max		<3.0			0.039		0.053						
Cheshire		11	<3.1	14		0.023		0.057	<0.031	0.014	0.011	<0.00010	<0.00010	
	max		<4.0	19		0.033		0.074						
Clwyd		12	<3.3	17		0.032		0.044	<0.042	0.0090	<0.0073	<0.00020	<0.00020	
	max		<4.0	39		0.070		0.069						
Cornwall		10	<3.5	14		0.042		0.058	<0.031	0.012	<0.0073	<0.00010	<0.00010	
	max		<4.0	20		0.068		0.13						
Devon		12	<3.3	15		0.041		0.047	0.052	0.014	<0.0073	<0.00020	0.00010	
	max		<4.0	23		0.062		0.086						
Co. Down		6	<3.5	19		0.037		0.14	<0.035	0.0070	<0.0073	<0.00020	<0.00010	
	max		<4.0	29		0.046		0.21						
Dumfries and Galloway		12	<25	17	<5.0	<0.10	<0.028	<0.10[d]						<0.27
	max			26			<0.050	0.37[d]						<0.28
Co. Fermanagh		6	<3.3	15		0.029		0.18	<0.037	0.013	<0.0073	<0.00010	<0.00010	
	max		<4.0	21		0.037		0.23						
Gloucestershire		12	<3.1	17		0.025		<0.040	<0.034	0.0080	<0.0073	0.00010	<0.00010	
	max		4.0	22		0.043		0.089						
Gwent[c]		10	<2.0			0.030		0.037	<0.035	<0.0050	<0.0073	<0.00010	<0.00010	
	max		3.0			0.039		0.046						
Gwynedd		9	<3.6	15		0.038		0.056	<0.033	0.0080	<0.0073	<0.00020	<0.00010	
	max		<4.0	23		0.052		0.079						
Hampshire		12	<3.1	14		0.025		0.053	<0.033	<0.013	<0.0073	<0.00010	<0.00010	
	max		<4.0	19		0.034		0.096						
Highland		12	<25	15	<5.0	<0.10	<0.028	<0.085[d]						<0.29
	max			18			<0.060	0.12[d]						<0.31
Humberside		12	<3.6	14		0.024		0.049	<0.034	0.0070	<0.0073	<0.00010	<0.00010	
	max		<5.0	21		0.053		0.10						
Lancashire		12	<3.8	15		0.033		0.057	<0.030	0.011	<0.0073	<0.00010	<0.00010	
	max		9.0	23		0.059		0.14						
Leeds		9	<3.2	15		0.025		0.047	<0.032	0.0090	<0.0073	<0.00020	<0.00010	
	max		<4.0	21		0.030		0.077						
Leicestershire		12	<3.3	16		0.022		<0.032	0.082	0.0080	<0.0073	<0.00010	<0.00020	
	max		<4.0	26		0.033		0.049						
Lincolnshire		12	<3.0	18		0.017		0.029	<0.041	0.0090	<0.0073	<0.00010	<0.00020	
	max		<4.0	30		0.028		0.053						

Table 11.7. continued

Location	Selection[a]	No. of sampling observ-ations[b]	^{3}H	^{14}C	^{35}S	^{90}Sr	^{129}I	Total Cs	^{210}Pb	^{210}Po	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	Total alpha
			Mean radioactivity concentration, Bq l^{-1}											
Co. Londonderry		6	<3.3	16		0.030		0.12	<0.037	0.0070	<0.0073	<0.00010	0.00020	
	max		<4.0	27		0.042		0.20						
Middlesex		10	<3.0	15		0.023		0.059	<0.033	<0.0060	<0.0073	<0.00010	<0.00010	
	max		<4.0	28		0.043		0.099						
Midlothian		12	<25	15	<5.0	<0.10	<0.028	<0.053[d]						<0.28
	max			16			<0.070	0.086[d]						<0.29
Norfolk		12	<3.2	17		0.016		0.041	<0.032	0.012	<0.0073	<0.00010	<0.00020	
	max		<4.0	29		0.028		0.091						
North Yorkshire		12	<3.4	15		0.024		0.049	<0.033	0.0080	<0.0073	<0.00010	<0.00020	
	max		6.0	23		0.036		0.073						
Oxfordshire		12	<3.3	18		0.021		0.058	<0.035	0.0080	<0.0073	0.00030	<0.00010	
	max		<4.0	31		0.030		0.10						
Renfrewshire		12	<25	14	<5.0	<0.10	<0.024	<0.11[d]						<0.25
	max			17			<0.030	0.32[d]						
Shropshire		12	<3.8	17		0.030		0.039	<0.030	0.010	<0.0073	<0.00010	<0.00010	
	max		10	35		0.050		0.064						
Somerset		12	<3.1	15		<0.044		0.053	<0.034	0.0070	<0.0073	<0.00010	<0.00020	
	max		5.0	20		0.064		0.091						
Suffolk		12	<3.3	15		0.015		0.042	<0.036	<0.0090	<0.0073	0.00010	<0.00010	
	max		<4.0	23		0.034		0.062						
Tyneside		12	<7.5	14		0.033		0.053	<0.036	0.012	<0.0073	<0.00010	<0.00010	
	max		23	21		0.043		0.14						
Co. Tyrone[c]		12	<2.6			0.032		0.14	<0.044	0.0080	<0.0073	0.00010	<0.0010	
	max		8.0			0.041		0.26						
West Midlands		12	<3.4	17		0.026		0.046	<0.033	<0.017	<0.0073	<0.00020	<0.00020	
	max		6.0	27		0.051		0.081						
Mean Values														
England			<3.5	16		<0.026		<0.047	<0.037	<0.010	<0.0075	<0.00013	<0.00014	
Northern Ireland			<3.1	16		0.032		0.16	<0.036	<0.0078	<0.0073	<0.00013	<0.00012	
Wales			<3.0	16		0.033		0.045	<0.037	<0.0073	<0.0073	<0.00017	<0.00013	
Scotland			<25	15	<5.0	<0.10	<0.027	<0.088[d]						<0.27
United Kingdom			<6.3	16		<0.038		<0.066	<0.037	<0.0093	<0.0074	<0.00013	<0.00013	

[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. See section 3 for definition

[b] *See section 3 for definition*

[c] *Sub-sets for ^{3}H, ^{90}Sr and Total Cs*

[d] *^{137}Cs only*

Table 11.8. Radioactivity in crops remote from nuclear sites, 1999

Location	Material	No of samples[a]	Mean radioactivity concentration (wet), $Bq\ kg^{-1}$													
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total Alpha
Cornwall																
Truro	Cabbage	1	<4.0	12		1.1	0.068	0.34	0.11	0.066	<0.0024	<0.020	0.00040	<0.00030	0.00060	
	Strawberries	1	<4.0	13		0.11	<0.026	<0.034	0.021	0.028	<0.0011	<0.017	<0.00020	<0.00030	0.00010	
Dorset																
Cranborne	Kale	1	5.0	4.0		0.38	0.031	0.86	0.33	0.078	0.0051	<0.031	<0.00030	<0.00020	<0.0010	
	Turnips	1	<4.0	8.0		0.16	<0.045	0.12	0.040	0.034	0.019	0.048	0.00030	0.00040	<0.00040	
Dumfries and Galloway																
Dumfries	Leafy Green Veg.	4	<25	4.6	<5.0	<0.10	<0.071[c]									<0.22
Co. Durham																
Westgate	Rosehips	1	<6.0	47		0.69	0.36	1.9	0.82	0.027	<0.0027	<0.037	<0.00030	0.00050	0.00050	
	Swede Tops/Leeks	1	<4.0	13		0.62	0.095	1.2	0.31	0.011	0.0090	0.054	<0.00020	<0.00030	0.00060	
East Lothian																
North Berwick	Leafy Green Veg.	4	<25	4.4	<5.0	<0.10	<0.11[c]									<0.20
Essex																
Great Dunmow	Cabbage	1	<4.0	15		0.063	<0.029	0.19	0.050	<0.010	<0.0055	<0.037	<0.00020	<0.00020	<0.00050	
	Strawberries	1	<4.0	12		0.079	<0.035	0.077	<0.019	0.015	<0.0082	<0.019	0.00010	0.00030	0.00020	
Hampshire																
Hungerford	Lettuce	1	<4.0	7.0		0.31	0.028	0.30	0.12	0.040	<0.011	0.14	<0.00020	<0.00030	0.00070	
	Rhubarb	1	<4.0	7.0		0.28	<0.032	0.11	0.048	0.028	<0.0021	<0.031	<0.00020	<0.00050	<0.00030	
Hereford and Worcestershire																
Ross-on-Wye	Raspberries	1	<4.0	12		<0.024	<0.030	<0.042	0.036	0.0030	0.00070	<0.020	<0.00020	0.0010	<0.00020	
	Sprouts	1	<4.0	10		0.060	0.069	0.059	0.033	<0.0020	<0.0020	<0.041	<0.00020	<0.00030	<0.00030	
Highlands																
Dingwall	Leafy Green Veg.	4	<25	4.1	<5.0	<0.10	<0.090[c]									<0.21
Kent																
Royal Tunbridge	Beetroot	1	<4.0	18		<0.0080	0.041	<0.039	0.030	0.060	0.012	0.035	0.00050	<0.00020	<0.00030	
Wells	Cabbage	1	<4.0	6.0		0.67	0.11	0.98	0.33	0.13	0.036	0.15	0.00030	<0.00020	<0.00060	
Lancashire																
Gisburn	Raspberries/ Gooseberries	1	<4.0	16		0.12	<0.037	0.14	0.048	0.021	<0.0036	<0.025	<0.00020	<0.00040	<0.00020	
Leciestershire																
Melton Mowbray	Blackberries	1	<4.0	26		0.12	<0.025	0.11	0.059	0.024	0.0013	<0.022	<0.00020	<0.00030	<0.00020	
	Cabbage/ Runner Beans/ Spinach	1	<4.0	10		0.050	0.049	0.053	0.038	0.023	0.0018	<0.030	0.00010	<0.00030	0.00030	

Table 11.8. continued

Location		Material	No of samples[a]	Mean radioactivity concentration (wet), Bq kg^{-1}													
				^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total Alpha
Lincolnshire																	
	Mablethorpe	Cabbage	1	<4.0	7.0		0.20	<0.028	0.16	0.035	0.031	0.0072	<0.040	<0.00020	<0.00020	<0.00040	
		Carrots	1	<4.0	13		0.065	0.091	0.13	0.044	0.052	0.068	0.14	<0.00020	<0.00030	0.0010	
Monmouthshire																	
	Abergavenny	Cabbage	1	<4.0	8.0		0.39	0.12	0.20	0.069	0.016	0.0027	<0.037	<0.00020	0.00050	<0.00020	
		Gooseberries	1	<3.0	15		0.14	<0.029	0.058	0.047	0.011	<0.00060	<0.014	0.00010	0.0010	<0.00020	
Norfolk																	
	Melton Constable	Cabbage/Sprouts	1	<4.0	15		0.066	0.038	0.13	0.030	0.0080	<0.0018	<0.037	<0.00020	<0.00020	<0.00030	
		Carrots/Swede	1	9.0	16		0.24	0.036	0.040	0.020	0.039	<0.0017	<0.035	<0.00020	<0.00040	0.00030	
North Yorkshire																	
	Pickering	Spinach	1	<4.0	9.0		0.12	0.084	0.049	0.042	0.038	0.011	<0.040	<0.00010	0.00020	0.00040	
		Swede	1	4.0	13		0.11	0.058	0.039	0.012	0.030	0.0068	<0.032	<0.00020	0.00050	<0.00020	
Oxfordshire																	
	Chipping Norton	Cabbage	1	<4.0	8.0		0.30	0.11	<0.056	0.040	0.015	<0.0021	<0.034	<0.00020	<0.00040	<0.00020	
		Potatoes	1	5.0	12		0.032	<0.037	<0.040	0.019	0.0090	0.0030	<0.033	<0.00020	<0.00030	0.00050	
Powys																	
	Machynlleth	Leeks	1	<4.0	13		0.57	0.20	0.58	0.29	0.058	0.028	0.17	<0.00020	0.0017	0.00080	
		Turnips	1	<3.0	3.0		0.28	0.049	0.15	0.042	<0.0040	0.0099	<0.030	0.00010	<0.00030	<0.00020	
Renfrewshire																	
	Paisley	Leafy Green Veg.	4	<25	5.3	<5.0	<0.10	<0.065[c]									<0.25
Shropshire																	
	Bridgnorth	Cabbage	1	<4.0	6.0		0.065	<0.038	<0.034	0.020	0.041	<0.00080	<0.027	<0.00020	<0.00040	<0.00020	
		Strawberries	1	<5.0	5.0		<0.023	<0.031	0.085	0.024	0.015	0.00090	<0.018	<0.00020	<0.00020	<0.00020	
Somerset																	
	Exford	Rape	1	<4.0	20		1.7	0.067	0.64	0.16	0.20	<0.0011	<0.035	0.00040	<0.00020	0.00090	
		Turnips	1	<4.0	7.0		0.34	0.051	0.064	0.015	0.020		<0.021	0.00050	<0.00020	0.00020	
Staffordshire																	
	Leek	Cabbage	1	<4.0	14		<0.019	0.23	0.68	0.36	0.15	0.018	0.15	<0.00020	0.00050	0.00070	
		Potatoes	1	<4.0	14		0.028	0.063	0.072	0.018	0.0050	0.0034	<0.031	<0.00020	0.00010	<0.00030	
Mean Values																	
	England			<4.3	13		<0.26	<0.067	<0.28	<0.11	<0.041	<0.0083	<0.046	<0.00024	<0.00033	<0.00041	
	Wales			<3.5	9.8		0.34	<0.10	0.25	0.11	<0.022	<0.010	<0.064	<0.00015	<0.00088	<0.00035	
	Scotland			<25	4.6	<5.0	<0.10	<0.083[c]									<0.21
	Great Britain			<11	9.9		<0.22	<0.074	<0.28	<0.11	<0.039	<0.0086	<0.048	<0.00023	<0.00039	<0.00041	

[a] *See section3 for definition*
[b] *Results are available for other artificial nuclides detected by gamma spectroscopy. All such results are less than the limit of detection*
[c] *^{137}Cs only*

Table 11.9. Radioactivity in bread in Scotland, 1999

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	4	<25	51	<5.0	<0.10	<0.12	<0.65
East Lothian (North Berwick)	4	<25	63	<5.0	<0.10	<0.13	<0.78
Highland (Dingwall)	4	<25	65	<5.0	<0.10	<0.10	<0.78
Renfrewshire (Paisley)	4	<25	57	<5.0	<0.10	<0.12	<0.76

Table 11.10. Radioactivity in meat in Scotland, 1999

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	4	<25	56	<5.0	<0.10	<0.13	<0.32
East Lothian (North Berwick)	4	<25	36	<5.0	<0.10	<0.10	<0.34
Highland (Dingwall)	4	<25	34	<5.0	<0.10	<0.20	<0.35
Renfrewshire (Paisley)	4	<25	36	<5.0	<0.10	<0.30	<0.35

Table 11.11. Radioactivity in freshwater in Scotland, 1999

Area	Location	No. of sampling observ-ations[a]	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Total alpha	Total beta
Angus	Loch Lee	11	<1.1	<0.0047	<0.0070		
Argyll and Bute	Auchengaich	1	<1.1	<0.0050		<0.020	0.024
Argyll and Bute	Helensburgh Reservoir	3			<0.0077	<0.014	<0.030
Argyll and Bute	Loch Ascog	3			<0.0083	<0.015	0.063
Argyll and Bute	Loch Eck	1	<1.1	<0.0050		<0.020	<0.020
Argyll and Bute	Loch Finlas	3			<0.0083	<0.014	<0.022
Argyll and Bute	Lochan Ghlas	3			<0.0093	<0.016	<0.036
Clackmannanshire	Gartmorn	1	<1.1	<0.0050		<0.020	0.022
Dumfries and Galloway	Black Esk	1	<1.1	<0.0050		<0.020	<0.020
Dumfries and Galloway	Purdomstone	3			<0.0083	<0.018	<0.061
Dumfries and Galloway	Winterhope	1	<1.1	<0.0050		<0.020	0.033
East Lothian	Hopes Reservoir	1	<1.1	<0.0050		<0.020	<0.020
East Lothian	Thorters Reservoir	1	<1.1	<0.0050		<0.020	0.035
East Lothian	Whiteadder	3			<0.010	<0.016	0.053
Fife	Holl Reservoir	1	<1.1	<0.0050		<0.020	<0.020
Highland	Loch Baligill	1	<1.1	<0.0050		<0.020	<0.020
Highland	Loch Calder	2			<0.0070	<0.018	0.044
Highland	Loch Glass	12	<1.1	<0.0057	<0.011		
Highland	Loch Shurrerey	1	<1.1	<0.0050		<0.020	0.048
North Ayrshire	Camphill	1	<1.1	<0.0050		<0.020	<0.020
North Ayrshire	Knockendon Reservoir	3			<0.0077	<0.018	<0.031
North Ayrshire	Munnoch Reservoir	1	<1.1	<0.0050		<0.020	<0.020
North Ayrshire	Outerwards	1	<1.1	<0.0050		<0.020	0.055
Orkney Islands	Heldale Water	1	<1.1	<0.0050		<0.020	<0.020
Perth and Kinross	Castlehill	2			<0.010	<0.017	0.042
Scottish Borders	Knowsdean	11	<1.1	<0.0055	<0.0071		
Stirling	Loch Katerine	12	<1.1	<0.0050	<0.0082		
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.1	<0.0050		<0.020	<0.020
West Lothian	Morton No. 2	1	<1.1	<0.0050		<0.020	<0.020

[a] *See section 3 for definition*

Table 11.12. Radioactivity in sea water from the Irish Sea and Scottish waters, 1999

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
		^{3}H	^{99}Tc	^{134}Cs	^{137}Cs
Seascale	4			0.003	0.24
St. Bees	12	12	0.16	<0.001	0.15
Whitehaven	1			*	0.19
Maryport	1			*	0.22
Silloth	1			0.002	0.30
Silecroft	1			0.003	0.17
Walney- west shore	4	12		*	0.16
Isle of Whithorn	1			*	0.15
Drummore	1			*	0.06
Half Moon Bay	1			*	0.21
Rossal (Fleetwood)	1			*	0.18
Ainsdale	1			*	0.21
New Brighton	1			*	0.12
Ross Bay	1			*	0.16
North of Larne	12		0.024	*	0.03
Seafield	4	640			0.40
Southerness[a]	4	5.8			0.24
North Solway	4	6.4			0.12
Knock Bay	8	<5.1		<0.05	0.25
Prestatyn	1			*	0.08
Llandudno	1			*	0.06
Holyhead	4	<2.2		*	0.03

* *not detected by the method used*

[a] *Concentrations of 0.00078, 0.0023 and 0.0026 Bq l^{-1} of ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were determined*

12. RESEARCH IN SUPPORT OF THE MONITORING PROGRAMME

The Food Standards Agency and SEPA have extramural programmes of special surveillance investigations and supporting research and development studies to complement the routine surveillance undertaken. This additional work has the following objectives:

- to evaluate the significance of potential sources of radionuclide contamination of the food chain;
- to identify and investigate specific topics or pathways not currently addressed by the routine surveillance programmes and the need for their inclusion in future routine surveillance;
- 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;
- to develop improved methods for handling and processing surveillance data.

A list of related research projects completed in 1999 is presented in Table 12.1., and is also available on the Food Standard Agency's Web site (www.foodstandards.gov.uk). Copies of the final reports for each of those projects funded by the Food Standards Agency are available from the Radiological Safety Unit, P O Box 31037, Ergon House, 17 Smith Square, London SW1P 3WG. A charge may be made to cover photocopying and postage. 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 projects that are completed is given here.

AFCF boli and sheep– project RP0322

This project developed and tested a bolus containing ammonium ferric hexacyanoferrate (AFCF) suitable for administration to the small lambs of hill-sheep breeds. The policy aim is to establish whether there is a practical method for reducing radiocaesium from the Chernobyl accident that is still found in sheep in parts of the United Kingdom. Boli were developed and tested on an upland farm within the restricted area of west Cumbria. A reduction in radiocaesium of over 30% was found 51 days after administration (Beresford *et al.,* 1999).

The Leeds study of boli and sheep – project RP0321

This second project used a vitrification process to produce boli containing *Aspergillus niger*, a mycelium with a good theoretical binding capacity for radiocaesium. Unfortunately the boli either broke down too readily or insufficiently during in vivo tests and produced no significant reduction in radiocaesium levels in lambs.

The sea-fish-fishmeal-animal-man pathway – project RP0438

This project assessed the importance of the transfer of radioactivity from the sea through fishmeal fed to animals to man. Individual and collective doses were assessed for natural and man-made radionuclides transferred to United Kingdom diet. The assessment considered (i) the quantities and sources of radioactivity in fishmeal and (ii) the amounts fed to fish, poultry, pigs, cows and sheep. Measurements of activity in fishmeal were made for samples from all around the world reflecting the global market in fishmeal.

Natural radionuclides dominated both individual and collective dose estimates. For man-made radionuclides, high-rate consumers were predicted to receive less than 0.010 mSv y^{-1}. Most of this was from carbon-14 transferred through milk consumption. The collective dose from man-made radionuclides was less than 5 mSv, again mostly from carbon-14 in milk (Smith and Jeffs, 1999).

Improved analysis of cerium-144 – project RP0325

The aim of the project was to produce a more sensitive method for analysing cerium-144 in milk than that currently offered by gamma spectrometry. The method developed used ion-chromatography in conjunction with Cerenkov counting of the praseodymium-144 daughter. A limit of detection of 0.05 Bq l^{-1} was achieved for a count time of 100 minutes depending on the sample size (Cobb and Chow-Wan, 1999).

Samplers for radionuclides in freshwater – RP0433

The goal of this project was to apply DGT (diffusive gradients in thin films) technology to the measurement of various radionuclides in freshwater. Suitable ion-exchange resin binders were found for cobalt-60, zinc-65 and radiocaesium. Field trials were conducted and, for radiocaesium, the detection limit was typically a few mBq l^{-1} (Kelly *et al*, 1999).

Radioactivity in household dust at Dounreay and Thurso

Studies into the levels of radioactivity in household dust in Thurso and Banff were carried out in 1989 and 1992 and published in 1994 and 1993 respectively. Subsequent analysis (ICI, 1994)of these results, published by SEPA in 2000, implied that in 1989 very low levels of plutonium and americium were being transported home by workers involved in nuclear fuel reprocessing activities at Dounreay. The highest radiation dose to occupants of houses in the Thurso area from inhalation and ingestion of household dust was 0.002 mSv which is 0.2% of the principal annual dose limit for members of the public of 1 mSv. Improvements in the monitoring of personnel leaving the fuel cycle area at Dounreay have been implemented.

Optimisation of MAFF’s monitoring programme - RP0320

Optimon-T is a software tool that has been developed to assist in the optimisation of the terrestrial surveillance programme around nuclear licenced sites. In order to optimise the programme, a two-part approach has been adopted. The first, or outer problem, is the determination of the budget available for a site and the second, inner, problem is the optimisation of the use of those funds. By careful structuring of the problem, the tool captures the implicit and explicit decisions made when deciding on the surveillance priorities for a site. It therefore allows the user to define the overall “best value” surveillance programme. It is currently under final test by the FSA.

Food and non-licensed sites - RP0441

This project is a desk study to assess the potential for radioactivity contained in liquid waste disposals from non licenced sites to contaminate the foodchain. The approach is to identify the river catchment area that could receive the largest amount of radioactivity, assuming all sites discharge 100% of their authorised limits, followed by modelling of the dispersion of liquid and solid waste from the sewage treatment works into the environment. The pathways under consideration include animal drinking water and crop irrigation from contaminated river water as well as food produced on land that has been treated with contaminated sewage sludge. Preliminary results indicate that these pathways are very minor routes of public exposure.

Table 12.1. Extramural projects in support of the monitoring programmes

	Further details	Target completion date
AFCF boli and sheep	F	Complete
The seafish – fishmeal – animal – man pathway	F	Complete
The Leeds study of boli and sheep	F	Complete
Optimisation of MAFF's monitoring programme	F	Complete
Discharges to sewers	S	Complete
Samplers for radionuclides in freshwaters	F	Complete
Improved analysis of cerium-144	F	Complete
Food and non-licensed sites	F	Complete
Assessments of contaminated land	S	Complete
Impact on Irish Sea coastal communities	S	Complete
Quality control for the determination of radionuclides in foodstuffs	F	Mar-00
Methods for censored data sets	F	Jun-00
Quality assessment of tritium in food	F	Jul-00
RIFE Trend studies	F	Aug-00
Impact on non-human species	S	Nov-00
Cardiff special survey	F	Nov-00
Development of TRAMS database	F	Mar-01
^{36}Cl method development	F	Mar-01
Accumulation of technetium-99 in the Irish Sea	F	Mar-01
Analysis of TDS and industrial samples 1997-2000	F	Mar-01
Organic tritium in seafood	F	Mar-01
Access to CEFAS data archive	F	Mar-01
Computerisation of archive records	F	Mar-01
Seasonal variations in radionuclides in crabs and lobsters	F	Jul-01
Cs, Am and Pu in Northern Irish waters	S	Dec-01
U analyses in food and indicators	F	Feb-02
Dietary studies near nuclear installations	F	Mar-02
Natural radionuclides in seafood	F	Mar-02
Uncommon seafoods	F	Mar-02
Tritium and carbon-14 in seafood	F	Mar-02
Natural radionuclides in wildfood	F	Jul-02

F = Food Standards Agency
S = Scotland and Northern Ireland Forum for Environmental Research

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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, 1999

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999	
			TBq[a]	% of limit[b]
British Nuclear Fuels plc				
Capenhurst[r]				
Rivacre Brook	Uranium	0.02	$2.3\ 10^{-3}$	11
	Uranium daughters	0.02	0.0019	<9
	Non-uranic alpha	0.003	$2.1\ 10^{-5}$	<1
	Technetium-99	0.1	0.00114	1
Chapelcross	Alpha	0.1	$1.78\ 10^{-4}$	<1
	Beta[e]	25	0.0675	<1
	Tritium	5.5	0.708	13
Drigg				
Sea pipeline	Alpha	0.1	$6.85\ 10^{-5}$	<1
	Beta[e]	0.3	0.00148	<1
	Tritium	120	0.392	<1
Stream[f]	Alpha	$9.0\ 10^{4}$	53.4	<1
	Beta[e]	$1.2\ 10^{6}$	564	<1
	Tritium	$6.0\ 10^{8}$	$5.9\ 10^{4}$	<1
Sellafield	Alpha	1	0.133	13
Sea pipelines	Beta	400	110	28
	Tritium	$3.1\ 10^{4}$	2520	8.1
	Carbon-14	20.8	5.76	28
	Cobalt-60	13	0.89	6.9
	Strontium-90	48	31.2	65
	Zirconium-95+Niobium-95	9	0.182	2.0
	Technetium-99	200	68.8	34
	Ruthenium-106	63	2.72	4.3
	Iodine-129	2	0.485	24
	Caesium-134	6.6	0.340	5.2
	Caesium-137	75	9.12	12
	Cerium-144	8	0.602	7.5
	Plutonium alpha	0.7	0.115	16
	Plutonium-241	27	2.87	11
	Americium-241	0.3	0.035	12
	Uranium[d]	2040	536	26
Sellafield				
Factory sewer	Alpha	0.0033	$3.9\ 10^{-5}$	1.2
	Beta	0.0135	$4.5\ 10^{-4}$	3.3
	Tritium	0.132	0.0148	11
Springfields	Alpha	4	0.239	5.9
	Beta	240	128	53
	Technetium-99	0.6	0.0387	6.4
	Thorium-230	2	0.146	7.3
	Thorium-232	0.2	0.0047	2.3
	Neptunium-237	0.04	0.0012	3.0
	Uranium	0.15	0.0498	33

* *Whilst great care has been taken in the compilation of Appendix 1, the Food Standards Agency and SEPA accept no responsibility for the accuracy of tables A1.1, A1.2, and A1.3*

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999 TBq[a]	% of limit[b]
United Kingdom Atomic Energy Authority				
Dounreay[h]	Alpha[c]	0.27	0.00173	<1
	Beta[e]	49	0.297	<1
	Tritium	30.8	0.137	<1
	Cobalt-60	0.46	0.00361	1.0
	Strontium-90	7.7	0.163	2.1
	Zirconium-95+Niobium-95	0.4	$9.44\ 10^{-4}$	<1
	Ruthenium-106	4.1	0.00229	<1
	Silver-110m	0.13	$3.56\ 10^{-4}$	<1
	Caesium-137	23	0.157	<1
	Cerium-144	0.42	0.00171	<1
	Plutonium-241	2.3	0.00867	<1
	Curium-242	0.04	$1.6\ 10^{-5}$	<1
Harwell (pipeline)	Alpha	0.001	$2.68\ 10^{-5}$	2.6
	Beta[e]	0.02	0.00227	11
	Tritium	4	0.0483	1.2
	Cobalt-60	0.007	$7.53\ 10^{-5}$	1
	Caesium-137	0.007	$4.32\ 10^{-4}$	6.2
Harwell (Lydebank Brook)	Alpha	$5\ 10^{-4}$	$3.08\ 10^{-5}$	6.2
	Beta[e]	0.002	$2.29\ 10^{-4}$	12
	Tritium	0.1	0.0175	17
Winfrith (inner pipeline)	Alpha	0.3	0.00114	<1
	Tritium	650	2.65	<1
	Cobalt-60	10	0.0146	<1
	Zinc-65	6	$3.88\ 10^{-4}$	<1
	Other radionuclides	80	0.00148	<1
Winfrith (outer pipeline)	Alpha	0.004	$5.36\ 10^{-5}$	<1.3
	Tritium	1	0.0081	<1
	Other radionuclides	0.01	$8.5\ 10^{-5}$	<1
Magnox Electric[v]				
Berkeley	Tritium	8	0.00638	<1
	Caesium-137	0.2	0.00768	3.8
	Other radionuclides	0.4	0.0178	4.5
Bradwell	Tritium	30	0.525	1.8
	Caesium-137	0.75	0.337	45
	Other radionuclides	1	0.300	30
Dungeness 'A' Station	Tritium	35	2.12	6.0
	Caesium-137	1.2	0.330	28
	Other radionuclides	1.4	0.441	32
Hinkley Point 'A' Station	Tritium	25	0.836	3.3
	Caesium-137	1.5	0.439	29
	Other radionuclides	1	0.273	27
Hunterston 'A' Station	Total activity[e]	2	0.197	9.9
	Tritium	5	0.0218	<1
Oldbury	Tritium	25	0.214	<1
	Caesium-137	0.7	0.066	9.4
	Other radionuclides	1.3	0.172	13

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999	
			TBq[a]	% of limit[b]
Sizewell				
'A' Station	Tritium	35	0.665	1.9
	Caesium-137	1.0	0.0687	6.9
	Other radionuclides	0.7	0.116	17
Trawsfynydd	Total activity[e,i,j]	0.72	0.0303	4.2
	Tritium	12	0.0402	<1
	Strontium-90	0.08	0.0232	29
	Caesium-137	0.05	0.0043	8.6
Wylfa	Tritium	40	4.59	11
	Other radionuclides	0.15	0.0185	12
British Energy Generation Ltd				
Dungeness				
'B' Station	Tritium	650	122	19
	Sulphur-35	2	0.242	12
	Cobalt-60	0.03	0.002	6.6
	Other radionuclides	0.25	0.0247	9.8
Hartlepool	Tritium	1200	409	34
	Sulphur-35	3	0.864	28
	Cobalt-60	0.03	0.00311	10
	Other radionuclides	0.3	0.00315	1.1
Heysham				
Station 1	Tritium	1200	395	33
	Sulphur-35	2.8	0.144	5.1
	Cobalt-60	0.03	0.0003	<1
	Other radionuclides	0.3	0.0116	3.9
Station 2	Tritium	1200	255	21
	Sulphur-35	2.3	0.0241	1.1
	Cobalt-60	0.03	0.00101	3.3
	Other radionuclides	0.3	0.0175	5.8
Hinkley Point				
'B' Station	Tritium	620	355	57
	Sulphur-35	5	0.591	12
	Cobalt-60	0.033	$4.20\ 10^{-4}$	1.2
	Other radionuclides	0.235	0.0190	8.1
Sizewell				
'B' Station	Tritium	80	55.7	69
	Other radionuclides	0.2	0.0458	22
British Energy Generation (UK) Ltd				
Hunterston				
'B' Station	Alpha	0.001	$1.1\ 10^{-4}$	11
	Beta[e,g,p]	0.45	0.00867	<1
	Tritium	800	416	52
	Sulphur-35	10	2.62	26
	Cobalt-60	0.03	$9.8\ 10^{-4}$	3.3
Torness	Alpha	0.001	$6.57\ 10^{-6}$	<1
	Beta[e,g,p]	0.45	0.00218	<1
	Tritium	800	335	42
	Sulphur-35	10	0.0451	<1
	Cobalt-60	0.03	$4.23\ 10^{-4}$	1.4

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999	
			TBq[a]	% of limit[b]
Ministry of Defence				
Aldermaston (pipeline)[k]	Alpha	$1.5\ 10^{-4}$	$1.39\ 10^{-5}$	9.3
	Tritium	0.05	0.00105	2.1
	Plutonium-241	$6.0\ 10^{-4}$	$5.59\ 10^{-5}$	9.3
	Other radionuclides	$1.5\ 10^{-4}$	$9.46\ 10^{-6}$	6.3
Aldermaston (Silchester)[k]	Alpha	$1.0\ 10^{-4}$	$6.77\ 10^{-6}$	6.8
	Beta	$3.0\ 10^{-4}$	$1.82\ 10^{-5}$	6.1
Barrow [l]	Tritium	0.02	$2.31\ 10^{-3}$	12
	Manganese-54	$2.5\ 10^{-7}$	$1.42\ 10^{-8}$	5.7
	Cobalt-58	$7.0\ 10^{-7}$	$1.55\ 10^{-8}$	2.2
	Cobalt-60	$7.0\ 10^{-8}$	$2.40\ 10^{-8}$	34
	Tin-113	$2.5\ 10^{-7}$	$1.43\ 10^{-8}$	5.7
	Antimony-124	$2.0\ 10^{-6}$	$2.08\ 10^{-8}$	1.0
	Other radionuclides	$3.5\ 10^{-6}$	$4.37\ 10^{-8}$	1.2
Burghfield[k]	Alpha	$2.0\ 10^{-6}$	$4.07\ 10^{-8}$	2.0
	Other radionuclides	$1.2\ 10^{-5}$	$8.15\ 10^{-8}$	<1
Devonport[m,n] (sewer)	Beta		$6.38\ 10^{-6}$	
	Tritium		$5.09\ 10^{-6}$	
	Cobalt-60		$2.47\ 10^{-7}$	
Devonport[m,n] (river)	Beta		Nil	
	Tritium		"	
	Cobalt		"	
Devonport[n,o] (sewer)	Total activity		$3.94\ 10^{-4}$	
	Cobalt-60		$3.75\ 10^{-4}$	
Devonport[o] (pipeline)	Total activity[e,p]	0.001	$4.45\ 10^{-4}$	44
	Tritium	0.12	0.100	84
	Cobalt-60	0.006	$7.76\ 10^{-5}$	1.3
Dounreay (Vulcan)	Alpha	$3.7\ 10^{-4}$	$5.0\ 10^{-6}$	1.4
	Beta	1	$1.55\ 10^{-4}$	<1
Faslane	Alpha activity	$2.0\ 10^{-4}$	$1.97\ 10^{-6}$	<1
	Beta activity[e,p]	$5.0\ 10^{-4}$	$1.01\ 10^{-5}$	2.0
	Tritium	1	0.0694	6.9
	Cobalt-60	$5.0\ 10^{-4}$	$3.64\ 10^{-6}$	<1
Greenwich[u]	Alpha	$2.0\ 10^{-8}$	$9.8\ 10^{-9}$	49
	Tritium	$5.0\ 10^{-6}$	$4.0\ 10^{-8}$	<1
	Other radionuclides	$5.0\ 10^{-6}$	$1.5\ 10^{-6}$	30
Rosyth[q]	Alpha	10^{-6}	$9.1\ 10^{-8}$	9.1
	Beta[e,p]	$5\ 10^{-4}$	$2.41\ 10^{-4}$	48
	Tritium	0.04	0.0147	37
	Cobalt-60	0.005	$6.03\ 10^{-4}$	12
Nycomed Amersham plc				
Amersham	Alpha	$3.0\ 10^{-4}$	$3.96\ 10^{-5}$	13
	Beta >0.4 MeV	0.1	0.00865	8.7
	Tritium	0.2	0.00140	<1
	Iodine-125	0.2	$6.03\ 10^{-4}$	<1
	Caesium-137	0.005	$1.88\ 10^{-5}$	<1
	Other radionuclides	0.3	0.0444	15

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999	
			TBq[a]	% of limit[b]
Cardiff	Tritium	900	105	12
	Carbon-14	2	1.15	58
	Phosphorus-32/33	0.01	$7.59\ 10^{-6}$	<1
	Iodine-125	0.05	0.00996	20
	Others	$5.0\ 10^{-4}$	$7.90\ 10^{-8}$	<1
Imperial College Reactor Centre				
Ascot	Tritium	$1.0\ 10^{-4}$	$6.87\ 10^{-6}$	6.8
	Other radioactivity	$4.0\ 10^{-5}$	$4.91\ 10^{-6}$	12
Imperial Chemical Industries plc				
Billingham	Beta/gamma	0.36	$1.2\ 10^{-7}$	<1
Rolls Royce Marine Power Operations Ltd				
Derby	Alpha[s]	0.00666	$3.10\ 10^{-4}$	4.6
	Alpha[t]	$1.85\ 10^{-4}$	$8.58\ 10^{-8}$	<1
	Beta[t]	0.00222	$4.14\ 10^{-5}$	1.9
Scottish Universities Research and Reactor Centre				
East Kilbride	Total activity	$1.56\ 10^{-3}$	$8.9\ 10^{-7}$	<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] *The limits took effect in August 1999*
[i] *Excluding caesium-137*
[j] *Excluding strontium-90*
[k] *Discharges are made by Hunting-BRAE Ltd*
[l] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges are made by Marconi Marine (VSEL) Ltd*
[m] *Discharges are made by the Ministry of Defence*
[n] *The current authorisation includes limits on concentrations of total activity (MoD 2 10^{-6} TBq m^{-3}; Devonport Royal Dockyard 4 10^{-6} TBq m^{-3}). At no time did the concentrations exceed the limits*
[o] *Discharges are currently made by Devonport Royal Dockyard Ltd.*
[p] *Excluding cobalt-60*
[q] *Discharges are 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*
[u] *Approval revoked in November 1999*
[v] *Magnox Electric is a wholly owned subsidiary of BNFL plc*

Table A1.2 Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 1999

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999 TBq	Discharges during 1999 % of limit
British Nuclear Fuels plc				
Capenhurst[d]	Tritium		<2.94	
	Uranium		2.8 10^{-5}	
Chapelcross	Tritium	5000	1420	28
	Sulphur-35	0.05	0.0265	53
	Argon-41	4500	2810	62
Sellafield[a,b]	Alpha	0.0017	1.62 10^{-4}	9.5
	Beta	0.048	7.83 10^{-4}	1.6
	Tritium	1400	236	17
	Carbon-14	8.4	2.65	32
	Sulphur-35	0.21	0.1	48
	Argon-41	3700	2590	70
	Cobalt-60	9.2 10^{-4}	3.95 10^{-5}	4.3
	Krypton-85	3.5 10^{5}	9.07 10^{4}	26
	Strontium-90	0.0016	6.33 10^{-5}	4.0
	Ruthenium-106	0.046	9.6 10^{-4}	2.1
	Antimony-125	0.005	2.53 10^{-4}	5.1
	Iodine-129	0.052	0.0253	49
	Iodine-131	0.055	0.00402	7.3
	Caesium-137	0.0073	5.83 10^{-4}	8.0
	Plutonium (alpha)	8.40 10^{-4}	1.07 10^{-4}	13
	Plutonium-241	0.0051	8.31 10^{-4}	16
	Americium-241 and curium-242	3.60 10^{-4}	7.67 10^{-5}	21
Springfields	Uranium	0.006	1.6 10^{-3}	27
United Kingdom Atomic Energy Authority[h]				
Dounreay[m] (Fuel Cycle Area)	Alpha[e]	9.8 10^{-4}	3.7 10^{-5}	3.8
	Beta[k]	0.045	1.8 10^{-4}	<1
	Tritium	2	0.19	9.5
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	5.7 10^{-4}	14
	Ruthenium-106	0.0039	2.7 10^{-5}	<1
	Iodine-129	0.0011	5.6 10^{-5}	<1
	Iodine-131	1.5 10^{-4}	2.4 10^{-5}	16
	Caesium-134	8.4 10^{-4}	3.3 10^{-6}	<1
	Caesium-137	0.007	3.8 10^{-5}	<1
	Cerium-144	0.007	2.4 10^{-5}	<1
	Plutonium-241	0.0033	1.9 10^{-4}	6
	Curium-242	2.7 10^{-4}	3.6 10^{-7}	<1
	Curium-244[i]	5.4 10^{-5}	4.8 10^{-7}	<1
Dounreay[m] (Fast Reactor)	Alpha	10^{-5}	2.84 10^{-9}	<1
	Beta	0.0015	5.91 10^{-8}	<1
	Tritium	4.5	0.00169	<1
	Krypton-85	4.0 10^{-4}	Nil	Nil
Dounreay[m] (Fast Reactor)	Alpha	10^{-5}	2.84 10^{-9}	<1
	Beta	0.0015	5.91 10^{-8}	<1
	Tritium	4.5	0.00169	<1
	Krypton-85	4.0 10^{-4}	Nil	Nil
Dounreay[m] (Prototype Fast Reactor)	Alpha	6 10^{-6}	6.51 10^{-8}	1.1
	Beta	5.1 10^{-5}	8.69 10^{-7}	1.7
	Tritium	22	0.675	3.1
	Krypton-85	4	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999 TBq	Discharges during 1999 % of limit
Dounreay[m]				
(East minor sources)	Alpha[l]	1.37 10^{-5}	10^{-7}	<1
	Beta[k]	3.71 10^{-4}	6.4 10^{-7}	<1
	Krypton-85	1	Nil	Nil
Dounreay[m]				
(West minor sources)	Alpha[l]	3 10^{-7}	2.9 10^{-10}	<1
	Beta[k]	7.5 10^{-5}	3.9 10^{-9}	<1
	Tritium	2.25 10^{-5}	Nil	Nil
Harwell	Alpha	7.0 10^{-6}	1.15 10^{-7}	1.7
	Beta	4.5 10^{-4}	2.00 10^{-6}	<1
	Tritium	150	2.55	1.7
Windscale	Alpha	1.2 10^{-5}	2.84 10^{-7}	2.4
	Beta	0.005	7.22 10^{-6}	< 1
	Tritium	2.3	0.00419	<1
	Krypton-85	14	0.0052	<1
	Iodine-131	0.0012	Nil	Nil
Winfrith	Alpha	2.0 10^{-6}	1 10^{-11}	<1
	Beta	2.5 10^{-5}	3.8 10^{-9}	<1
	Tritium	5	0.145	2.9
	Carbon-14	0.3	0.001	<1
	Krypton-85	150	0.003	Nil
Magnox Electric[p]				
Berkeley	Alpha and beta	2.0 10^{-4}	1.54 10^{-6}	<1
	Tritium	2	3.87 10^{-2}	<1
	Carbon-14	0.2	1.22 10^{-4}	<1
	Sulphur-35	0.006	Nil	Nil
(Technology Centre)	Alpha and beta	2.0 10^{-5}	1.28 10^{-6}	6
Bradwell	Beta	0.001	2.25 10^{-4}	23
	Tritium	1.5	0.781	52
	Carbon-14	0.6	0.199	33
	Sulphur-35	0.2	0.0370	19
	Argon-41	1000	279	28
Dungeness				
'A' Station	Beta	0.001	3.11 10^{-4}	31
	Tritium	2	0.507	25
	Carbon-14	5	3.56	71
	Sulphur-35	0.4	0.052	13
	Argon-41	2000	1250	63
Hinkley Point[o]				
'A' Station	Beta	0.001		
	Tritium	25		
	Carbon-14	4		
	Sulphur-35	0.2		
	Argon-41	4500		
Hunterston				
'A' Station	Beta[j]	10^{-4}	4.7 10^{-7}	<1
	Tritium	1	Nil	Nil
	Carbon-14	0.2	"	"
Oldbury	Beta	0.001	1.08 10^{-4}	11
	Tritium	5	2.42	48
	Carbon-14	6	3.93	66
	Sulphur-35	0.75	0.33	44
	Argon-41	500	191	38

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999 TBq	% of limit
Sizewell 'A' Station	Beta	0.001	$1.47\ 10^{-4}$	15
	Tritium	7	1.41	20
	Carbon-14	1.5	1.09	73
	Sulphur-35	0.6	0.123	21
	Argon-41	3000	1680	56
Trawsfynydd	Beta	0.002	$2.07\ 10^{-6}$	<1
	Tritium	10	0.0900	<1
	Carbon-14	5	$8.77\ 10^{-4}$	<1
	Sulphur-35	0.4	Nil	Nil
	Argon-41	3500	"	"
Wylfa	Beta	0.001	$7.80\ 10^{-5}$	7.8
	Tritium	20	4.84	24
	Carbon-14	2.4	1.48	62
	Sulphur-35	0.5	0.30	60
	Argon-41	120	36.5	30
British Energy Generation Ltd				
Dungeness 'B' Station	Beta	0.001	$1.15\ 10^{-5}$	1.2
	Tritium	15	1.20	8.0
	Carbon-14	5	0.470	9.4
	Sulphur-35	0.45	0.0101	2.3
	Argon-41	150	0.156	<1
	Iodine-131	0.005	$3.15\ 10^{-6}$	<1
Hartlepool	Beta	0.001	$4.30\ 10^{-6}$	<1
	Tritium	6	1.41	24
	Carbon-14	5	1.74	35
	Sulphur-35	0.16	0.0548	34
	Argon-41	60	37.7	63
	Iodine-131	0.005	$2.81\ 10^{-5}$	<1
Heysham Station 1	Beta	0.001	$6.42\ 10^{-6}$	<1
	Tritium	6	0.978	16
	Carbon-14	4	0.688	17
	Sulphur-35	0.12	0.0185	15
	Argon-41	60	6.52	11
	Iodine-131	0.005	$7.58\ 10^{-5}$	1.5
Heysham Station 2	Beta	0.001	$8.10\ 10^{-6}$	<1
	Tritium	15	1.21	8.0
	Carbon-14	3	1.09	36
	Sulphur-35	0.3	0.0729	24
	Argon-41	85	13.0	15
	Iodine-131	0.005	$4.30\ 10^{-5}$	<1
Hinkley Point 'B' Station	Beta	0.001	$5.56\ 10^{-5}$	5.6
	Tritium	30	2.20	7.3
	Carbon-14	8	1.21	15
	Sulphur-35	0.4	0.020	5
	Argon-41	300	36.0	12
	Iodine-131	0.005	$8.73\ 10^{-6}$	<1
Sizewell 'B' Station (outlets 1-3)	Noble gases	295	7.29	2.5
	Halogens	0.0027	$3.35\ 10^{-4}$	12
	Beta	0.01	$3.54\ 10^{-6}$	<1
	Tritium	7.8	0.686	8.8
	Carbon-14	0.59	0.0232	3.9

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999 TBq	% of limit
Sizewell				
(Approved places)	Noble gases	5	Nil	Nil
	Halogens	3.0 10^{-4}	“	“
	Tritium	0.2	“	“
	Carbon-14	0.01	“	“
British Energy Generation (UK) Ltd				
Hunterston				
‘B’ Station	Beta[j]	0.002	6.78 10^{-5}	3.4
	Tritium	20	3.52	18
	Carbon-14	3	2.00	67
	Sulphur-35	0.8	0.0714	8.9
	Argon-41	220	68.1	31
Torness	Beta[j]	0.002	4.59 10^{-6}	<1
	Tritium	20	1.31	6.6
	Carbon-14	3	0.575	19
	Sulphur-35	0.8	0.0218	2.7
	Argon-41	220	10.5	4.8
Ministry of Defence				
Aldermaston[a,n]	Alpha	9.0 10^{-7}	1.01 10^{-7}	11
	Beta[f]	4.6 10^{-6}	8.1 10^{-8}	1.8
	Tritium	340	3.69	1.1
	Krypton-85	0.4	4.69 10^{-3}	1.2
Barrow[g]	Tritium	3.2 10^{-6}	Nil	Nil
	Argon-41	0.08	“	“
Burghfield[a,n]	Alpha	2.0 10^{-8}	1.10 10^{-9}	5.5
	Tritium	0.35	Nil	Nil
	Krypton-85	1	“	“
Coulport	Tritium	0.05	0.0025	5
Dounreay				
(Vulcan)	Alpha[j]	10^{-6}	1.17 10^{-7}	12
	Beta[j]	10^{-4}	1.6 10^{-6}	1.6
	Noble gases	0.027	Nil	Nil
	Iodine-131	3.7 10^{-4}	2.94 10^{-5}	7.9
Greenwich[m]	Argon-41	[d]	Nil	
	Alpha	5.0 10^{-10}	6.8 10^{-11}	14
	Tritium	2.9 10^{-5}	4.0 10^{-6}	14
	Other activity	1.0 10^{-6}	8.3 10^{-9}	<1
Rosyth[c]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	“	“
Nycomed Amersham plc				
Amersham	Alpha	2.0 10^{-6}	1.4 10^{-7}	7.0
	Other (penetrating)	0.05	7.8 10^{-5}	<1
	Other (non-penetrating)	0.5	0.018	3.6
	Tritium	40	Nil	Nil
	Selenium-75	0.03	2.80 10^{-4}	<1
	Iodine-125	0.1	6.9 10^{-3}	6.9
	Iodine-131	0.05	5.40 10^{-4}	1.1
	Radon-222	10	1.6	16
Cardiff	Soluble tritium	400	117	29
	Insoluble tritium	1000	383	38
	Carbon-14	6	2.05	34
	Phosphorus-32/33	2.0 10^{-4}	2.92 10^{-6}	1.5
	Iodine-125	5.0 10^{-4}	1.25 10^{-4}	25
	Other activity	0.04	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1999	
			TBq	% of limit
Imperial College Reactor Centre				
Ascot	Tritium	$5.0\ 10^{-4}$	$1.28\ 10^{-4}$	26
	Argon-41	2.5	0.582	23
Imperial Chemical Industries plc				
Billingham	Tritium	2	$7.3\ 10^{-7}$	<1
	Argon-41	2	Nil	Nil
Johnson and Johnson Clinical Diagnostics Ltd				
Cardiff	Iodine-125	0.015	0.0012	8
	Other activity	$5.0\ 10^{-4}$	Nil	Nil
Rolls Royce Marine Power Operations Ltd				
Derby	Alpha	[d]	$1.11\ 10^{-6}$	
Scottish Universities Research and Reactor Centre				
East Kilbride	Tritium	19.2	Nil	Nil
	Argon-41	3.33	"	"
Urenco (Capenhurst) Ltd				
Capenhurst	Uranium	$2.5\ 10^{-6}$	$8.15\ 10^{-8}$	3.3

[a] *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 the THORP plant and may thus vary from year to year*
[c] *Discharges are 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 are made by Marconi Marine (VSEL) 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] *The limits took effect in August 1999*
[n] *Discharges are made by Hunting-BRAE Ltd*
[o] *In January 2000 BNFL reported that their estimates of discharges of gaseous wastes had been found to be unreliable. Data for 1999 will be issued in due course*
[p] *Magnox Electric is a wholly owned subsidiary of BNFL plc*

Table A1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 1999

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 1999	
			TBq	% of limit
Drigg	Tritium	10	0.39	3.9
	Carbon-14	0.05	0.007	14
	Cobalt-60	2	0.21	10
	Iodine-129	0.05	$1.0\ 10^{-4}$	<1
	Radium-226 plus thorium-232	0.03	0.004	14
	Uranium	0.3	0.032	11
	Other alpha[a]	0.3	0.08	27
	Others[a,b]	15	3.49	23
Dounreay[c]	Alpha		$7.34\ 10^{-4}$	
	Beta/gamma		$8.25\ 10^{-2}$	

[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 RADIOACTIVITY IN FOODSTUFFS

2.1 Introduction

There are two cases where the results of terrestrial monitoring in 1999 have been amended or supplemented when carrying out assessments of exposures to consumers. Firstly some data for Sellafield, Drigg, Ravenglass and the Isle of Man have been changed where relatively high limits of detection exist or where no measurements were made. Secondly, data for Chapelcross, Dounreay, Hunterston and Torness have been supplemented to provide a more complete coverage of food groups. The methods and data are outlined below.

2.2 Sellafield, Drigg, Ravenglass and the Isle of Man

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.

2.3 Chapelcross, Dounreay, Hunterston and Torness

Soil to plant concentration ratios for green vegetables and potatoes are similar to or less than those for pasture (Simmonds *et al*., 1995). These food groups make up a substantial part of the plant based intake by humans which is likely to be locally sourced. Therefore, in the absence of site-specific data for vegetables at Chapelcross and Dounreay, Hunterston and Torness, concentrations of activity in green vegetables and potatoes were assumed to be the same as those measured in grass. This approach does not take account of the relative foliar uptake of different crops and therefore may underestimate the activities in foodstuffs.

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 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]	$1.97\ 10^{-4}$	[b]	[b]	$7.35\ 10^{-6}$
	Ravenglass	[a]	$4.44\ 10^{-4}$	$4.28\ 10^{-3}$	$9.79\ 10^{-3}$	$1.06\ 10^{-5}$
	Drigg	[a]	$7.58\ 10^{-4}$	[b]	$6.07\ 10^{-3}$	$2.17\ 10^{-5}$
	Isle of Man	[a]	$3.99\ 10^{-4}$	$4.16\ 10^{-3}$	$6.93\ 10^{-4}$	[a]
Beef	Sellafield	$3.23\ 10^{-2}$	$1.97\ 10^{-1}$	[b]	[b]	$7.35\ 10^{-4}$
	Ravenglass	[a]	$4.44\ 10^{-1}$	$2.14\ 10^{-1}$	2.45	$1.06\ 10^{-3}$
Lamb	Sellafield	$3.72\ 10^{-2}$	$2.28\ 10^{-1}$	[b]	[b]	$3.39\ 10^{-4}$
	Ravenglass	[a]	$5.12\ 10^{-1}$	$2.47\ 10^{-1}$	2.82	$4.87\ 10^{-4}$
	Drigg	[a]	$8.75\ 10^{-1}$	[b]	1.75	$1.00\ 10^{-3}$
Beef offal	Sellafield	[a]	$1.97\ 10^{-1}$	[b]	[b]	[a]
	Ravenglass	[a]	$4.44\ 10^{-1}$	[a]	19.6	[a]
Lamb offal	Sellafield	[a]	$2.28\ 10^{-1}$	[b]	[b]	[a]
	Ravenglass	[a]	$5.12\ 10^{-1}$	[a]	16.9	[a]
	Drigg	[a]	$8.75\ 10^{-1}$	[b]	10.5	[a]

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

APPENDIX 3. ABBREVIATIONS

AEAT	AEA Technology plc
AFCF	Ammonium ferric hexacyanoferrate
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BNFL	British Nuclear Fuels plc
CBC	Copeland Borough Council
CEC	Commission of the European Communities
CEFAS	Centre for Environment, Fisheries and Aquaculture Science (MAFF)
DETR	Department of the Environment, Transport and the Regions
DGT	Diffusive gradients in thin films
DoH	Department of Health
DRPS	Defence Radiological Protection Service
EA	Environment Agency
EU	European Union
FARM	Food and Agriculture Monitoring Programme
FEPA	Food and Environment Protection Act
HEPA	High efficiency particulate air
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
JRC	Joint Research Centre of the European Commission
LoD	Limit of Detection
MAFF	Ministry of Agriculture, Fisheries and Food
MOD(N)	Ministry of Defence (Navy)
MRL	Minimum reporting level
ND	Not detected
NDS	National Discharge Strategy
NEA	Nuclear Energy Agency
NII	Nuclear Installations Inspectorate
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
PWR	Pressurised Water Reactor
RIFE	Radioactivity in Food and the Environment
RNAD	Royal Naval Armaments Depot
RNC	Royal Naval College
RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
SGHWR	Steam Generating Heavy Water Reactor
TDS	Total Diet Study
TRAMP	Terrestrial Radioactivity Monitoring Programme
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
VLA	Veterinary Laboratories Agency
WVP	Waste Vitrification Plant

APPENDIX 4. CONSUMPTION, HANDLING AND OCCUPANCY RATES

This appendix gives the consumption, handling and occupancy rate data used in the assessment of exposures. Consumption rates for terrestrial foods 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.

Table A4.1 Consumption rates for terrestrial foods

Food Group	Consumption rates (kg y^{-1})							
	Average				Above average consumption rate*			
	Adult	15 year old	10 year old	Infant	Adult	15 year old	10 year old	Infant
Beef	15	15	15	3	45	35	30	10
Cereals	50	50	45	15	100	95	75	30
Eggs	8.5	7	6.5	5	25	25	20	15
Fruit	20	15	15	9	75	50	50	35
Game	6	6	4	0.8	15	10	7.5	2.1
Green Vegetables	15	9	6	3.5	45	25	20	10
Honey	2.5	2	2	2	9.5	5	7.5	7.5
Lamb	8	5.5	4	0.8	25	15	10	3
Legumes	20	10	8	3	50	30	25	10
Milk	95	110	110	130	240	260	240	320
Mushrooms	3	2	1.5	0.6	10	5.5	4.5	1.5
Nuts	3	2	1.5	1	10	9.5	7	2
Offal	5.5	3.5	3	1	20	10	10	5.5
Pork	15	10	8.5	1.5	40	30	25	5.5
Potatoes	50	60	45	10	120	130	85	35
Poultry	10	6.5	5.5	2	30	20	15	5.5
Root crops	10	7.5	6	5	40	20	20	15
Wild fruit	7	3.3	3	1	25	13	10	2

* *These rates are the 97.5th percentile of the distribution across all consumers*

Table A4.2 Consumption, handling and occupancy rates for aquatic pathways

Site	Group[a]	Rates
Aldermaston		1 kg y^{-1} pike 360 h y^{-1} over riverbank
Amersham		1 kg y^{-1} pike 1600 h y^{-1} over riverbank
Barrow		1000 h y^{-1} over mud and sand
Berkeley and Oldbury		17 kg y^{-1} flounders 4.9 kg y^{-1} shrimps 980 h y^{-1} over mud
Bradwell		44 kg y^{-1} fish 3.1 kg y^{-1} crustaceans 6.5 kg y^{-1} molluscs 2900 h y^{-1} over mud
Capenhurst		0.0025 kg y^{-1} sediment 2.5 l y^{-1} water
Cardiff		34 kg y^{-1} fish 1.4 kg y^{-1} prawns 990 h y^{-1} over mud and sand
Channel Islands		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	A	8.7 kg y^{-1} flounders
		11 kg y^{-1} salmonids
		7.3 kg y^{-1} shrimps
		0.45 kg y^{-1} mussels
		1000 h y^{-1} over mud and sand
	B	1200 h y^{-1} over salt marsh
	C	250 h y^{-1} handling nets
Devonport		14 kg y^{-1} salmonids
		13 kg y^{-1} fish
		5 kg y^{-1} crustaceans
		2000 h y^{-1} over mud
Dounreay	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
Drinking water	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness		59 kg y^{-1} fish
		17 kg y^{-1} crustaceans
		15 kg y^{-1} molluscs
		1500 h y^{-1} over mud and sand
Faslane	A	500 h y^{-1} over mud
	B	38 kg y^{-1} fish
		4.8 kg y^{-1} molluscs
		670 h y^{-1} over mud and sand
Hartlepool		59 kg y^{-1} fish
		35 kg y^{-1} crab
		9.4 kg y^{-1} winkles
		520 h y^{-1} over sand
Harwell		1 kg y^{-1} pike
		650 h y^{-1} over river bank
Heysham		54 kg y^{-1} fish
		21 kg y^{-1} shrimps
		22 kg y^{-1} mussels and cockles
		900 h y^{-1} over mussel beds
Hinkley Point	A	48 kg y^{-1} flounder
		6.5 kg y^{-1} shrimps
		780 h y^{-1} over mud
	B	1000 h y^{-1} over mud
Holy Loch		900 h y^{-1} over mud
Hunterston		82 kg y^{-1} fish
		41 kg y^{-1} Nephrops
		21 kg y^{-1} scallops
		860 h y^{-1} over sand and mud
Rosyth	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	43 kg y^{-1} cod (50%) and plaice (50%)
		24 kg y^{-1} crab (80%) and lobster (20%)
		25 kg y^{-1} winkles (50%) and other molluscs (50%)
		1000 h y^{-1} over sand and mollusc beds
	B	1200 h y^{-1} handling nets and pots

Table A4.2. continued

Site	Group[a]	Rates
Sellafield (cont.)		
	C (bait diggers)	950 h y^{-1} handling sand
	D (farmers)	1900 h y^{-1} over saltmarsh (Rockcliffe)
	E (Whitehaven commercial)	40 kg y^{-1} plaice and cod
		9.7 kg y^{-1} Nephrops
		15 kg y^{-1} whelks
	F (Morecambe Bay)	See Heysham
	G (Fleetwood)	93 kg y^{-1} plaice and cod
		29 kg y^{-1} shrimps
		23 kg y^{-1} whelks
	H (Dumfries and Galloway)	38 kg y^{-1} fish
		15 kg y^{-1} Nephrops (50%), crabs (25%) and lobsters (25%)
		8.2 kg y^{-1} winkles and mussels
		1000 h y^{-1} over winkle beds
	I (Laverbread)	47 kg y^{-1} laverbread
	J (Trout)	6.8 kg y^{-1} rainbow trout
	K (typical fish consumer)	15 kg y^{-1} cod and plaice
	L (Isle of Man)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	M (Northern Ireland)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	N (North Wales)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
Sizewell		56 kg y^{-1} fish
		6.6 kg y^{-1} crustaceans
		3.8 kg y^{-1} molluscs
		260 h y^{-1} over mud
Springfields	A	35 kg y^{-1} fish
		34 kg y^{-1} shrimps
		3.0 kg y^{-1} cockles and mussels
		5.1 kg y^{-1} samphire
		1100 h y^{-1} over sand
	B (farmers)	410 h y^{-1} over saltmarsh
Torness	A	58 kg y^{-1} fish
		11 kg y^{-1} crab and lobster
		10 kg y^{-1} Nephrops
		2.2 kg y^{-1} molluscs
	B	430 h y^{-1} over sand
	C	640 h y^{-1} over winkle beds
Trawsfynydd		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		37 kg y^{-1} fish
Whitehaven		32 kg y^{-1} fish
		17 kg y^{-1} lobsters (40%) and crab (60%)
		3.0 kg y^{-1} winkles (20%) and mussels (80%)
Winfrith		77 kg y^{-1} cod
		26 kg y^{-1} crab
		39 kg y^{-1} whelks
Wylfa		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.*

APPENDIX 5. DOSIMETRIC DATA

Radionuclide	Half Life (years)	Mean β energy (MeV per disintegration)	Mean γ energy (MeV per disintegration)	Dose per unit intake by ingestion using ICRP-60 methodology ($Sv.Bq^{-1}$)			
				Adults	15 yr.	10 yr.	1 yr.
H 3	1.24E+01	5.683E-03	0.000E+00	1.80E-11	1.80E-11	2.30E-11	4.80E-11
OT3 (f)	1.24E+01	5.683E-03	0.000E+00	4.20E-11	4.20E-11	5.70E-11	1.20E-10
C 14	5.73E+03	4.945E-02	0.000E+00	5.80E-10	5.70E-10	8.00E-10	1.60E-09
P 32	3.91E-02	6.950E-01	0.000E+00	2.40E-09	3.10E-09	5.30E-09	1.90E-08
S 35 (g)	2.39E-01	4.884E-02	0.000E+00	7.70E-10	9.50E-10	1.60E-09	5.40E-09
CA45	4.46E-01	7.720E-02	0.000E+00	7.10E-10	1.30E-09	1.80E-09	4.90E-09
MN54	8.56E-01	4.220E-03	8.364E-01	7.10E-10	8.70E-10	1.30E-09	3.10E-09
FE55	2.70E+00	4.201E-03	1.691E-03	3.30E-10	7.70E-10	1.10E-09	2.40E-09
CO57	7.42E-01	1.860E-02	1.250E-01	2.10E-10	3.70E-10	5.80E-10	1.60E-09
CO58	1.94E-01	3.413E-02	9.976E-01	7.40E-10	1.10E-09	1.70E-09	4.40E-09
CO60	5.27E+00	9.656E-02	2.500E+00	3.40E-09	7.90E-09	1.10E-08	2.70E-08
ZN65	6.67E-01	6.870E-03	5.845E-01	3.90E-09	4.50E-09	6.40E-09	1.60E-08
SE75	3.28E-01	1.452E-02	3.946E-01	2.60E-09	3.10E-09	6.00E-09	1.30E-08
SR90 †	2.91E+01	1.131E+00	3.163E-03	3.07E-08	8.33E-08	6.59E-08	9.30E-08
ZR95 †	1.75E-01	1.605E-01	1.505E+00	1.53E-09	1.93E-09	2.99E-09	8.78E-09
NB95	9.62E-02	4.444E-02	7.660E-01	5.80E-10	7.40E-10	1.10E-09	3.20E-09
TC99	2.13E+05	1.010E-01	0.000E+00	6.40E-10	8.20E-10	1.30E-09	4.80E-09
RU103 †	1.07E-01	7.478E-02	4.685E-01	7.30E-10	9.20E-10	1.50E-09	4.60E-09
RU106 †	1.01E+00	1.422E+00	2.049E-01	7.00E-09	8.60E-09	1.50E-08	4.90E-08
AG110M †	6.84E-01	8.699E-02	2.740E+00	2.80E-09	3.40E-09	5.20E-09	1.40E-08
SB125	2.77E+00	1.007E-01	4.312E-01	1.10E-09	1.40E-09	2.10E-09	6.10E-09
I 125	1.65E-01	1.940E-02	4.205E-02	1.50E-08	2.20E-08	3.10E-08	5.70E-08
I 129	1.57E+07	6.383E-02	2.463E-02	1.10E-07	1.40E-07	1.90E-07	2.20E-07
I 131 †	2.20E-02	1.935E-01	3.813E-01	2.20E-08	3.40E-08	5.20E-08	1.80E-07
CS134	2.06E+00	1.634E-01	1.550E+00	1.90E-08	1.90E-08	1.40E-08	1.60E-08
CS137 †	3.00E+01	2.486E-01	5.651E-01	1.30E-08	1.30E-08	1.00E-08	1.20E-08
BA140 †	3.49E-02	8.493E-01	2.502E+00	4.60E-09	6.20E-09	1.00E-08	3.10E-08
CE144 †	7.78E-01	1.278E+00	5.282E-02	5.20E-09	6.50E-09	1.10E-08	3.90E-08
PM147	2.62E+00	6.200E-02	4.374E-06	2.60E-10	3.20E-10	5.70E-10	1.90E-09
EU154	8.80E+00	2.923E-01	1.237E+00	2.00E-09	2.50E-09	4.10E-09	1.20E-08
EU155	4.96E+00	6.340E-02	6.062E-02	3.20E-10	4.00E-10	6.80E-10	2.20E-09
PB210 †	2.23E+01	4.279E-01	4.810E-03	6.91E-07	1.90E-06	1.90E-06	3.61E-06
BI210	1.37E-02	3.890E-01	0.000E+00	1.30E-09	1.60E-09	2.90E-09	9.70E-09
PO210 (c)	3.79E-01	0.000E+00	0.000E+00	1.20E-06	1.60E-06	2.60E-06	8.80E-06
PO210 (d)	3.79E-01	0.000E+00	0.000E+00	1.92E-06	2.56E-06	4.16E-06	1.41E-05
RA226 †	1.60E+03	9.559E-01	1.765E+00	2.80E-07	1.50E-06	8.00E-07	9.60E-07
TH228 †	1.91E+00	9.130E-01	1.567E+00	1.43E-07	3.07E-07	4.31E-07	1.10E-06
TH230	7.70E+04	1.462E-02	1.553E-03	2.10E-07	2.20E-07	2.40E-07	4.10E-07
TH232	1.41E+10	1.251E-02	1.332E-03	2.30E-07	2.50E-07	2.90E-07	4.50E-07
TH234 †	6.60E-2	8.815E-01	2.103E-02	3.40E-9	4.20E-09	7.40E-09	2.50E-08
U 234	2.44E+05	1.320E-02	1.733E-03	4.90E-08	7.40E-08	7.40E-08	1.30E-07
U 235 †	7.04E+08	2.147E-01	1.815E-01	4.70E-08	7.00E-08	7.10E-08	1.30E-07
U 238 †	4.47E+09	8.915E-01	2.235E-02	4.84E-08	7.12E-08	7.54E-08	1.45E-07
NP237 †	2.14E+06	2.668E-01	2.382E-01	1.10E-07	1.10E-07	1.10E-07	2.10E-07
PU238 (a)	8.77E+01	1.061E-02	1.812E-03	2.30E-07	2.20E-07	2.40E-07	4.00E-07
PU238 (b)				9.20E-08	8.80E-08	9.60E-08	1.60E-07
PU239 (a)	2.41E+04	6.738E-03	8.065E-04	2.50E-07	2.40E-07	2.70E-07	4.20E-07
PU239 (b)				1.00E-07	9.60E-08	1.08E-07	1.68E-07
PU a (e)	2.41E+04	6.738E-03	8.065E-04	2.50E-07	2.40E-07	2.70E-07	4.20E-07
PU240 (a)	6.54E+03	1.061E-02	1.731E-03	2.50E-07	2.40E-07	2.70E-07	4.20E-07
PU240 (b)				1.00E-07	9.60E-08	1.08E-07	1.68E-07
PU241 (a)	1.44E+01	5.246E-03	2.546E-06	4.80E-09	4.80E-09	5.10E-09	5.70E-09
PU241 (b)				1.92E-09	1.92E-09	2.04E-09	2.28E-09
AM241 (a)	4.32E+02	5.207E-02	3.253E-02	2.00E-07	2.00E-07	2.20E-07	3.70E-07
AM241 (b)				8.00E-08	8.00E-08	8.80E-08	1.48E-07
CM242	4.46E-01	9.594E-03	1.832E-03	1.20E-08	1.50E-08	2.40E-08	7.60E-08
CM243	2.85E+01	1.384E-01	1.347E-01	1.50E-07	1.40E-07	1.60E-07	3.30E-07
CM244	1.81E+01	8.590E-03	1.700E-03	1.20E-07	1.20E-07	1.40E-07	2.90E-07

† *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) PU239 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 MAFF. 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 250 Bq ^{14}C natural/kg C (Collins, *et al*., 1995). Typical values are given in table A6.1

Table A6.1 Radioactivity in seafood due to natural sources

Radionuclide	Concentration of radioactivity (Bq kg^{-1} (wet))								
	Fish	Crustaceans	Crabs	Lobsters	Molluscs	Winkles	Mussels	Cockles	Whelks
Carbon-14	26	27			24				
Lead-210	0.025	0.08	0.3	0.08	0.69	0.69	1.1		
Polonium-210	0.28	5.2	15	5.2	9.4	12	33	18	9.4
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. RADIOACTIVITY IN SEDIMENT DREDGED FROM WHITEHAVEN HARBOUR, CUMBRIA, 1999

Location	Radioactivity concentration (dry)[a], Bq kg^{-1}													
and depth	^{60}Co	^{106}Ru	^{125}Sb	^{137}Cs	^{154}Eu	^{155}Eu	^{210}Po	^{210}Pb	^{212}Pb	^{214}Bi	^{226}Ra	^{228}Ac	^{233}Pa	^{234}Th	^{241}Am
A Top	30	56	<5.7	1100	17	6.0	170	170	38	63	65	36	18	900	1100
A Middle	6.5	15	11	990	18	<4.8	130	150	38	43	47	37	87	870	1300
A Bottom	3.2	<12	<4.9	910	12	<4.9	410	340	36	160	200	30	27	2600	740
B Top	23	67	<5.0	890	12	<4.5	150	150	40	54	63	36	*	1000	1000
B Middle	4.0	<14	<5.7	1100	16	<5.9	520	560	43	220	260	40	38	3700	1200
B Bottom	5.9	<15	<6.3	1900	14	<5.9	450	460	42	190	220	33	*	3100	1100
C Top	<1.0	<11	<4.3	270	<3.4	<5.0	380	710	50	340	400	43	*	3200	850
C Middle	1.8	<18	<8.0	2800	20	<6.8	300	440	45	150	190	38	*	1600	2200
C Bottom	<0.53	<6.1	<2.0	130	<1.6	<2.7	22	35	23	49	56	18	*	500	120
D Top	19	42	<4.7	810	12	<4.3	180	200	38	93	110	26	*	520	890
D Middle	6.4	<14	<5.9	1100	18	9.6	200	240	36	70	88	37	45	610	1500
D Bottom	4.0	<14	<5.6	1100	19	<5.7	750	730	45	270	320	48	34	1500	1300

** Not detected by the method used*
[a] All short-lived nuclides assumed to be unsupported

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Radioactivity in Food and the Environment, 1999

ISSN 1365-6414